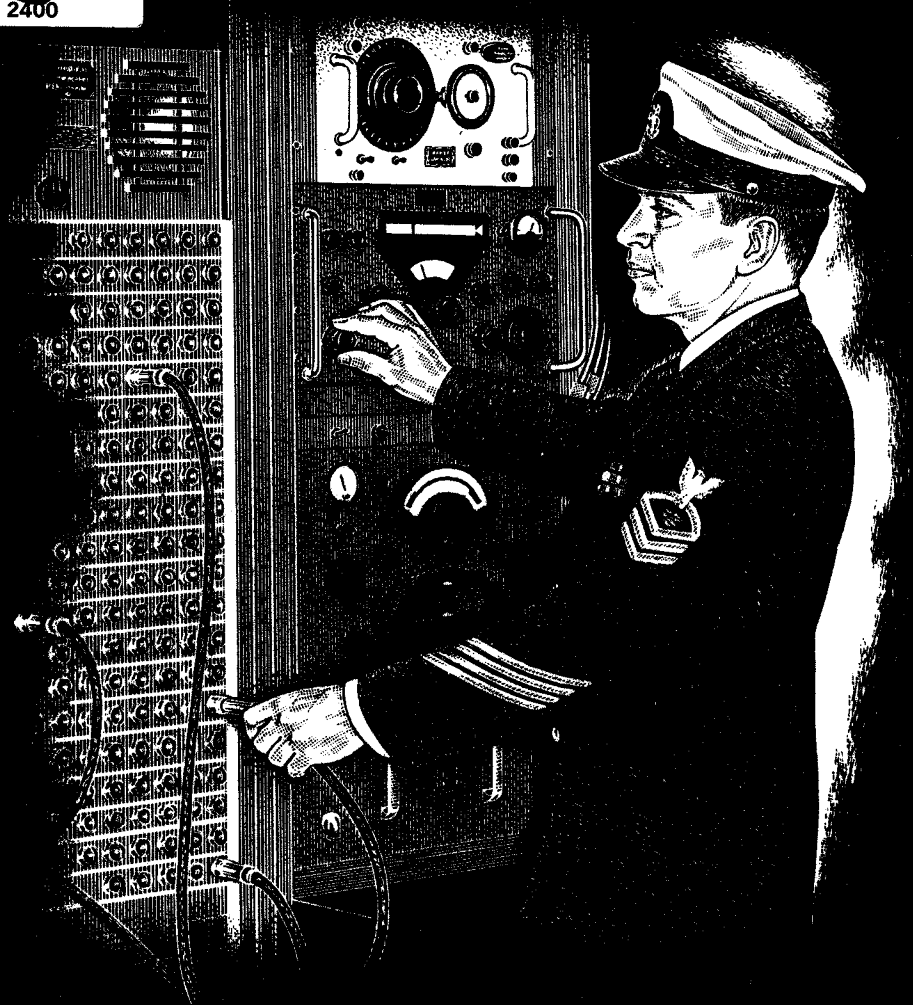

RADIOMAN 1 & C

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSE NAVPERS 10229–D

PREFACE

This book is written for Radiomen of the United States Navy and Naval Reserve who are studying for advancement in rating to RM1 or RMC. Study of this text should be combined with practical experience, with review of other applicable Navy Training Courses, and with a study of pertinent communication doctrinal and procedural publications and equipment technical manuals.

Those who work in communications know how fast procedures and equipment evolve, so you may find yourself working with equipment different from that described in this training course.

This book is revised from time to time. Between revisions, some obsolescence may be unavoidable. For this reason it is suggested that the student with access to official communication publications use them as much as possible in his study.

As one of the Navy Training Courses, Radioman 1 and C was prepared for the Bureau of Naval Personnel by the Training Publications Division, Naval Personnel Program Support Activity, and was reviewed by the U. S. Naval School, Radiomen, Class B, Bainbridge, Maryland.

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Reprinted with major changes 1954
Revised 1958
Second edition 1963
Revised 1966

READING LIST

NAVY TRAINING COURSES

Radioman 1 & C, NavPers 10229-D
Radioman 3 & 2, NavPers 10228-D
Basic Electricity, NavPers 10086-A
Basic Electronics, NavPers 10087-A

OTHER NAVY PUBLICATIONS

ACPs (effective editions) 121, 122
DNCs 5, 14, 26
NWP 16

Department of the Navy Security Manual for Classified Information, OpNavInst 5510.1B

Handbook of Test Methods and Practices, NavShips 900,000.103

Bureau of Ships Technical Manual, chapter 67 (9670)

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your educational services officer (or training officer or division officer, as applicable)*. A partial list of correspondence courses applicable to your rate follows.

Number	Title
D 290	Physics I
D 291	Physics II
B 890	Radio Servicing and Repair I
B 891	Radio Servicing and Repair II

*Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials, if the orders calling them to active duty specify a period of 120 days or more, or if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CHAPTER 1

ADVANCEMENT

This training course is intended to help you meet the professional qualifications for advancement to Radioman First Class and Chief Radioman.

Whether you are in the Regular Navy or Naval Reserve, this text must be completed satisfactorily before you can advance to RM1 or RMC. It is recommended that you study this opening chapter carefully before beginning intensive study of the remainder of this course.

REWARDS AND RESPONSIBILITIES

Advancement in rating brings you increased rewards as well as increased responsibilities. The time to start looking ahead and considering the rewards and responsibilities of advancement is right now, while you are preparing for advancement to RM1 or RMC.

By this time, you are well aware of many of the advantages of advancement in rating: higher pay, greater prestige, more interesting and challenging work, and the satisfaction of getting ahead in your chosen career. Also, you probably have discovered that one of the most enduring rewards of advancement is the personal satisfaction you find in developing your skills and increasing your knowledge.

The Navy also benefits by your advancement. Highly trained personnel are essential to the functioning of the Navy. Each advancement in rating enhances your value to the Navy in two ways. First, you become more valuable as a technical specialist in your own rating. Second, you become more valuable as a man who can supervise, lead, and train others and thus make far-reaching and long-lasting contributions to the Navy.

The extent of your contribution to the Navy depends, in large measure, upon your willingness and ability to accept increasing responsibilities as you advance in rating. When you assumed your RM3 duties, you began to accept a certain amount of responsibility for the work of others. With each advancement in rating you accept greater responsibility in military matters and in the professional requirements of the Radioman rating.

You will find that your responsibilities for military leadership are about the same as those of petty officers in other ratings. The reason for this parallel is that every petty officer is a military person before becoming a technical specialist.

Although some broad aspects of military leadership are included in this text, the training course is not designed to give you extensive information on military requirements for advancement to petty officer first or to CPO. Material covering these requirements is found in Military Requirements for Petty Officer 1 & C, NavPers 10057 and should be studied carefully.

TECHNICAL LEADERSHIP

Your responsibilities for technical leadership are special to your rating and are directly related to the nature of your work. The dual role of operating and maintaining a ship's communication system is a job of vital importance. It requires an exceptional kind of leadership ability that can be developed only by personnel who have a high degree of technical competence and a deep sense of personal responsibility. At this point, let's consider some of the broader aspects of your growing responsibilities for military and technical leadership—the direction and extent of your responsibilities.

Direction of Responsibility

Your responsibilities will extend both upward and downward. Officers and enlisted personnel alike will expect you to translate general orders given by officers into detailed, practical, on-the-job language that can be understood and executed by even relatively inexperienced personnel. In dealing with your juniors, it is up to you to see that they perform their work properly. At the same time, you must be able to explain to officers any important needs or problems of the enlisted men.

Extent of Responsibility

Even if you are fortunate enough to have highly skilled and well-trained radio personnel, you still will find that training is necessary. For example, you will always be responsible for training lower rated men for advancement in rating. Also, some of your men may be transferred, and inexperienced or poorly trained men may be assigned to replace them. In such a circumstance your skill and experience must be brought into play to bring these men up to Navy standards and to guide their professional development. Chapter 13 of this training course should prove valuable in assisting you to fulfill your training responsibilities.

WORKING WITH OTHERS.—As you advance to RM1 and then to RMC, you will be taking a greater part in planning for training in your ship. At times this training will also affect a large number of personnel not in your division nor even in your department. It becomes increasingly important, therefore, to understand the duties and responsibilities of personnel in other ratings. The more you know about related ratings, the more complete and comprehensive will be your training plans—especially those requiring an interdivisional effort to achieve their goals.

As your responsibilities for planning with others expand, so also must your ability to communicate clearly and effectively. The basic requirement for effective communication is a knowledge of your own language. Always use correct language in speaking and in writing. Remember that the basic purpose of all communication is improvement of understanding. To lead, supervise, and train other men, you must be able to speak and write in such a way that they can understand exactly what you mean.

A second requirement for effective communication in the Navy is a sound knowledge of the "Navy way" of saying things. Some Navy terms have been standardized for the purpose of ensuring efficient communication. When a situation calls for standard Navy terminology, use it.

Still another requisite for effective communication is precision in application of technical terms. A command of the technical language of the Radioman rating will enable you to receive and convey information accurately and to exchange ideas with others. A person who does not understand the precise meaning of terms used in connection with the work of his own rating is handicapped when he tries to read official publications relating to his work. He is also at a disadvantage when he takes written examinations for advancement in rating, Although it is always advisable for you to use technical terms correctly, this practice is particularly significant when you are dealing with lower rated men. Sloppiness in the use of technical terms is likely to be confusing to an inexperienced man.

KEEPING UP WITH NEW DEVELOPMENTS.—You are responsible for keeping up with new developments within the Navy. Practically everything in the Navy is subject to change and development—policies, procedures, equipment, publications, systems, and so on. As RM1, and even more importantly as RMC, you must make every effort to keep yourself informed about all changes and new developments that might affect your rating or your work.

Some changes will be called directly to your attention, but you will have to look for others. Try to develop a special kind of alertness for new information. Above all, keep an open mind on the subject of new radio and associated equipment. Open mindedness is especially important in the Radioman rating, because the Navy, in an effort to keep parallel with modern advances in communication development, is experimenting constantly with new and different high-speed communication devices. These new developments often call for changes in procedures in handling message traffic and sometimes for changes in a complete system.

REQUIREMENTS FOR ADVANCEMENT

In general, to qualify for advancement, you must—

1. Have a certain amount of time in grade.
2. Complete required military and professional training courses.
3. Demonstrate ability to perform all the PRACTICAL requirements for advancement by

completing the Record of Practical Factors, NavPers 760.

4. Be recommended by your commanding officer.

5. Demonstrate your KNOWLEDGE by passing a written examination based on (a) military requirements for advancement and (b) professional qualifications for advancement in the Radioman rating.

Advancement in rating is not automatic. Meeting all the requirements makes you eligible for advancement, but it does not guarantee your advancement. Some factors that determine which persons actually will be advanced in rating are (1) scores made on the written examination, (2) length of time in service, (3) performance marks, and (4) quotas for the rating.

Remember that requirements for advancement may change from time to time. When preparing for advancement, and when helping lower rated men prepare for advancement, check with your division officer or training officer to make sure you have the latest requirements.

To prepare for advancement, you need to be familiar with (1) military requirements and professional qualifications given in the Manual of Qualifications for Advancement in Rating, NavPers 18068; (2) Record of Practical Factors, NavPers 760; (3) appropriate Navy Training Courses; and (4) any other material that may be required or recommended in Training Publications for Advancement in Rating, NavPers 10052. These materials are discussed later in this chapter.

RADIOMAN RATING

You have been a Radioman long enough to realize the importance of your rating to the Navy. Radiomen, along with Radarmen, Signalmen, and Electronics Technicians, are essential members of the operations department team. A former CNO, speaking of the operations department's task of providing external communications, operating the CIC, and repairing electronic equipment, assessed the significance of the operations department in these words:

> "The effectiveness of the many changes taking place in ships, in equipment, and in weapons rests more and more heavily upon the capability and output of the operations department. The men who man, maintain, and give effect to the components of the operations department exert a preponderant influence upon the quality of the ship's total capability."

In addition to sea duty billets, Radiomen are assigned to shore duty at communication stations in the United States and at overseas bases. Radiomen are also assigned as instructors in Radiomen schools. Other important billets are at the Naval Examining Center, Great Lakes, where Radiomen assist in preparation of fleetwide advancement examinations, and at the Training Publications Division, Naval Personnel Program Support Activity, Washington, D. C., where Radiomen prepare and revise Navy Training Courses and other training materials.

SCOPE OF THIS TRAINING COURSE

Before studying any book, it is a good idea to know its purpose and scope. Following are some pointers you should know about this Navy Training Course.

- It is intended to aid the Radioman in performing professional duties and to assist in preparing for advancement to petty officer first and chief petty officer.
- It must be completed satisfactorily before you can advance to RM1 or RMC, whether you are in the Regular Navy or Naval Reserve.
- It is not designed to give you information on military requirements for advancement to PO1 or CPO. Before taking the examination for advancement, be sure you study Military Requirements for Petty Officer First and Chief, NavPers 10057.

Professional (technical) Radioman qualifications used as a guide in preparing this training course are promulgated in the Manual of Qualifications for Advancement in Rating, NavPers 18068. Because your major purpose in studying this training course is to meet the qualifications for advancement to RM1 or RMC, it is urged that you obtain and study a set of current Radioman quals.

This training course includes information that is related to both the KNOWLEDGE factors and PRACTICAL factors of qualifications for advancement to RM1 and RMC. For developing skill in practical factors, though, remember that no training course can take the place of actual on-the-job experience. The Record of Practical Factors, NavPers 760 should be utilized, whenever possible, in conjunction with this training course.

SOURCES OF INFORMATION

It is essential that you have an extensive knowledge of references to consult for detailed, authoritative, up-to-date information on all subjects related to military requirements and professional qualifications of the Radioman rating.

A few of the publications discussed here are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is kept current by means of changes, be sure your copy has all official changes entered in it.

BUPERS PUBLICATIONS

The BuPers publications described here include some that are absolutely basic for anyone seeking advancement in rating. Some, although nonessential, are extremely helpful.

Quals Manual

The Manual of Qualifications for Advancement in Rating, NavPers 18068 gives minimum requirements for advancement to each rate within each rating. The Quals Manual lists the military requirements applicable to all ratings, as well as the professional or technical qualifications that are applicable to each rating.

The Quals Manual is kept current by means of numbered changes. Because changes are issued more frequently than most Navy Training Courses can be revised, the training courses cannot always reflect the latest qualifications for advancement. When preparing for advancement, therefore, you should always check the LATEST Quals Manual and its LATEST changes to ensure that you know the current requirements for advancement in your rating.

When studying qualifications for advancement, remember that—

1. The quals are the MINIMUM requirements for advancement to each rate within each rating. If you study more than the required minimum, you naturally will have that much advantage when you take the written examinations for advancement in rating.

2. Each qual has a designated rate level—third class, second class, first class, chief. You are responsible for meeting all quals specified for advancement to the rate level to which you are seeking advancement AND all quals specified for lower rate levels.

3. Written examinations for advancement in rating contain questions relating to the practical factors and the knowledge factors of BOTH military requirements and professional qualifications.

A special form, known as the Record of Practical Factors, NavPers 760, is used to record satisfactory completion of practical factors, both military and professional, listed in the Quals Manual. This form is available for each rating. Whenever a person demonstrates his ability to perform a practical factor, appropriate entries must be made in the Date and Initials columns. As RM1 or RMC, you often will be required to check the practical factor performance of lower rated men, and report the results to your supervising officer. To facilitate record keeping, group records of practical factors are often maintained aboard ship. Entries from the group records must, of course, be transferred to each individual's Record of Practical Factors at appropriate intervals.

Because changes are made periodically to the Quals Manual, new forms of NavPers 760 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the Quals Manual. The Record of Practical Factors also provides space for recording demonstrated proficiency in skills that are within the general scope of the rating but are not identified as minimum qualifications for advancement. Keep this provision in mind when you are training and supervising lower rated personnel. If a man demonstrates proficiency in some skill that is not listed in the Radioman quals but falls within the general scope of the rating, report this fact to the supervising officer so that an appropriate entry can be made for that man.

The Record of Practical Factors should be kept in each man's service record, and it should be forwarded with his service record to his next duty station. Each man should also keep a copy of the record for his own use.

Training Publications for Advancement in Rating

Another vital publication for anyone preparing for advancement in rating is Training Publications for Advancement in Rating, NavPers 10052. It lists required and recommended Navy Training Courses and other reference material to be consulted or studied by personnel working for advancement in rating. This publication is revised and issued once each year by the Bureau of Naval Personnel. Each revised edition is identified by a letter after the NavPers number. When using this publication, be sure you have the most recent edition.

The required and recommended references are listed by rate level in NavPers 10052. You are responsible for all references at lower rate levels, as well as those listed for the rate to which you are seeking advancement.

Navy Training Courses that are marked with an asterisk (*) in NavPers 10052 are MANDATORY at the indicated rate levels. A mandatory training course may be completed by (1) passing the appropriate Enlisted Correspondence Course based on the mandatory training course, (2) passing locally prepared tests based on information given in the mandatory training course, or (3) in some instances, successfully completing an appropriate Navy school.

Notice that all references listed in NavPers 10052—whether mandatory or recommended—may be used as source material, at the appropriate rate levels, for written examinations.

Navy Training Courses

Navy Training Courses are written for the specific purpose of helping personnel prepare for advancement in rating. Some courses are general in nature and are intended for use by more than one rating. Others (such as this one) are applicable to a particular rating.

Navy Training Courses are revised from time to time to bring them up to date. A revision of a Navy Training Course is identified by a letter after the NavPers number. You can tell whether a Navy Training Course is the latest edition by checking the NavPers number and the letter after the number in List of Training Manuals and Correspondence Courses, NavPers 10061.

Three Navy Training Courses are specially prepared to present information on military requirements for advancement. These courses are—

- Basic Military Requirements, NavPers 10054.
- Military Requirements for Petty Officer 3 & 2, NavPers 10056.
- Military Requirements for Petty Officer 1 & C, NavPers 10057.

Each of the military requirements courses is mandatory at the indicated rate levels. In addition to giving information on military requirements, these three books contain a good deal of useful information on the enlisted rating structure; how to prepare for advancement; how to supervise, train, and lead other men; and how to meet your added responsibilities as you advance in rating.

Some of the Navy Training Courses that may be useful to you when you are preparing to meet the professional qualifications for advancement to RM1 and RMC are discussed briefly in the following paragraphs. For a complete listing of Navy Training Courses, consult List of Training Manuals and Correspondence Courses, NavPers 10061.

Mathematics, Vol. 1, NavPers 10069 and Mathematics, Vol. 2, NavPers 10071 are two training courses that may be helpful if you need to brush up on your mathematics. Volume 1, in particular, contains basic information needed for using formulas and for making simple computations. Information in volume 2 is more advanced.

Correspondence Courses

Most Navy Training Courses and Officer Texts are used as the basis for correspondence courses. Completion of a mandatory training course can be accomplished by passing the correspondence course that is based on the training course. You will find it helpful to take other correspondence courses, as well as those based on mandatory training courses.

Other BuPers Publications

Additional BuPers publications that you may find useful in connection with your responsibilities for leadership, supervision, and training include Manual for Navy Instructors, NavPers 16103 and Naval Training Bulletin, NavPers 14900 (published quarterly).

NAVSHIPSYSCOM PUBLICATIONS

A number of publications issued by the Naval Ships System Command will be of interest to you. Although you do not need to know everything given in the publications mentioned here, you should have a general idea of where to find information in these publications.

BuShips Technical Manual

The Bureau of Ships Technical Manual, NavShips 250-000 is the basic doctrine publication of the Naval Ships System Command. The Manual is kept up to date by means of quarterly changes. All copies of the Manual should have all changes made in them as soon as possible after changes are received.

Beginning with the quarterly changes dated 15 July 1963, NavShips began to renumber individual chapters in the BuShips Technical Manual according to the Navy-Marine Corps Standard Subject Classification System. Under this system, all chapters of the Manual will eventually be part of the 9000 series, which identifies ship design and ship's material subject groups. When all chapters are renumbered to conform to the 9000 numbering system, old chapter numbers will be eliminated. In the meantime, you should consult the sheets in the front of the first volume of the Manual, which cross-reference the new numbering system and the old. Some of the Manual chapters remain in their old positions, so the new and the old numbers have a definite relationship to each other. For example, old chapter 67 will in time be renumbered as 9670, and old chapter 48 will be renumbered as 9480. Some chapters, however, will be moved to new locations, and will also be renumbered; in these instances there is no clear relationship between the old numbers and the new. For example, old chapter 96 has been moved to a new location and is now renumbered 9006.

The following chapters of the BuShips Technical Manual, identified by both old number and new number, are of particular importance to you.

Chapter Number		Title
Old	New	
2	9001	Publications and Plans
6	9004	Inspections, Records and Reports
67	9670	Electronics
69	9690	Electrical Measuring and Test Instruments

It should be noted that you may see some chapters of the BuShips Technical Manual referred to in various Navy publications by either the old chapter number or the new chapter number, depending upon which number was in use at the time of writing. If you have trouble locating the chapter by the number given, check the cross-reference sheets in the front of the first volume of the Manual.

Naval Ship Systems Command Technical News

The Naval Ship Systems Command Technical News, a monthly technical publication, contains current unclassified information on the work and problems of NavShips and its field activities. The magazine is particularly useful because it presents information that supplements and clarifies articles in the BuShips Technical Manual, and because it contains data on new equipment, policies, and procedures.

Manufacturers' Technical Manuals

Manufacturers' technical manuals, furnished with most electronic units and many types of equipment, are valuable sources of information on operation, maintenance, and repair. Manufacturers' technical manuals for radio and associated equipment usually bear NavShips numbers.

Electronics Information Bulletin

The Electronics Information Bulletin, (EIB) NavShips 900,022A is a biweekly authoritative publication containing advance information on field changes, installation techniques, maintenance notes, beneficial suggestions, and technical manual distribution. A file of all EIBs should be kept available for handy reference.

Electronics Installation and Maintenance Book

The Electronics Installation and Maintenance Book (EIMB) (formerly EMB), NavShips 900,000 provides subordinate policies, installation, maintenance standards, and procedures required to implement the policies of chapter 67 of the BuShips Technical Manual. The EIMB consists of several volumes covering each major electronic field.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. A selected list of training films that may be useful to you is given in appendix I of this training course. Other films that may be of interest are listed in the United States Navy Film Catalog, NavWeps 10-1-777. This catalog, published in 1966, supersedes three earlier publications: the former catalog with the same title but numbered NavPers 1000-A; the Supplement, NavWeps 10-1-772; and the Navy Classified Film Catalog, NavPers 10001-A.

When selecting a film, note its date of issue listed in the film catalog.

As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may still have sections that are useful, but it is important to note procedures that have changed. If there is any doubt, verify current procedures.

CHAPTER 2

COMMUNICATION PLANNING

Communications is the link by which an operational commander directs his forces, receives instructions from his superiors, and keeps them informed of the local situation. It must, therefore, be a two-way street affording reliability, speed, and security needed for successful conclusion of any given task. Before this end can be attained, however, the ways and means by which it is to be accomplished must be known. The communication annex of an operation order or operation plan conveys this knowledge.

PLANNING

Before formulating the communication plan itself, some preliminary planning must be done to decide what information it should include. The communication planner must know, for instance, the following data:

- Task and purpose of the mission, so he can decide the types and quantity of circuits that are necessary.
- Types of ships, aircraft, and/or troops assigned, so he can determine the command and tactical radio nets that will be required.
- Type and amount of each unit's equipment, and number of Radiomen and their rates, so he can determine the type and number of circuits they can handle. To carry out the assigned task, he may have to ask for more equipment and personnel.
- Physical characteristics of operational area should be obtained, if possible, in order to know long-range circuit requirements and most suitable frequencies.

The foregoing requirements are but a few of many aspects that must be considered by the communication planner. When writing a communication plan, Naval Operational Planning, NWP 11 should be used as a guide.

BASIC PROBLEMS

In communication planning, three basic problem areas exist. They are (1) flexibility in meeting command requirements, (2) operating limitations, and (3) protecting communications.

Flexibility

The commander of a naval operation organizes his forces principally to attain its objectives as effectively and efficiently as possible. Communications must provide him the means for directing and redirecting his forces so that he can take advantage of every favorable opportunity offered by the enemy and be able to meet any enemy threats. He must be able to reorganize his forces to do different jobs than those originally assigned, and communications must be equal to any situation.

As an example of the flexibility just described, if a certain task unit within a task force should be the anti-air warfare (AAW) unit, and the enemy made a full-scale submarine attack too large for the present antisubmarine (ASW) unit to handle, the commander might want to divert some ships from the AAW unit and put them under operational control of the ASW unit commander. For this changeover to take place smoothly and without complications, ships that are diverted must be able to shift without difficulty to ASW circuits. To meet this demand the communication plan must be flexible.

The task force commander must be in constant contact with his task group and task unit commanders. Also, task group and unit commanders must be in constant contact with their units and with individual ships. Ships within a unit must be in constant contact with each other.

All necessary circuits needed for the operation must be included in the communication plan, which must be arranged in such a manner that it can be easily read and understood. Too many circuits could cause confusion and tax communication facilities of participating ships and units. For these reasons care must be taken, when writing a communication plan, to meet the flexibility that a task force must have.

Operating Limitations

Communications must meet the demands of the task organization and contribute to its tactical effectiveness. Conversely, overall plans for the operation must be compatible with communications that can be provided. Three main areas that impose limitations on communications are: (1) selection of radiofrequencies, (2) availability of equipment, and (3) availability of personnel.

Usually the choice of frequencies allocated to an operation is limited because of the constant heavy load placed on the frequency spectrum. From the allocated frequencies, the communication planner makes his selection on the basis of the purpose of the operation, geography of the area, seasonal and solar influences on frequency performance, and equipment available.

The communication planner should consider the capacity of each command in drafting its communication plan. He must therefore have available information concerning equipment and personnel aboard each command.

Although certain frequencies may be desirable for use, the planner must ensure that adequate equipment is available before he makes his selection. Because of time limitations, availability of equipment in a forward area, and space needed for installation, additional equipment may be out of the question.

Often, availability of communication personnel is limited. This limitation must be considered when the communication planner assigns circuits and makes guardship arrangements for individual commands.

Each command must organize its communication department so as to handle assigned workloads as efficiently as possible. Work capacity of the department and of individual personnel must be considered. When a command makes up its watch bill, care should be taken so that each position is filled by a qualified man. If training is needed to fill any positions, it should be inaugurated before commencing the operation.

Protecting Communications

Inasmuch as most communications of any operation are handled by radio circuits, protection of these circuits is a prime factor in planning. They must be protected against enemy interception or interference. Some methods used for these purposes are authentication, used to determine authenticity of a transmission; codes and ciphers to provide crypto security; use of on-line cryptodevices that electronically encrypt and decrypt messages as they are transmitted and received; and imposition of radio silence to shield movements of forces. The communication planner should see that necessary publications are available and that proper overall training is given to the force in communication security.

REQUIREMENTS

After preliminary planning is completed and all communication aspects and considerations are taken into account, the communication planner establishes requirements for the operation. From information gathered from various sources, he makes a preliminary outline for the communication plan. Data considered are capabilities and facilities of participating commands, estimates resulting from staff studies, and information received from DNC on facilities and services available within the Naval Communication System.

The outline for the communication plan should include four basic requirements. They are—

1. Command primary and secondary communications. From this requirement comes the primary and secondary command nets the commander uses to contact his own forces, commanders of other forces, and the command he comes under.
2. Communications for logistic and other service and support activities. These circuits are for administrative and supply traffic to rear echelons and supporting activities.
3. Tactical communications. These circuits are used to interconnect various groups and units engaged in the same type of activity, such as air defense and shore bombardment.
4. Communication security. Provisions must be made for protecting communications discussed earlier.

From his outline and other information gathered, the planner can formulate the communication plan.

OPERATION ORDERS

Operation orders (OpOrders) are directives issued by naval commanders to subordinates for the purpose of effecting coordinated execution of an operation in the immediate or near future. These directives are prepared in accordance with a standard approved form, as set forth in NWP 11, Naval Operational Planning. Common understanding between individual services and, in larger aspect, between different Allied Nations is basic to successful combat. The approved format is designed to reduce to a minimum any areas of possible misunderstanding.

An operation order usually consists of a basic plan made up of the heading, body, and ending, and detailed procedures (in the form of enclosures) called annexes and appendixes as necessary. The basic plan is kept concise, and contains only those details necessary for a clear, overall picture of the operation. Annexes themselves may be brief or protracted. They often have appendixes and tabs to elaborate on the many details to be considered in a large and complicated tactical operation.

Among subjects that properly may be discussed in annexes are battle plans, search and rescue communications, intelligence, logistics, anti-air warfare, and antisubmarine warfare. This list is not all-inclusive, however.

Amplifying information that is inappropriate for inclusion in the annex may be prepared as an appendix to the annex. In the same way, appendixes may be amplified by preparation of tabs to an appendix. Each one is given a name descriptive of its contents. Appendixes are listed at the end of the annex to which they belong. Tabs are listed at the end of their governing appendix.

DIFFERENCE BETWEEN OPERATION PLANS AND OPERATION ORDERS

An operation plan (OpPlan) is a directive for carrying out operations extending over a large geographical area and usually covering a considerable period of time. Ordinarily an OpPlan is based upon, and therefore restricted by, various appropriate assumptions. It is prepared well in advance of an impending operation, and includes information concerning the time it will become effective. This information may be included in the plan, or it may state merely that it will become effective when signaled by appropriate authority. The OpPlan is the instrument upon which subordinate commanders base directives to their commands covering specific tasks assigned.

An operation order (OpOrder) is prepared in a prescribed form, similar in most respects to an operation plan. It is issued by a commander to his subordinates to effect coordinated execution of a specific operation. It directs that the operation be carried out. No assumptions are included and, unless otherwise stated, the OpOrder is effective from the time and date signed.

Rarely in peacetime—and only infrequently in wartime—is the shipboard communicator called on to use an operation plan, although much of his daily routine in handling messages and circuits is part of the communication plan. On the other hand, almost all coordinated operations experienced in the daily life of a sailor are carried out as the result of OpOrders.

HEADING

Figure 2-1 is a sample heading of an operation order. At the right, below the classification, is the title of the issuing headquarters. Omitted from the illustration is the copy number. It would be required on each copy of the directive if joint or combined operations have involved, or for plans and orders concerning only U. S. Navy forces if the document were classified higher than Confidential. Each copy would bear a different number, and a record of disposition must be maintained.

SECURITY CLASSIFICATION

Fourth Fleet
TG 47.5 and ComCarDiv 1
YORKTOWN (CVS 10), Flagship
Norfolk, Virginia
DTG 311200R, October 1965
Message Ref: 0059/65

Operation Order
ComCarDiv 1
No. 52-65

Time Zone: Use time zone plus 5 (ROMEO) for operations.

50.2

Figure 2-1.—Operation order heading.

The issuing headquarters title is preceded by titles of higher echelons considered necessary to ensure proper identification. The name of the flagship (or headquarters, if on shore) must be included as shown. The geographical location of the issuing commander is listed; or, if at sea, latitude and longitude. The date-time group of the signature, including zone description, appears next. Unless stated to the contrary in paragraph 3x of the order, the DTG is the effective time of the order. A message reference number is the originator's serial number for identification. It is used for in-the-clear message acknowledgment of the order. A message reference number should contain no indication that it is associated with a plan or order.

Underlined words Operation Order appear to the left. This identifying title is sufficient when only one service takes part. If more than one service participates, such descriptive words as Joint Army-Navy Operation Order might be used.

Immediately below the directive designation is the short administrative title of the originator and the serial number of the directive. Each commander serializes his OpOrders consecutively throughout the calendar year.

Pertinent references, if applicable, are listed next; for example, REFERENCES: NWP 20, NWP 16(A). None were necessary in the example, so none are shown.

The time zone to be used in the operation is then included, as in figure 2-1.

BODY

The body of the OpOrder consists of the task organization, five numbered paragraphs, and acknowledgment instructions. They are illustrated in figure 2-2.

In the task organization listing, each paragraph is lettered alphabetically beginning with the small letter a. Each subdivision of the commander'e entire force to be assigned a task is listed separately with its designated task name (Heavy Unit, Screen Unit, etc.), followed by the name of the ship or administrative title of the officer in command of the force, group, unit, or task element.

Because an individual ship often is assigned several different tasks to perform during various phases of an operation, it is common for a ship to be listed under several subheadings of the task organization.

Five Numbered Paragraphs

Paragraph 1 covers the situation. Here the commander sets forth only so much of the general situation as enables all his subordinates to understand the background of a planned operation. A history of preceding events is not desired. All information is brief and to the point. In addition, paragraph 1 always contains three lettered subparagraphs (a, b, and c).

Subparagraph a relates to enemy forces. In a wartime situation, this topic reflects the best intelligence estimate of what the enemy has available. If information is so extensive that it is ineffective in this location, a separate annex may be written, and in the subparagraph a statement such as "See Annex______" is included. If none (as in peacetime), a statement to this effect is made; this section cannot be left blank.

Subparagraph b concerns friendly forces. It refers only to friendly forces not listed in the task organization. Information on friendly forces is always brief and restricted to that required for proper coordination of operations.

Subparagraph c is for listing attachments and detachments. Included here are any forces that will join or be detached from the force as the operation progresses; if none, this information is so stated. If a "Schedule of Events" annex contains this information, reference to that annex is sufficient. (To repeat, none of the three subparagraphs may be omitted or left blank.)

Paragraph 2 states the mission, which either may have been assigned by higher authority or deduced from his instructions. In effect, paragraph 2 contains the most important information in the directive. Often it is the first item to be read by a subordinate upon receipt of the document. It consists of the task to be accomplished and the purpose for accomplishing it, separated by the phrase "in order to." By reading the mission paragraph, each subordinate should be able to understand what is to be done and why. No other place in the operation order gives such a concise statement of the intent of the operation.

Paragraph 3 is the execution paragraph. Opening with "This force will," it sets forth, in concise terms exactly what the overall organization is to accomplish.

In succeeding subparagraphs, beginning with letter a, tasks assigned to elements of the organization are prescribed in detail. Letters a, b, c, and so on, identify additional subparagraphs describing tasks assigned each unit of a force.

Task Organization:

a. 47.5.2	Heavy Unit YORKTOWN (CVS 10)	 RADM R. M. P. 1 CVS
	PLATTE (AO 24)	CAPT E. C. R. 1 AO
b. 47.5.3	Screen Unit DesDiv 152	 CDR B. D. W. 4 DD
c. 47.5.4	Anti-Air Warfare, Coordination Unit DesDiv 153	 CDR W. C. M. 4 DD

1. SITUATION. ComNavAirLant Notice 03360 of 16 February 1965 scheduled an opposed ASW/AAW coordination sortie on 4 November with ComCarDiv 1 as OCE and OTC. This OpOrder covers the conduct of the sortie.

a. Enemy Forces: None

b. Friendly Forces: None

c. Attachments and Detachments: None

2. MISSION. On 4 November 1965 conduct a combined opposed ASW/AAW coordinated sortie exercise from Narragansett Bay in order to train assigned units in antisubmarine warfare and AAW coordination.

3. EXECUTION. This force will conduct a combined opposed ASW/AAW coordination sortie exercise from Narragansett Bay on 4 November 1965.

a. Heavy Unit - Sortie in accordance with Annexes ALFA and DELTA.

b. ASW Screen Unit - Sortie in accordance with Annexes ALFA and DELTA, and protect heavy unit from submarine and air attack.

c. Anti-Air Warfare Unit-Coordinate anti-air warfare of the sortie group in accordance with Annex GOLF.

x. Coordinating Instructions.

(1) This operation order is effective for planning on receipt and for operations commencing 4 November 1965.

(2) Search and rescue in accordance with CINCLANFLT OpOrder 1-65, NWP 37, NWIP 23-6, and Annex HOTEL. Submarine Search and Rescue Plan in accordance with COMSUBLANT OpPlan 27-65 (SUBMISS-SUBSUNK) and Annex HOTEL.

4. ADMINISTRATION and LOGISTICS. Administration and Logistics in accordance with existing instructions.

5. COMMAND and SIGNAL.

a. Communications in accordance with Annex CHARLIE.

b. Use zone time plus 5 (ROMEO).

c. Commander Carrier Division 1 in USS YORKTOWN (CVS 10) is OCE and OTC.

d. Commander Destroyer Squadron FIFTEEN in USS PUTNAM second in command.

Acknowledgment Instructions:

Units listed in Task Organization acknowledge receipt of this directive by message using message reference number.

50.3-.5

Figure 2-2.—Task organization and the five numbered paragraphs.

An additional subparagraph, "Coordinating Instruction," follows, identified by letter x. Here are listed items of information to more than one task subdivision as well as instructions relating to security, cooperation, duration of events, and the like. If the directive is to become effective at some time or date besides the date-time group in the heading, this fact is stated in coordinating instructions.

Paragraph 4 is for administration and logistics. Necessary arrangements and procedures for accomplishing the mission are set forth in this paragraph. As in other paragraphs of the basic plan, it is permissible to refer to a logistics annex if one is appended. Or, as often happens in comparatively small local training operations, refer simply to existing instructions.

Paragraph 5 is the command and signal paragraph. As used here, signal means communications. Contained in this paragraph are all special features of command. These features include designation of the officer second in command, and also the location of the commander and his second in command. Additionally, division of responsibility among various commanders is clarified, and the communication plan is described or, customarily, the communication annex is referenced. A complete annex and one or more appendixes are necessary—even for routine operations down to the division level of destroyer operations—because the problem of communications is so enormous and vital.

Acknowledgment instructions usually are included, but are not required. An acknowledgment means that the directive was received and is understood.

ENDING

The ending of the OpOrder includes the signature, list of annexes, distribution list, authentication, and security classification.

To make it effective, the directive requires the signature (fig. 2-3) of the commander. It appears below the acknowledgment instructions,

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Figure 2-3.—The OpOrder—Signature.

to the right side of the page, over his rank and command title. For OpOrders and OpPlans concerning United States Navy units only, operational and administrative titles are added. The commander signs the original OpOrder and each annex, appendix, and tab.

The security classification must appear on the top and bottom of each page of the directive. Below the signature are listed appended annexes (fig. 2-4), each designated by capital letters. Each appendix and tab to the various annexes are included in the list also.

A distribution list (fig. 2-5) is inserted after the list of annexes. For comparatively short distribution lists, each addressee is listed as part of the basic plan. For longer lists (this practice is usual in all but the simplest directives), the distribution list may be a separate annex. The number of copies each addressee is to receive is indicated. If some are to receive all but certain portions, the deleted part is so indicated. Administrative titles are used in the distribution list, because tactical titles might serve to compromise the directive as well as cause mailing delays.

COMMUNICATION ANNEX

In addition to paragraph 5 of the basic directive, the most important portion of the OpOrder (for communication personnel) is the communication annex. Purpose of the communication annex is to give information on communications that is too extensive to be included in the basic operation order.

Customarily, the communication annex is designated Annex C (fig. 2-6). The heading and ending of the annex are identical to those of the OpOrder. The numbering of paragraphs in the communication annex follows the numbering of related matters in NWP 16 that are to be amplified or modified.

In the communication annex for a combined operation, usually no reference is made to NWP 16 because not all Allied Nations have access to that publication.

The amount and type of information found in a communication annex depend on the purpose of the plan or order and on the mission of the command for which it is being made.

Types of information that may be found in communication annexes are radio checks, call signs and address groups, frequency plans, distress communications, guardship lists, exercise communications, visual communications, authentication, and broadcast shifts. This list is

SECURITY CLASSIFICATION

ANNEXES

A	–	Time Schedule
B	–	Navigation Instructions
C	–	Communications
		APPENDIX I – Frequency Plan
		APPENDIX II – Aircraft Communications
		Tab A
		Tab B
		APPENDIX III – ASW Circuits
D	–	Antisubmarine Warfare Plan
E	–	Air Strike Plan
		APPENDIX I – Strike Schedule
F	–	Friendly Air Schedule
G	–	Anti–Air Warfare Plan
		APPENDIX I – Picket, CAP, and Strike Control assignments
		APPENDIX II – AA Coordination Plan
H	–	Safety
R	–	Reports
Z	–	Distribution

SECURITY CLASSIFICATION

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Figure 2-4.—Table on annexes.

not all-inclusive, however. Each of these headings is numbered according to the numbering of associated paragraphs in NWP 16.

Appendixes

An appendix amplifies portions of annex material much the same as an annex amplifies a basic directive.

Figure 2-7 is an example of Appendix I (Call Sign List) to Annex C of the OpOrder studied in this chapter. The heading and ending are the same as the annex it appends.

Column 1 lists commands within the task group. Columns 2 and 3 give the letter call sign and voice call sign, respectively. These three columns are the only ones necessary in the call sign list. In this example columns 4 and 5 are added to give further information. Column 4 shows call letters of the ship, occupied by various commanders. Column 5 lists the task group or task unit of which each command and ship is a part.

Any headings mentioned as being in the annex could be made into appendixes if sufficient information warrants.

Tabs

When necessary to amplify a portion of an appendix, a separate page is added as a tab. Appendix II (Frequency Plan), shown in figure 2-8, is broken down into tabs. Figure 2-9 is a condensed surface frequency plan designated Tab A. Possibly tab B (not shown) could be the aircraft frequency and channelization plan.

Numbering

Annexes are designated serially by capital letters; appendixes, serially by Roman numerals; and tabs, serially by capital letters. Thus, a tab might be referred to as Tab C to Appendix IV to Annex W. Pages of the basic directive are numbered serially starting with Arabic numeral 1; pages of annexes, serially by annex letter followed by page number, as C-2. Appendix pages are numbered by adding the Roman numeral in the appropriate place; for example, C-II-1 is page 1 of appendix II to Annex C. Tabs add the capital letter, as appropriate, after the Roman numeral.

SECURITY CLASSIFICATION

Fourth Fleet
TG 47.5 and ComCarDiv 1
Yorktown (CVS 10), Flagship
Norfolk, Virginia
DTG 311200R, October 1965
Message Ref: 0059/65

Operation Order
ComCarDiv 1 No. 52-65

ANNEX ZULU

Distribution List	Distribution
CNO	10
CINCLANTFLT	10
COMAIRLANT	2
COMSUBLANT	2
COMCRUDESLANT	2
PRES NAVWARCOL	2
COMONE	1
COMNAVBASE NPT	2
COMDESFLOT TWO	2
COMCARDIV 1	3 (less Appendix I to Annex ECHO)
COMDESRON 15	1 (less Appendix I to Annex ECHO)
USS DUPONT	3 (less Appendix I to Annex ECHO)
USS PUTNAM	3
USS KEITH	3
USS HENLEY	3
USS AULT	3
USS WALDRON	3
USS HAYNSWORTH	5 (less Appendix I to Annex ECHO)
USS JOHN W. WEEKS	3
USS YORKTOWN	5

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Figure 2-5.—Distribution list as an annex.

SECURITY CLASSIFICATION

Fourth Fleet
TG 47.5 and ComCarDiv 1
YORKTOWN (CVS 10), Flagship
Norfolk, Virginia
DTG 311200R, October 1965
Message Ref: 0059/65

Operation Order
ComCarDiv 1 No. 52-65

ANNEX CHARLIE

Communications

113. EFFECTIVENESS

1. Communications in accordance with NWP 16(A), and appropriate Joint, Allied, and Navy Department Publications. NWP 16(A) is effective throughout as applicable to the existing situstion unless modified or amplified by this Annex. The numbering of paragraphs herein follows the numbering of related material in NWP 16(A). The interpretation as to the applicability of a specific article is a function of the command concerned.

410. CALL SIGNS AND ADDRESS GROUPS

1. The call signs for CTG 47.5 and TG 47.5 are effective for use commencing 040600R.
2. Call signs will be those regularly assigned to participating units. (See Appendix I to this Annex.)

619. FREQUENCY PLAN

1. Radiofrequency plan is contained in Appendix II to this Annex.
2. Surface force frequency plan is contained in Tab A to Appendix II.
3. Aircraft frequency plan and channelization is contained in Tab b to Appendix II.

810. EMERGENCY, DISTRESS, AND COMBAT SCENE OF ACTION COMMUNICATIONS.

1. Distress communication guard assignments are prescribed in Appendix II of this Annex.
2. Ships or units not in company shall maintain a continuous split-phone guard on the distress frequencies prescribed.
3. Combat scene of action and ASW incident communications shall be as prescribed in Appendix II of this Annex.

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Figure 2-6.—Communication annex.

SECURITY CLASSIFICATION

Fourth Fleet
TG 47.5 and ComCarDiv 1
YORKTOWN (CVS 10), Flagship
Norfolk, Virginia
DTG 311200R, October 1965
Message ref: 0065/65

Operation Order
ComCarDiv 1 No. 52-65

APPENDIX I TO ANNEX CHARLIE

CALL SIGN LIST

Command	Call Sign	Voice Call	Aboard	TG/TU
CTG 47.5	A5BC	JETSTREAM	NWKJ	
TG 47.5	C7FG	GLOBEMASTER		
CTU 47.5.2	B6DE	STARFIRE	NEJQ	
TU 47.5.2	D8HI	MOONGLOW		
CTU 47.5.3	E9JK	SUNFISH	NWKJ	
TU 47.5.3	FØLM	BLUESTAR		
CTU 47.5.4	G4NO	GREENSEA	NHXO	
TU 47.5.4	H3PQ	BROADSIDE		
COMCARDIV 1	XYAC	HIGHBROW	NWKJ	CTG 47.5
COMSERVRON 3	STCO	LIGHTSIDE	NEJQ	CTU 47.5.2
COMDESRON 15	DLHU	BEESTING	NHXO	CTU 47.5.4
COMDESDIV 152	XDBY	OVERBOARD	NHXO	TU 47.5.4
COMDESDIV 153	OSBR	CHANGEOVER	NTIR	TU 47.5.3
DUPONT (DD 941)	NTIR	PACEMAKER		TU 47.5.3
PUTNAM (DD 757)	NHXO	GOGETTER		TU 47.5.4
KEITH (DD 241)	NXDO	WANDERER		TU 47.5.3
HENLEY (DD 762)	NHXW	FASTENER		TU 47.5.3
AULT (DD 698)	NTWR	STICKPIN		TU 47.5.3
WALDRON (DD 699)	NTEX	FROGMAN		TU 47.5.4
HAYNSWORTH (DD 700)	NJTA	DRAGSTER		TU 47.5.4
JOHN W. WEEKS (DD 701)	NHEK	LOWBOY		TU 47.5.4
YORKTOWN (CVS 10)	NWKJ	HONEYCOMB		CTU 47.5.3
PLATTE (AO 24)	NEJQ	OILSLICK		TU 47.5.2

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Figure 2-7.—Appendix I—call sign list.

SECURITY CLASSIFICATION

Fourth Fleet
TG 47.5 and ComCar Div 1
YORKTOWN (CVS 10), Flagship
Norfolk, Virginia
DTG 311200R, October 1965
Message Ref: 0065/65

APPENDIX II TO ANNEX CHARLIE

FREQUENCY PLAN

1. All frequencies in accordance with JANAP 195(F) and as assigned by ComFourthFlt.

2. Frequency shifts as necessary controlled by the circuit net control station.

3. Surface frequency plan is contained in Tab A to this Appendix.

4. Aircraft frequency plan and channelization is contained in Tab B to this Appendix.

5. Radio checks will be conducted at 020800R, 031500R, and 040700R on all circuits in consecutive order.

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Figure 2-8.—Appendix II—frequency plan.

SECURITY CLASSIFICATION

Fourth Fleet
TG 47.5 and ComCarDiv 1
Yorktown (CV 510), Flagship
Norfolk, Virginia
DTG 311200R, October 1965
Message Ref: 0059/65

Operation Order
ComCarDiv 1 No. 52–65

TAB A TO APPENDIX II TO ANNEX C

SURFACE FREQUENCY PLAN

Circuit	Use	Desig.	Freq.	Emission	CTG	Screen	Main body	AAW	Picket	Remarks
1	TG M & W(P) (PRITAC)	C3.5A	318.6	V	N	X	X	X	X	Pickets may secure when in station
2	ASW Common (SURFACE–AIR)	C3.7B	324.1	V	N	X	X	X	X	
3	TG CIC (P) (PRI CI)	C3.5F	345.8	V	N	X	X	X	X	
4 5 6	SAU TAC PRI (A) SAU TAC PRI (B) SAU TAC PRI (C)	C3.15D C3.20L C3.5D	283.4 389.8 315.2	V		X				See Appendix IV
7	TG Common	C3.5C	442	CW	N	L	L	L	L	Alt Air Safety Net, if required
8 9 10	SAU CI (A) SAU CI (B) SAU CI (C)	C3.14A C3.14D C3.14J	148.68 134.46 158.04	V		X				See Appendix IV

X – Guard
N – Net Control
L – Listen

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50.10

Figure 2-9.—Tab A—frequency plan.

CHAPTER 3

COMMERCIAL TRAFFIC

Naval communications do not compete with privately owned and operated commercial communication companies. By terms of the Communication Act of 1934, however, the Navy is authorized to use its radio stations for reception and transmission of press messages and private commercial messages between ships, between ship and shore, and between shore stations and privately operated ships whenever privately owned and operated stations are incapable of meeting normal communication requirements.

Instructions contained in DNC 26 cover the handling, by U. S. naval communications, of all commercial communications, including official Government traffic involving tolls, and unofficial traffic involving and not involving tolls. These instructions are based upon the International Telecommunications Convention, Geneva, 1959, and the telegraph regulations (Geneva revision, 1958) annexed thereto; the Communication Act of 1934, as amended; rules and regulations of the Federal Communications Commission; and Western Union Telegraph Company tariff books.

WORD COUNT SYSTEMS

As a means of collecting fees for expense incurred when handling commercial communications, the Navy uses two systems of word count. Domestic word count applies to domestic messages and is based on domestic rules and regulations. International word count is used for radiotelegrams and international telegrams, and is based on international rules and regulations.

Domestic telegrams are messages originated at and addressed to points on shore within the continental United States, Canada, Mexico, Alaska, or Saint Pierre-Miquelon Islands, and transmitted in domestic form by wire or radio over all or part of its route.

A radiotelegram is a message originating in or intended for a mobile station, transmitted over all or part of its route by radio communication channels of the mobile service. International telegrams are messages originating at or destined to points except the continental United States, Canada, Mexico, Alaska, or Saint Pierre-Miquelon Islands. Both radiotelegrams and international telegrams are drafted in international form.

A detailed explanation of both word count systems is given in DNC 26, hence is not repeated here. Many examples in DNC 26 illustrate the rules effectively, showing how representative words and groups are counted differently according to their location in a message address, text, or signature.

COMMERCIAL TRAFFIC CLERK

Each Navy ship, station, or activity authorized to handle commercial traffic or to receive personal messages for transmission via naval communications has a commercial traffic clerk. He is designated in writing by the commanding officer. An experienced Radioman is selected for this task, although usually not the senior Radioman aboard.

The commercial traffic clerk handles all commercial traffic funds. He is not required to be bonded unless DNC so directs. A summary of duties of the commercial traffic clerk follows.

1. Maintain a complete file of all commercial messages accepted for transmission.

2. Keep a complete file of all incoming commercial messages and all official Government messages, received from other sources than naval communications, for abstracting purposes.

3. Maintain and understand all instructions and materials concerned with handling commercial traffic, such as rate sheets, bulletins, publications, and forms.

4. Collect proper charges and safeguard funds collected and in his custody.

5. Prepare prescribed reports on time and forward them to the communication officer for review.

The commercial traffic clerk performs his duties under supervision of the communication officer. All reports or other correspondence addressed to the Commanding Officer, U. S. Navy Finance Center (Code FC), Washington, D. C., or to the Chief of Naval Operations (DNC) are prepared for the commanding officer's signature.

COMMERCIAL TRAFFIC FUNDS

The commandant of a naval district or commanding officer of a ship, station, or activity establishes the maximum amount of naval commercial traffic funds permitted to accumulate in the possession of the commercial traffic clerk. Unless approved by DNC, however, this sum cannot exceed $100. Accumulated funds must be deposited at least weekly with the supply officer or disbursing officer. Only such amount is retained as is needed to make change.

When required for remittance, funds so deposited must be made available to the commercial traffic clerk by U. S. Treasury check, payable to the order of U. S. Navy Finance Center, Washington, D. C. or Western Union Telegraph Company, as appropriate.

Commercial traffic funds are kept separate and independent from other funds. Records are required to be inspected at least once a month by an auditing board. If practicable, this board includes as members the communication officer and supply officer. Their inspection includes verification of the cash balance and a complete audit of all accounts, including verification of rates used.

Reports of inspections are retained for 2 years if no irregularities are indicated. Records are subject to call for the original copy by CNO (DNC) or Commanding Officer, NAVFINCEN Washington. Any report of inspection showing irregularity must be forwarded to NAVFINCEN Washington, via official channels, with endorsements to show what action, if any, has been taken or is recommended.

Whenever the commercial traffic clerk is relieved, a special inspection and audit must be made. The report is forwarded to NAVFINCEN Washington. If the commercial traffic clerk is relieved and no replacement is nominated immediately, commercial traffic funds are retained in custody of the supply officer or assistant for disbursing.

Neither the communication officer nor the naval postal clerk is authorized to handle commercial traffic funds.

USES OF COMMERCIAL TRAFFIC FUNDS

Expenditures of commercial traffic funds are authorized for the following purposes:

1. Money order fees.
2. Postage (as necessary) to mail reports, or for mailing class D messages when originator requests delivery by mail.
3. Registration fees where the commanding officer determines that registered mail is necessary to protect or ensure delivery of the reports.
4. Refund of charges paid on non-Government messages when delivery cannot be made owing to causes not considered the responsibility of the sender.

An exchange-for-cash U. S. Treasury check may be used in preference to a money order. Use of these checks is a protection to the commercial traffic clerk, because, in case of loss, a second original can be issued without necessity of filling a bond.

All such expenditures must be reported in detail on the statement of account form submitted with a message abstract.

Commercial traffic funds cannot be used for such purposes as taxi fare, messenger service, special delivery, or telephone toll calls.

ABSTRACT FORMS

The word "abstract" refers to the series of report forms used for tabulating, reporting, and accounting for various categories of commercial traffic handled by naval communications. Three forms are utilized in reporting commercial traffic. Each one is illustrated and described later in this chapter. Following are the form numbers and titles, plus a brief rundown of classes of traffic reported on each.

1. NavCompt Form 2132, U. S. naval communication service abstract (fig. 3-1): This form replaces NavCompt Forms 2063, 2064, and 2066. It is used for—

a. All class D messages, including those by radiotelephone, originated by a naval ship.

b. All class D messages received and delivered on board or relayed by a naval ship.

NAVCOMPT FORM 2132 (8-64)

U.S. NAVAL COMMUNICATIONS SERVICE ABSTRACT

NAVCOMPT 2101.2

NOTE: Report all messages sent and received including those to and from foreign stations. Submit the original report, two message copies, original and one copy of "Statement of Account," (NAVCOMPT FORM 2065) for personal messages and remittance payable to Commanding Officer, by the fifth of each month. For detailed instructions refer to DNC 26(A).

JOURNAL VOUCHER NO.

PAGE 1 OF 1 PAGES

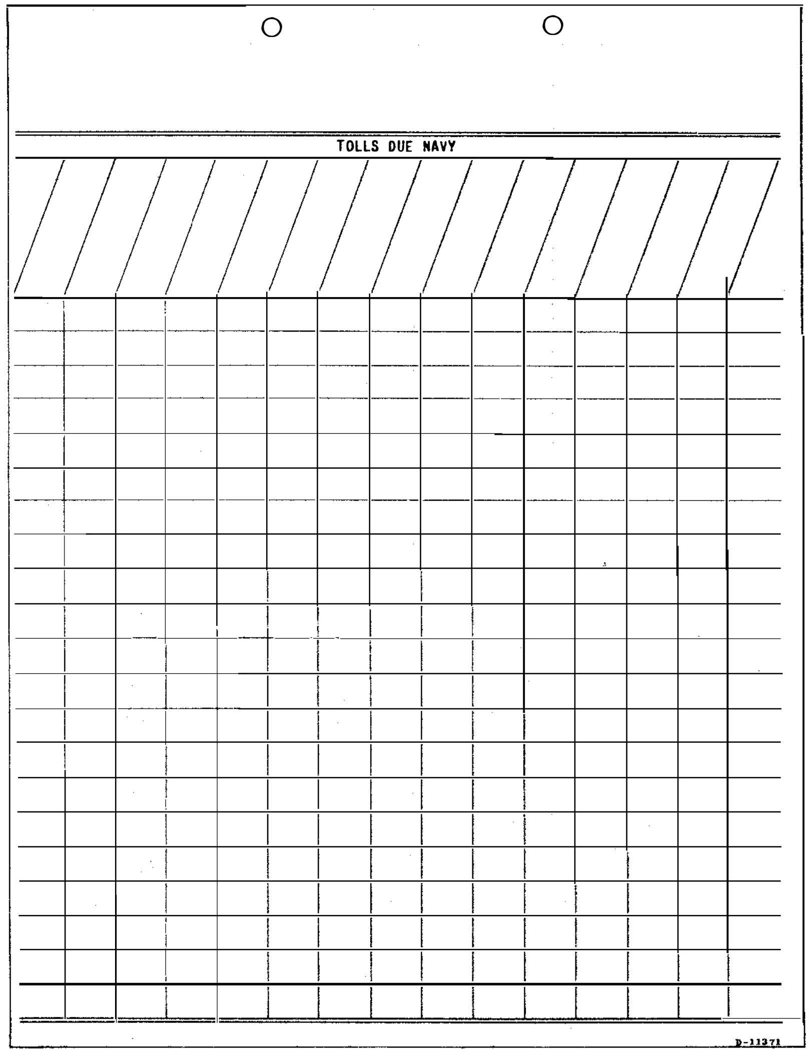
NAME OF SHIP/STATION/ACTIVITY: USS OVERSEAS DD123

FOR MONTH OF: SEPTEMBER

COMMUNICATIONS OFFICER (Signature): A. B. Cook — A. B. COOK LTJG, USN

COMMANDING OFFICER (Signature): D. E. Fairly — D. E. FAIRLY CDR, USN

SRS NO.	DATE SENT	DATE REC'D	OFFICE OF ORIGIN	ADDRESSEE	DESTINATION	TRANSMITTING DATA (Use call letters only) RECEIVED FROM	TRANSMITTING DATA SENT TO	DO NOT USE	NUMBER OF WORDS	COASTAL OR SHIP STATION CHARGE	TOLLS DUE CONNECTING CARRIER								TOTAL AMOUNT DUE OR CASH REMITTED	REMARKS OR EXTENSION
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
1D	2		USS OVERSEAS	AMCON	CAIRO, EGYPT		SUK		10	1.33										
2D		4	CHRISTCHURCH N.Z.	COOK	U.S.S. OVERSEAS	NPM			14	1.83										
3D		5	AUCKLAND, N.Z.	WITTIG	USS. OVERSEAS	ZLP			22	2.87										
4D	10		USS. OVERSEAS	AMCON	AUCKLAND, N.Z.		ZLP		12	1.60										
									TOTAL $											



50.134

Figure 3-1.—U.S. naval communication service abstract, NavCompt Form 2132.

c. All class D messages originated, received, forwarded, or delivered by a naval station or activity.

d. All class A and B messages (including official radiotelephone messages) transmitted by a naval ship direct to a domestic or foreign commercial shore radio station.

e. All class A and B messages received by a naval ship direct from a commercial shore radio station.

2. NavCompt Form 2065, statement of account (fig. 3-2): This form is required when forwarding remittances for class D private commercial messages, press messages, and radiophotos, and for class D messages entitled to class E privilege. It is not required for class E messages.

3. NavCompt Form 2067, abstract of class E messages (fig. 3-3): This form is used by both ships and shore stations originating class E messages involving tools, and class D messages entitled to class E privilege.

Abstract forms and message copies comprising commercial traffic reports must be retained on file by the commercial traffic clerk for a period of 24 months.

SERIAL NUMBERS

For identification and accounting purposes, all commercial traffic handled by naval communications is assigned serial numbers. These numbers are known as SRS numbers. They are in addition to regular station serial numbers normally assigned. The SRS numbers are never transmitted with the message. They are written or typed on each commercial message and are listed on commercial abstract forms for identification and accounting.

Each commercial message handled (including paid service messages) must be assigned an SRS number by each ship or station participating in its disposition. As a result, the same message bears a different SRS number at each station handling it.

Additional information concerning specific uses of SRS numbers appears later in this chapter.

Naval communication stations and the Naval Station Guantanamo Bay assign SRS numbers consecutively up to 10,000. All other Navy activities and ships assign SRS numbers consecutively, on a monthly basis, commencing with number 1 each month.

A capital letter (called a suffix) is added to the SRS number to identify the class of commercial message reported. When service messages concerning a message are sent, they are given the SRS numbers of the message to which they refer, succeeded by letter "a" for the first service, "b" for the second, and so on. A group of suffix letters, together with an example of each, is given in the accompanying list.

Class of message	Suffix letter	Example
A	A	SRS 1A
B	B	SRS 2B
D (radiotelegram)	D	SRS 3D
D (press)	P	SRS 4P
D (radiophoto)	R	SRS 5R
D (entitled to class E privilege)	G	SRS 6C
E	E	SRS 7E
E (Christmas greetings)	H	SRS 7H
Service message		SRS 7Ea

REPORT SYMBOLS

The Comptroller of the Navy has assigned NavCompt report symbols to commercial communication reports to aid in handling, auditing, and accounting for these reports. Report symbols consist of the word NavCompt followed by a number. For example, NavCompt 7210-1 is the Statement of Accounts report. Other report symbols are given in separate discussions of each message class. The appropriate report symbol must be placed on envelope or cover when forwarding commercial traffic reports. It should also appear on the abstract form itself. More than one report symbol may be used on one abstract form.

RESPONSIBILITY FOR REPORTS

Commercial traffic reports are required whenever commercial messages involving tolls

STATEMENT OF ACCOUNT
(NAVAL COMMUNICATIONS)
NAVCOMPT FORM 2065 (REV. 8-64)

NAVCOMPT 7210-1

REPORT FOR THE MONTH OF

TO: COMMANDING OFFICER, U.S. NAVY FINANCE CENTER (CODE FC), WASHINGTON, D.C. 20390

REPORTING ACTIVITY (SHIP OR STATION): U.S.S. OVERSEAS DD 123

DATE FORWARDED: 1 SEP. 66

INSTRUCTIONS

1. Forward in duplicate with remittance to Navy Finance Center, Washington, D.C. 20390 for Class "D" and Class "D" entitled to "E" privilege traffic.
2. Naval Commercial Traffic Funds shall be forwarded by exchange-for-cash U.S. Treasury check when possible.
3. For further instructions refer to DNC-26.

RECEIVED		AMOUNT		PAID OUT		AMOUNT	
CHARGES ON MESSAGES FILED DURING THE CURRENT MONTH		$ 23	15	REFUNDS			
FEDERAL TAX COLLECTED DURING THE CURRENT MONTH		1	05	MONTH	ERROR NOTICE REFERENCE NUMBER		
COLLECTIONS ON MESSAGES PREVIOUSLY REPORTED ON WHICH NO CHARGE OR A SHORT CHARGE WAS MADE						$	
MONTH	ERROR NOTICE REFERENCE NUMBER						
				REPLY PAID VOUCHER NUMBERS			
				REMITTANCE HEREWITH:		24	20
				CHECK OR MONEY ORDER NUMBER 384552			
				DATED 9/1/66			
				DRAWN ON			
TOTAL AMOUNT RECEIVED		$ 24	20	TOTAL AMOUNT PAID OUT		$ 24	20

TOTAL AMOUNT RECEIVED MUST EQUAL TOTAL AMOUNT PAID OUT

FOR USE BY REGIONAL ACCOUNTS OFFICE ONLY

I certify this is a true statement of all moneys received and disbursed by me this month for the Naval Commercial Traffic Fund of this command, Class "D" Traffic. There is forwarded herewith a remittance in the sum recorded on this form.

CERTIFICATION: *(Commercial Traffic Clerk)*
G. H. Isaly
G. H. Isaly RMI , USN

REVIEWED: *(Communications Officer)*
A. B. Cook
A. B. Cook LTJG , USN
(Signature)

FORWARDED: *(Commanding Officer)*
D. E. Fairly
D. E. Fairly CDR USN , USN
(Signature)

D-10504

50.18

Figure 3-2.—Statement of account, NavCompt Form 2065.

NAVCOMPT FORM 2067 (REV. 8-64)

U. S. NAVAL COMMUNICATION SERVICE

Abstract of Class "E" messages

NAVCOMPT 2101-1
SHEET NO. ONE

To: Commanding Officer, U.S. Navy Finance Center (Code FC), Washington, D.C. 20390

DURING MONTH OF: SEPTEMBER

NAME OF ACTIVITY: USS OVERSEAS DD123

COMMUNICATIONS OFFICER (Signature): A. B. Cook LTJG USN

COMMANDING OFFICER (Signature): D. E. Fairly CDR, USN

SRS NO.	DATE	ADDRESSEE	DESTINATION	STATION SENT TO (Call Letters)	DO NOT USE	NO. WORDS	CREDIT TOLLS	CREDIT TAX	DR. CASH
5E	2	JONES	MOREHEAD CITY, N.C.	NSS		15	1.29		1.29
6E	10	TAYLOR	ELLWOOD CITY, PA.	NSS		10	1.08		1.08
7E	12	CUNNINGHAM	BERKLEY, W.VA.	NSS		8	1.13		1.13
8E	18	TURNER	WALTHAM, MASS.	NSS		12	1.29		1.29
TOTALS							4.79	—	4.79
TOTALS BROUGHT FORWARD FROM SHEET NO.									
GRAND TOTAL									4.79

CERTIFICATION (Commercial Traffic Clerk)

I certify this is a true statement of all moneys received and disbursed by me this month for the Naval Commercial Traffic Fund of this Command, CLASS "E" Traffic. There is forwarded herewith a remittance of $ 4.79

SIGNATURE: G. H. Isely

DATE: 1 SEP. 66

50.20

Figure 3-3.—Class E message abstract, NavCompt Form 3067.

are handled by a ship or station during any calendar month. Monthly traffic reports, consisting of an abstract form, message copies, a remittance, and a statement of account, are mailed to the Commanding Officer, U. S. Navy Finance Center, Washington, D. C. Ships must mail their traffic reports by the 5th day of the month; shore stations by the 10th.

If a ship or station has not handled any class D or class E traffic during any calendar month, a negative report is not required. A statement is required, however, on the first line of the first class D or class E abstract submitted for any subsequent month; for example, "No class D (or E, as appropriate) traffic handled during the month(s) of ________."

Class A and class B messages are refiled only by those shore stations and activities designated in JANAP 117 as commercial refile activities. Their reports must be forwarded direct to CNO within 10 days after receipt and verification of the commercial communication carrier's refiled traffic billing. Negative reports to CNO are required of these stations for any month in which no class A or class B messages are refiled.

Considerable time may elapse before NAVFINCEN Washington is billed for commercial messages. In extreme cases concerning messages sent to foreign radio stations, involved international paperwork may take more than a year before NAVFINCEN Washington finally gets the bill. If NAVFINCEN Washington then finds that the message has not been reported, that office must check with the originating ship before payment can be made. This procedure takes additional time, and may be hard to do after so much time has elapsed—the originator's message files may have been disposed of already, and responsible personnel transferred, discharged, or retired. Thus, it is readily apparent that incorrect or incomplete reports can lead to complications.

Not all commercial traffic reports are sent to NAVFINCEN Washington. Later portions of this chapter explain which reports are sent to NAVFINCEN Washington and which ones go elsewhere.

COMMERCIAL ABSTRACTING

This section is devoted to a more detailed discussion of message classes and methods of commercial abstracting.

Of the five classes of messages, class C messages are not involved in commercial abstracting, thus they are not mentioned further.

CLASS A AND CLASS B MESSAGES

Class A and class B messages are official U. S. Government messages. Class A messages consist of official messages of the Department of Defense. Class B comprises official messages of U. S. Government departments and agencies besides the Department of Defense. Both classes are treated together in this section because of similarities in handling, abstracting, and accounting.

Both class A and class B messages are prepared in joint form for transmission over military circuits. Detailed coverage of procedures for handling messages over military circuits are provided in Radioman 3 & 2.

Class A and class B messages requiring commercial refile must always carry an accounting symbol to denote the Government department or agency responsible for payment of commercial charges. When filed with a domestic communication company, the accounting symbol is preceded by the Government indicator GOVT. This indicator appears twice in each message, once after the check and again as the first word in the address. In messages sent to or via foreign communication companies, the Government indicator is changed to US GOVT.

HANDLING OVER COMMERCIAL COMMUNICATION SYSTEMS

When it is necessary to file or refile a class A or class B message with a commercial communication company, the following rules apply.

1. When filed directly with a commercial communication company by an originator outside the continental United States, or destined to an addressee outside the U. S., messages are sent via the nearest U. S. military communication facility serving the area in which originated.

2. Provided either originator or addressee is not served by military communications, messages may be filed or refiled directly with Western Union without further transmission on military circuits. This rule applies when charges for delivery to an addressee are the same as (or less than) such charges for delivery from a designated commercial refile point.

3. When refiled by a shore station within the continental U. S. and addressed to a point in the United States, Canada, Mexico, Alaska, or Saint Pierre-Miquelon Islands, domestic form with domestic word count is used. The point of actual origin is added to the signature.

4. When refiled by a shore station in the continental U. S. and addressed to points outside the United States, Alaska, Canada, or Mexico, international form and word count are used. The point of refile is treated as the point of origin; point of actual origin is added to the signature.

5. When filed or refiled by a shore station outside the continental U. S., international form and word count are used. The point of file serves as point of origin, or point of refile is the point of origin, and point of actual origin is added to the signature.

6. When a message in joint form must be sent through a commercial communication system for further transmission by a military system, the message in joint form—complete with heading—is embodied in the text of the commercial message.

7. When transmitted direct by a Navy ship to a commercial shore radio station, international form and word count are used.

The following example shows the form for a GOVT NAVY message as transmitted by a ship to a shore station for refile with a commercial communication company.

NSS DE NMWW-
T -
R-291646Z-
FM USS GOODSHIP-
TO JOHN Q DOE 1014 BEACHTREE LANE ERIE PA
NAVY GR12
BT
YOUR LEAVE EXPIRES ON BOARD AT NORFOLK VA
0745 6 AUG 66
BT
K

The preceding message would be commercially refiled in the following form. (Chargeable words are underscored.)

CK 12 WASHINGTON DC 29 JULY 66 515PME
GOVT NAVY
JOHN Q DOE
1014 BEACHTREE LANE ERIE PA
YOUR LEAVE EXPIRES ON BOARD AT NORFOLK VA
0745 6 AUG 66
COMMANDING OFFICER
USS GOODSHIP

ABSTRACTING

Class A and B messages transmitted direct to a commercial shore radio station by a Navy ship must be reported on NavCompt Form 2132. (See fig. 3-1.)

This monthly report, under symbol NavCompt 2101.2, must be forwarded to both CNO (OP-09B1C) and U. S. Navy Finance Center, Washington. Two copies of all messages are required with each report. No remittance is made; settlement of accounts is the responsibility of CNO/DNC. Reports from ships must be mailed by the 5th of the month after handling.

Incoming class A and B messages received by Navy ships direct from commercial shore radio stations are reported on NavCompt Form 2132. Other requirements are the same as for outgoing messages, explained earlier.

Naval shore stations designated commercial refile activities in JANAP 117 are required to submit monthly reports of all class B messages and all class A messages (except accounting symbol GOVT NAVY) refiled with commercial communication companies. A speedletter report is made, and does not utilize any of the NavCompt forms mentioned previously.

Reports are mailed direct to the Chief of Naval Operations (OP-09B1C), within 10 days after receipt and verification of the commercial communication company's traffic billing. A speedletter report must contain the following information in the order indicated.

1. Month and year of report (e.g., AUG 1966).
2. Inclusive class A (less GOVT NAVY) and class B message serial numbers reported (as SRS 1A through 26A, 12B through 23B).
3. Commercial company and tolls (less GOVT NAVY) billed and verified (e.g., Western Union $25.12, RCA $31.70, Mackay $32.15).
4. Number of commercial traffic words (less GOVT NAVY) refiled with each company (e.g., Western Union 120, RCA 94, Mackay 102).
5. Total number of commercial traffic words (less GOVT NAVY) refiled during calendar month (as 316).

The speedletter report must be accompanied by two copies of each message reported.

One copy must be in the military form in which received, arranged in SRS number order, on metal file fasteners, between cardboard covers, and in groups of 100 or fewer messages. Its cover must be labeled to indicate type of traffic, name of reporting station, and month and year of commercial refile.

The second copy of each message must be in the commercial form in which refiled, segregated into packets according to accounting symbols.

Both message copies must bear complete transmission data, and include the following information in the lower right corner:

1. SRS number (e.g., SRS 23B).
2. Accounting symbol (e.g., INT).
3. Commercial company and city where refiled (as Western Union, WASHDC).
4. Commercial service indicator (e.g., NL).
5. Commercial check (e.g., CK 40).
6. Commercial charges (e.g., $1.25).
7. Date and time of refile (as 011300Z/AUG).

Copies of service messages relating to commercially refiled class A and B messages must be forwarded with a copy of message to which they pertain.

RESPONSIBILITY FOR PAYMENT

A reporting activity does not collect toll charges nor send remittances when forwarding class A and B messages reports. In brief, payment for class A and B messages refiled with commercial communication companies is effected according to the ensuing explanation. For class A and B messages transmitted by Navy ships to commercial shore stations, CNO is responsible for settlement of accounts. Because bills submitted by commercial companies often contain amounts for other classes of messages, however, initial payment is made by NAVFINCEN Washington. Charges for class A and B traffic are then billed to CNO by NAVFINCEN Washington. In turn, CNO bills other Government agencies responsible for originating their class A and B messages involving toll charges. Thus naval communications is reimbursed for non-Navy messages handled.

Payment is handled differently for class A and B messages refiled with commercial companies by shore stations. Commercial communication companies bill a refile activity directly. The refile station verifies the monthly billing, certifies it as official U. S. Government traffic, and forwards the certified billing (with supporting message copies), for payment, to the local disbursing office of the NAVFINCEN serving the area in which refiling activity is located.

CLASS D MESSAGES

Class D messages are non-Government (private-commercial) messages handled by naval communications that were received or sent via commercial communication companies. Class D messages include—

1. Commercial (private) messages.
2. Commercial (private) messages entitled to class E privilege.
3. Press messages.
4. Radiophotos.

Class D messages are always in commercial form. Handling of class D traffic by Navy ships and stations usually is suspended or curtailed in wartime.

Each category of class D messages is discussed in greater detail in the remainder of this section.

COMMERCIAL (PRIVATE) MESSAGES

Any naval ship at sea, or in a port that has inadequate or unreliable commercial communication facilities, is authorized to file class D commercial (private) messages. This same authorization extends to overseas shore stations at locations where adequate and reliable commercial facilities do not exist.

Only three shore stations are presently authorized to handle commercial ship-to-shore and shore-to-ship traffic. These authorized shore stations are NavCommStas Balboa, Guam, and Kodiak.

In the following example of class D commercial messages in international form, chargeable words or groups are underscored. An explanation of component parts is given at the conclusion of this message example.

PCH DE NMWW NR1 INTL USS GOODSHIP/NMWW CK26
12 1430
BT <u>MP</u> BT
<u>LOUIS</u> <u>COLBUS</u>
<u>69</u> <u>EASTTHIRTYSIXST</u>
<u>NEWYORKCITY</u>
BT
<u>SELL</u> <u>TEN</u> <u>SHARES</u> <u>COMPTOMETER</u> <u>AND</u> <u>TWENTY</u> <u>SHARES</u> <u>PULLMAN</u> <u>BUY</u> <u>SIXTY</u> <u>SHARES</u> <u>MAGNAVOX</u> <u>ALL</u> <u>AT</u> <u>MARKET</u> <u>ADVISE</u> <u>TRANSACTION</u> <u>DATE</u> BT <u>FORD</u> <u>COX</u> AR NMWW K

After the call and station serial number in this example appears the international abbreviation INTL. Next is the office of origin, USS GOODSHIP, followed by her call sign.

The check (CK26) consists of the number of chargeable words in the address, text, and signature. (Remember that chargeable words are underscored in this example.) In a commercial message such as this one, the date and local time of filing are always given in two numeral groups, with the date separated by a space from the four-digit hours and minutes group.

The message address contains the paid service indicator MP in addition to the name and address of the addressee. This particular paid service indicator (MP) means that the sender requests delivery of his message to the addressee in person, not by mail or telephone. More than a dozen different service indicators are authorized; DNC 26 carries the complete list. As shown in this message example, the paid service indicator is the first word of the address, it is counted as a chargeable word, and is included in the CK.

After the text is the sender's name, called the signature. Although the signature is not obligatory, when given it is chargeable and is separated from the text by prosign B̄T̄.

Prosign B̄T̄ in this message example has many appearances. This prosign separates the preamble from the paid service indicator, paid service indicator from the rest of address, address from text, and text from signature. Prosign B̄T̄ is never counted or charged in the CK.

Charges and Accounting

Charges to be collected from the sender by the commercial traffic clerk for class D messages include the following specific instances.

1. Charges that accrue to land radio stations.
2. Charges that accrue to the ship radio station.
3. Charges for service over landlines or cable, if any.
4. Relay charges of any intermediate land or mobile radio station.
5. Charges, if any, for special service requested by a sender.

RATE REQUESTS

The International Telecommunications and Radio Conferences held at Geneva in 1959 authorized shipboard stations to make inquiry without cost to coastal stations concerning proper rates for messages for which they do not have necessary information. Because Navy ships are not issued commercial tariff books used for computing charges for class D messages, it is necessary to send a rate request (QSJ or service message) to determine charges on each message. Operating signal QSJ (preceded by ĪN̄T̄ for military usage, or followed by ĪM̄Ī when operating with commercial stations) means "What is the charge to be collected per word to______including your internal telegraph charge?" As a reply QSJ means "The charge to be collected per word to______including my internal telegraph charge is______francs."

Examples of rate requests are not shown in DNC 26. Two examples are given here. The first one shows the procedure observed by Navy stations on point-to-point circuits. Transmissions from a Navy ship to a commercial shore station constitute the second example of a rate request.

In point-to-point circuit operation between military stations, the total charge for a message is given in United States dollars. Consider the following teletypewriter message, originated at Kwajalein and sent to Honolulu for commercial refile. Note how the operator added INT QSJ at the end of the message.

```
RR RBHPU
DE RBHPV ØØ9
KWAJALEIN CK13 15 Ø745
POLAROID CORP
CAMBRIDGEMASS
REFERENCE YOUR WIRE MARCH 3
   DELAYED SHIPMENT
   K6732 PERMISSIBLE
TRATEXCO. INT QSJ
15/1945Z
```

After computing charges, the operator at Honolulu replied with the following service message:

```
RR RBHPV
DE RBHPU 58
ZNR
R 152Ø31Z
BT
UNCLAS. YOUR ØØ9/15Ø745 COMLCHGS
   TWO DOLLARS FORTYSEVEN
   CENTS. NAVYCHGS SEVENTYEIGHT
   CENTS.
   TOTAL PLUS TAX
BT
15/2Ø31Z
```

Accordingly, the commercial traffic clerk at Kwajalein collected the following charges from the sender:

Commercial charges	$2.47
Navy charges	.78
	3.25
10% tax	.33
Total	$3.58

A transmission by a shipboard operator to a foreign commercial shore station forms the second example of a rate request. Commercial charges in international communications are quoted per word in gold francs or centimes (100 centimes = 1 gold franc). The gold franc is an international monetary unit used by all member nations in the International Telecommunications Union. Rate of exchange with United States currency is 3 gold francs per U. S. dollar.

Assume that NHDY has a 10-word class D message for an addressee in Rotterdam. After establishing communications with foreign commercial station PCH, the Radioman transmits:

PCH DE NHDY QSJ ROTTERDAM $\overline{\text{IMI}}$ K Station PCH replies:
NHDY DE PCH QSJ ROTTERDAM CC 4Ø LL 17.5 CTMS K

Station PCH's reply has the following meaning: CC (coastal charge) represents charges that accrue to the land radio station; LL (landline) is the charge for service over landlines or cable; CTMS is an abbreviation for centimes.

According to the preceding explanation, charges for this message to Rotterdam are 57.5 centimes (40 + 17.5), or 0.575 franc, per word. For NHDY's message of 10 chargeable words, the total charge to be collected from the sender is 5.75 francs (0.575 x 10). This amount, converted to U. S. dollars at the 3 for 1 rate explained previously, would be $1.92 (5.75 francs ÷ 3).

An important point to remember when obtaining rate requests from commercial stations is to be sure that the operator includes all charges due his station: his station charge, plus any landline or cable charge, relay charge, or charges for special service requested by the sender. This reminder is mentioned here in discussing class D messages, but it applies as well to all classes of messages involving commercial refile. Operators sometimes fail to include all these charges in their QSJ, yet include them in their company's billing. This problem causes no end of difficulty to NAVFINCEN Washington in settling the account. It may test an operator's patience and tact in overcoming language barriers on a radiotelegraph circuit. That commercial charges are computed accurately in most instances attests to the ability and commonsense of radio operators, both Navy and commercial.

Copies of all QSJ exchanges must be forwarded to NAVFINCEN Washington, with the series of messages to which they pertain.

Abstracting Class D Messages

Class D messages are reported on NavCompt Form 2132. Whenever class D messages originate in own ship or station, money paid by senders must be forwarded with the abstract. The Treasury check or money order used for a remittance must be made payable to the U. S. Navy Finance Center, Washington, D. C. Actual transfer of funds between naval communications and commercial communication companies is made by NAVFINCEN Washington.

A complete class D message report consists of the—

1. Abstract (NavCompt Form 2132).
2. Copy of each class D message.
3. Statement of account, NavCompt Form 2065.
4. Remittance.

Special attention is directed to the necessity of reporting all class D messages handled (whether charges are involved or not), together with any QSJ or service message exchanges. Ships sometimes mistakenly fail to report class D messages received over Navy circuits. Failure to make these reports often results in financial loss to the Government. Such failure to make the required report of either sent or received messages usually results in needless correspondence and delay in settlement of accounts.

Message copies forwarded with an abstract must be legible and complete, including full transmission or receiving data. Duplicates must be retained in ship or station files for at least 12 months. Message copies forwarded and duplicates retained in files must show any discrepancies in counting chargeable words; an explanation of delays exceeding 1 hour between receipt and transmission in relaying, or between filing time and transmission time; charges collected, if any; and other pertinent information deemed appropriate.

In communications with naval or merchant ships, be sure to indicate the call sign, on both abstract and message copy, immediately after name of ship. A fraction bar (/) separates the ship's name and call sign.

CLASS D MESSAGES ENTITLED TO CLASS E PRIVILEGE

Occasionally, because of the location of addressees, naval personnel are unable to send a message in class E form, even though message contents comply in all respects with provisions for class E messages. In other words, the addressee will be at a geographical location other than the continental United States; for example, Hawaii, Puerto Rico, Panama, Japan, or Europe.

A category of messages known as "Private commercial message (class D) entitled to class E privilege," has been established with the view of making available to such personnel a modified version of class E message. Particular care must be taken in handling this category of message, and accounting for it, to ensure that it is not combined and reported with regular class E traffic.

Class D messages entitled to class E privilege are handled in international form as shown in the message example at the conclusion of this explanation. For identification purposes, each message carries the symbol COMLE as the first word of text; COMLE is counted and charged for as one word. Following is an example of a class D message entitled to class E privilege.

```
NSS DE NMWW-
T-
R-271949Z
BT
USS GOODSHIP/NMWW CK21 27 1500 BT
MRS J V KELLY
CARIBE HILTON HOTEL
SAN JUAN PR
BT
COMLE MOTHER AND I WILL MEET
   YOU THURSDAY IN CHICAGO BT
   JIM
BT
K
```

Handling this type of message by naval communications is without charge. The sender, however, has to pay charges incurred by commercial refile at San Juan. To determine the amount, the ship must send a rate request by QSJ or service message. Charges must be ascertained and paid before transmission of class D message.

An exception to the foregoing rule applies in a class D message entitled to class E privilege destined to an addressee on the island of Oahu, Hawaii. Such a message is delivered by the refile activity at Honolulu by phone or other means not involving commercial refile. The message is written up and handled as a class E message free of toll charges and, as such, is not included in the commercial traffic report. This exception does not apply to messages destined to Hawaiian islands other than Oahu. Commercial refile is required, however, resulting in toll charges, abstracting, and accounting.

Abstracting

Ships and stations originating class D messages entitled to class E privilege are required to submit monthly reports under report symbol NavCompt 2101-1 covering all messages originated. For this report, NavCompt Form 2067 is used.

Reports of class D messages entitled to class E privilege are comprised of the following forms:

1. Abstract, NavCompt Form 2067.
2. One copy of each message, showing complete transmission data. A related rate request (QSJ or service message) must be attached to the message.
3. Statement of Account, NavCompt Form 2065, in duplicate.
4. The remittance, made payable to U. S. Navy Finance Center, Washington, D. C.

An additional monthly report is required of shore stations effecting commercial refile of class D messages entitled to class E privilege. For this report, NavCompt Form 2132 is the proper form. If the shore station also handled "regular" class D traffic during the month, the two reports can be combined.

PRESS MESSAGES

In peacetime, the Navy frequently grants permission for duly accredited news reporters to go to sea in Navy ships for the purpose of reporting naval operations and activities. In such instances reporters usually are authorized to file press messages on board. The same privilege may be extended at isolated overseas bases where commercial communication facilities are unavailable.

Three examples of press messages illustrate the message form. The first example shows an international form press message from a Navy ship to a commercial shore station.

ZLB DE NMWW NR 1
INTL USS GOODSHIP/NMWW CK 145 16 1430 BT
PAGE 1/50 BT
PRESSE BT
YOMIURI PRESS TOKYO BT
(FIRST 46 WORDS OF PRESS TEXT WHICH, ADDED TO SERVICE INDICATOR AND 3 WORDS OF ADDRESS, MAKE 50 WORDS IN PAGE 1) BT
NR 1 USS GOODSHIP 1430 PRESS PAGE 2/50 BT (NEXT 50 WORDS OF PRESS TEXT) BT
NR 1 USS GOODSHIP 1430 PRESS PAGE 3/45 BT (REMAINING 44 WORDS OF PRESS TEXT AND ONE WORD OF SIGNATURE BT
TSUBOKAWA BT K

Note the page identification in the preceding message example. A radiotelegram of more than 50 words is transmitted in pages of 50 words. The page number is separated by a slant sign from the figure indicating number of words. Included in the first page are the paid service indicator, PRESSE (used only in international communications), and the words in the address. Each succeeding page is identified as in the example.

The next example shows a domestic/commercial form press message with Navy heading for transmission to a continental Navy shore station for refile with Western Union to an addressee in the continental United States.

NSS DE NMWW -
T -
R-252130Z
BT
CK 95 DPR COLLECT USS GOODSHIP/NMWW
25 JUL 1962 415 PME VIA WESTERN UNION BT
DPR COLLECT
NEW YORK JOURNAL AMERICAN
220 SOUTH STREET NEW YORK BT
TSUBOKAWA BT K

In the preceding press message the domestic service indicator DPR (day press rate) is used instead of the international indicator PRESSE (in the first example). Indicator DPR is for all press messages to or from a continental Navy activity and handled commercially by Western Union. As appropriate, DPR is followed by COLLECT, as in this example, or PAID.

The third example is of a press message for an addressee outside the continental United States transmitted to a Navy shore station. The message is in international form but has a Navy heading added for handling over Navy circuits.

NPM DE NMWW-
T-
P-162045Z
BT
USS GOODSHIP/NMWW CK 145 16 1435 BT
PAGE 1/50 BT
PRESSE BT
(PRESS MESSAGE TEXT DIVIDED INTO PAGES AS IN FIRST EXAMPLE) BT
TSUBOKAWA BT K

Abstracting Press Messages

Ships and stations handling press messages are required to submit monthly reports. Press messages are reported on NavCompt Form 2132.

The SRS serial numbers assigned to press messages use the suffix letter P after the number; for example, SRS 116P. Remember that SRS numbers are used for message identification in abstracting and accounting only. They are never transmitted.

Press message abstracts, accompanied by message copies and remittances, are forwarded to U. S. Navy Finance Center, Washington. Remittances are by Treasury check or money order, made payable to U. S. Navy Finance Center, Washington. Reports from ships are due in the mail by the 5th of the month after handling; from shore stations, by the 10th.

RADIOPHOTOS

Radiophoto transmission is between Navy facsimile units only. Exceptions to this rule must be authorized by CNO.

In addition to official Navy pictures and graphic material, including those for general distribution to news associations, Navy radiophoto services may be authorized for transmission of commercial pictures. Commercial pictures are of two classes: (1) those for general distribution to newspapers and news associations, and (2) exclusive commercial pictures filed by correspondents and addressed specifically to newspapers or news associations to which they are accredited.

Exclusive commercial pictures are the only ones for which the Navy charges for handling. Thus they are the only ones requiring abstracting and accounting.

Exclusive commercial pictures are abstracted in the same manner as press messages. They also are reported on the same NavCompt form. Abstracts forwarded to NAVFINCEN Washington should be mailed by the 5th of the month from ships, by the 10th from shore stations, and must be accompanied by a copy of each exclusive commercial picture transmitted and received.

For exclusive commercial pictures, SRS numbers are followed by the letter R; for example SRS 24R.

Normally, charges for exclusive commercial picture transmissions are not collected at the time of transmission. Accounting necessary for settlement of Navy charges due is performed by NAVFINCEN Washington. If the sender desires, however, charges may be collected in advance of transmission. In such an instance the remittance and statement of account are included in the report.

CLASS E MESSAGES

Class E messages, as defined earlier in this chapter, are personal messages. Part of the leading Radioman's job is to restrict the routing of such messages so as to keep them personal. Subordinates should be instructed that under no circumstances are they allowed to divulge the contents of class E messages to any unauthorized person.

On board ship, incoming class E messages normally are received on the fleet broadcast. They are typed on a regular message form and routed only to the communication officer and addressee. Usually the addressee is called to the communication office to accept delivery. A personal message concerning death, serious illness, or injury is routed to the chaplain for delivery to the addressee. If the ship has no chaplain, the message is routed first to the captain or executive officer.

Class E messages are handled free of charge by naval communications. The only complication concerning class E messages is that most of them have to be refiled with Western Union because of the location of the addressee with respect to the sender. This procedure involves toll charges that must be paid by the sender, and accounting and abstracting by the commercial traffic clerk.

Class E messages were illustrated and described in Radioman 3 & 2. To narrow the present discussion, those class E messages that are free of toll charges are eliminated. In general, these are personal messages handled between ships, and from ship-to-shore, shore-to-ship, and shore-to-shore, when both originator and addressee are outside the continental United States and in the same ocean area. Outbound class E messages also are eliminated from this coverage. Outbound class E messages are originated in the United States and addressed to naval personnel aboard ships or overseas bases. The originator of such a message usually sends a Western Union telegram (he can also use mail) to one of four refile points for outbound class E messages. Depending on the location of the addressee, these refile points are NavComSta San Francisco, Washington, Norfolk, or Newport. When an outbound class E message arrives at one of these refile stations, the sender already has paid Western Union for transmission from point of origin to refile point. The refile station places the message on an appropriate fleet broadcast or overseas circuit, for which there is no charge. No accounting or abstracting are necessary because the Navy handled no money whatsoever.

This treatment of class E messages is confined to those originating aboard ship or overseas bases addressed to persons within the United States. These inbound class E messages are subject to toll charges because the refile station must transfer them to Western Union for delivery to the addressee.

Naval communication activities authorized to receive and commercially refile class E messages with Western Union are the following:

NavSta Charleston
NavSta Key West
NavCommSta Newport
NavCommSta Norfolk
NAS Whidbey Island, Wash.
NavCommSta San Diego
NavCommSta San Francisco
NavCommSta Washington

All of the activities listed are authorized to refile class E messages from ships. Only the last two, San Francisco and Washington, can refile from overseas bases.

ABSTRACTING CLASS E MESSAGES

All ships and stations originating class E messages involving toll charges must submit monthly reports under report symbol NavCompt 2101-1. All reports are mailed to the Commanding Officer, U.S. Navy Finance Center, Washington, D.C. Ships must mail their class E traffic report by the 5th of the month after handling; shore stations, by the 10th.

Class E message reports consist of three items. They are—

1. Abstract, NavCompt Form 2067.
2. One copy of each class E message handled, showing complete transmission data.
3. Remittance necessary to cover commercial tolls of all class E messages reported. Remittance must be in the form of an exchange-for-cash U. S. Treasury check, U. S. postal money order, or American Express money order. (Cash, postage stamps, or personal checks are not allowed.)

Remittance covering class E messages addressed to the continental United States, and refiled for final delivery by Western Union Telegraph Company, must be made payable to Western Union Telegraph Company, Washington, D.C. Make sure that only those funds due Western Union Telegraph Company are included in the check or money order made payable to that company.

Details for Preparation

When filling in the class E abstract form, messages are arranged in groups according to shore stations to which messages were addressed for refile with Western Union. If there was a considerable volume of messages, a separate sheet must be used for each refile station. For reporting only a few messages, a single sheet will suffice, but be sure to leave a blank space of at least three lines to separate the groups of refile stations.

Copies of class E messages must be arranged and attached to the abstract form in the exact order of listing on the abstract. This requirement will probably cause SRS numbers to appear out of order, but cannot be avoided.

In listing messages on the abstract, use only the last name of addressees. City of destination can be abbreviated.

Be sure that only class E messages destined for refile with and final delivery by Western Union Telegraph Company are included in the class E message report.

CLASS E RATES

Rate tables for class E messages list toll charges applicable from each refile station to each state (except Alaska and Hawaii) and the District of Columbia. Rate tables are given in DNC 26; they are not repeated here.

In determining rates to be charged for class E messages, the following procedures are observed.

1. Count number of words to be charged. This count includes all words in text and all matter in the signature except name and rank of sender.
2. Consult schedule of rates for city at which message will be refiled with Western Union.
3. Applicable rate appears opposite listing of state in which destination of message is located. In these rate schedules amount shown is the rate for a full-rate fast telegram of 15 words or less. A separate table is given for determining rates for each additional word above the 15-word minimum charge.
4. If message is to be sent as a day letter (deferred day service) or a night letter (overnight service), determine 15-word full rate as outlined in the preceding step, then refer to separate table of day letter and night letter rates. Its rates correspond to the full-rate charge determined previously. It should be noted that the minimum charge for a day letter or night letter is for 50 words, and that additional words in excess of that minimum are charged for in groups of five words—not by individual words.

CHAPTER 4

U.S. COMMUNICATION SYSTEMS

United States communication systems are in a continual state of change. Newer and better types of equipment constantly are being developed and introduced. Communication systems change accordingly so that newer equipment can be put to use effectively. All these changes are necessary to keep communications flexible in order to provide a speedier and more reliable type of communications for the forces and activities they serve.

This background sketch concerning U. S. communication systems must be kept in mind while studying this chapter.

NATIONAL COMMUNICATIONS SYSTEM

The objective of the National Communications System (NCS) is to provide all necessary communications for the President and the Federal Government—at all times and under all conditions. Such conditions may conceivably range from a normal situation to national emergencies and international crises, including nuclear attack. The system is developed and operated so as to be responsive to a variety of needs of national command authorities. It must be capable of meeting priority requirements under all emergencies. To obtain survivability of essential communications in all circumstances, the system must possess necessary combinations of hardness, mobility, and circuit redundancy.

The Secretary of Defense is executive agent for the NCS. It encompasses assets of the Department of Defense, State, FAA, NASA, and Federal telecommunications systems managed by General Services Administration.

The NCS has designed and is continually improving the necessary technical and procedural standards and establishing the necessary degree of interconnection required to integrate its several elements. Such assets as just mentioned. are thus ensured of being utilized effectively to serve national needs in emergencies.

DEFENSE COMMUNICATIONS

The Defense Communications System (DCS) is under the operational and management direction of the Defense Communications Agency (DCA). It is an agency of the Department of Defense (DOD). Within the DCS the chain of command is from the Secretary of Defense, through the Joint Chiefs of Staff (JCS), to the Director, DCA.

The Defense Communications System comprises all worldwide, long-haul, Government-owned and leased, point-to-point circuits, terminals, control facilities, and tributaries of the three military departments, as well as other Department of Defense activities.

DEFENSE COMMUNICATIONS AGENCY

The DCA consists of a Director, a Deputy Director, a headquarters establishment, and other subordinate units, facilities, and activities as are established by or specifically assigned to the agency. Guidance to the Director, DCA is furnished by the Secretary of Defense or by the Joint Chiefs of Staff, by authority and direction of the Secretary of Defense.

The DCA has established and operates a communication control complex consisting of a requisite number of operational control centers. The objective of this complex is to accomplish the mission of the DCA. The mission of the DCA is to—

- Ensure that the Defense Communications System (DCS), as established, will be improved and operated so as to meet the long-haul, point-to-point, telecommunication requirements of the Department of Defense and other governmental agencies as directed.
- Provide technical support to the National Military Command System.
- Be the strong focal point for continuing integration of space and ground elements of the

communications satellite systems to meet DOD requirements.

The organization of the Defense Communications Agency is shown in figure 4-1. This chapter is concerned with the function of only those offices and activities that pertain to Radiomen.

MILITARY COMMUNICATIONS-ELECTRONICS BOARD

The mission of the Military Communications-Electronics Board (MCEB) is to—

- Achieve coordination on military communications-electronics matters among DOD components, between DOD and other Government departments and agencies, and between DOD and representatives of foreign nations.
- Provide DOD guidance and direction in those functional areas of military communications-electronics for which the MCEB is assigned responsibility.
- Furnish advice and assistance, as requested, on military communications-electronics matters to the Secretary of Defense, Joint Chiefs of Staff, military departments, and other DOD components.

The MCEB is composed of the following members, supported by a permanent secretariat:

Director, DCA—Chairman;
Chief Signal Officer, U. S. Army;
Director, Naval Communications, U. S. Navy;
Director of Command Control and Communications, U. S. Air Force;
Chief, Communications-Electronics, Headquarters, U. S. Marine Corps;
Director for Communications-Electronics, Joint Staff;
A representative of the Director, National Security Agency.

Under the policies and direction of the Secretary of Defense and the Joint Chiefs of Staff, acting under the authority and direction of the Secretary of Defense, the MCEB must—

1. Assemble military frequency requirements.
2. Develop common procedures for interservice coordination and allocation of frequencies.
3. Allocate and coordinate the use of emission frequencies.
4. Prepare and promulgate assignments and changes in assignments in call signs, address groups, and routing indicators.
5. Determine format, assignment of printing responsibilities, and distribution of communications-electronics publications, except those communication security publications that are the responsibility of other DOD elements.
6. Establish joint and coordinate allied communications-electronics operating methods and procedures.
7. Establish joint and coordinate allied principles and procedures for obtaining compatibility and standardization of communications-electronics systems and equipment.
8. Develop joint operation characteristics for communications-electronics systems and equipment.
9. Provide DOD membership to appropriate allied technical panels and working groups.
10. Provide studies, reports, and recommendations in the fields of electronic warfare, electronic navigational aids, recognition and identification, communications security, and cryptography.
11. Develop and implement procedures for participation in the DOD Electromagnetic Compatibility Program, as required.
12. Develop and process the DOD position for negotiation with representatives of other nations on communications-electronics matters for which the MCEB is responsible.
13. Provide advice and assistance to DOD components in the communications-electronics field on such matters as may be proposed and considered appropriate for MCEB consideration.
14. Perform such other duties as may be assigned by the Secretary of Defense or Joint Chiefs of Staff.

COMMUNICATIONS SATELLITE PROJECT OFFICE

The Communications Satellite Project Office (CSPO) provides the focal point for continuing integration of all elements of communications satellite systems to meet DOD requirements of the Defense Communications Satellite Program (DCSP). It gives technical direction, and continuously reviews the execution and progress of approved programs.

The CSPO ensures that Director, DCA and cognizant elements of the Office of Secretary of Defense, Joint Chiefs of Staff, and military departments are informed promptly and adequately regarding the status of the communications satellite program, as well as any actions taken or recommended.

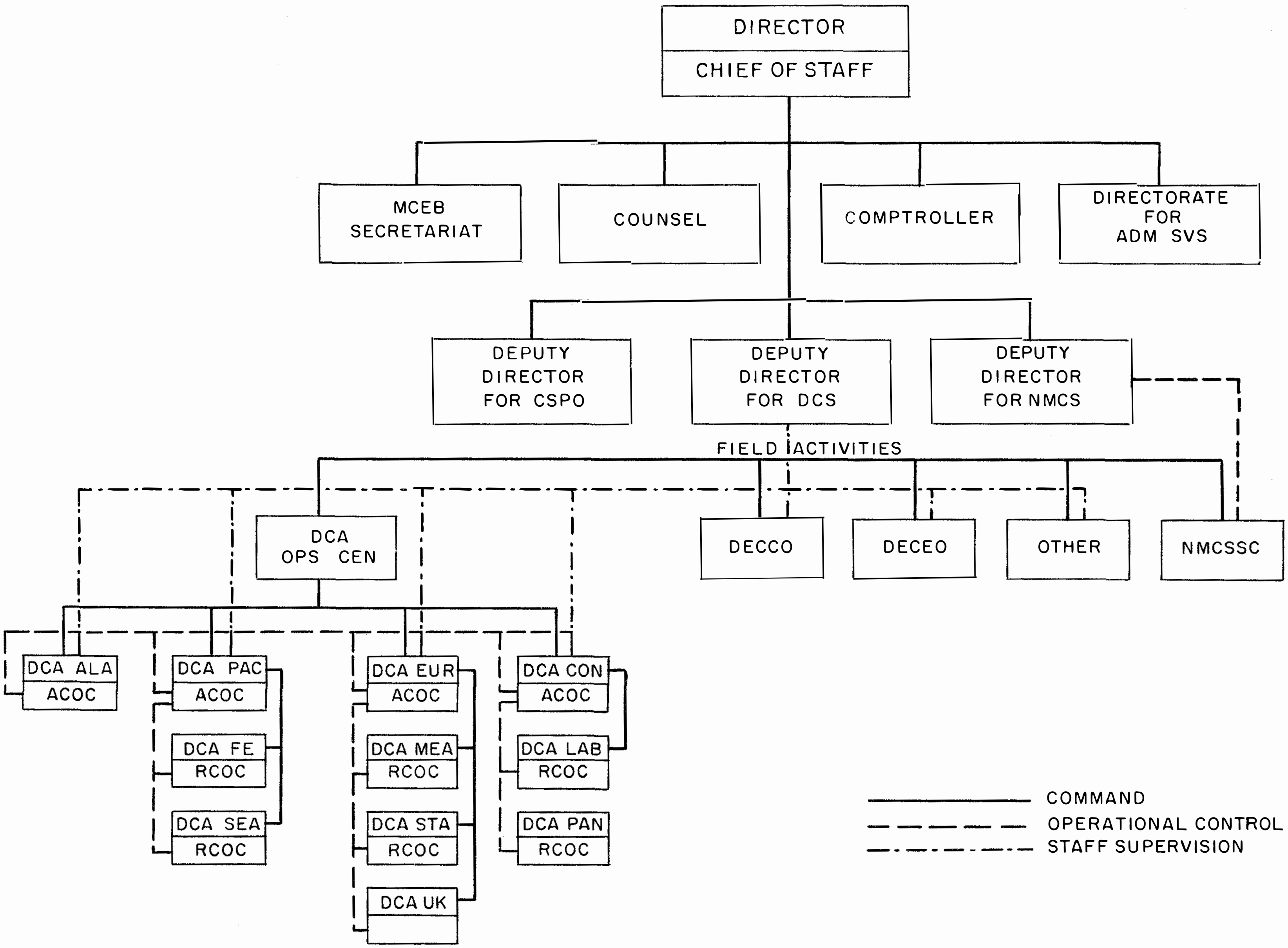


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Figure 4-1.—Defense Communications Agency organizational chart.

NATIONAL MILITARY COMMAND SYSTEM

The mission of the National Military Command System (NMCS) is to—

- Provide the means for carrying out strategic direction of U. S. military forces.
- Ensure that technical elements of the NMCS can survive any attack, and can function effectively in any environment that may prevail.
- Provide the basis for a unified national survivable communication system.

The NMCS is that complex of the worldwide military command and control system consisting of facilities, equipment, doctrine, procedures, and survivable communications provided specifically for use by national command authorities.

National Military Command System Support Center

The mission of the National Military Command System Support Center (NMCSSC) is to support the NMCS and such other elements of the Department of Defense as are necessary to carry out the functions enumerated.

1. Provide direct automatic data processing support for operating command centers of the National Military Command System (NMCS) as directed.
2. Prepare and disseminate appraisals and analyses of attack hazards and vulnerabilities of forces and resources worldwide—friendly, enemy, and allied.
3. Prepare promptly, at the outset of hostilities, and on a continuing basis, assessment of nuclear damage to all forces and resources essential to executing DOD responsibilities.
4. Perform such other appropriate tasks as may be assigned, including (but not limited to) technical and computational support of joint war gaming.
5. Conduct a development program designed to improve performance of tasks enumerated in preceding steps.
6. Assist in technical system design of the NMCS.

DEFENSE COMMERCIAL COMMUNICATIONS OFFICE

The Defense Commercial Communications Office (DECCO) is responsible for procurement, accounting, and payment for leased private line communication facilities within or emanating from the United States for the Department of Defense and other Government agencies as directed by the Secretary of Defense.

The DECCO ensures that the Federal Government receives the best possible rates for commercial communication facilities leased to meet department, office, and agency requirements. It develops and provides to the departments, offices, and agencies basic costs and contingent termination liabilities of existing leased commercial communications for financial plans and budget estimates. Also, DECCO performs all leasing actions with U. S. commercial communication carriers for approved NATO circuit requirements.

DEFENSE COMMUNICATIONS ENGINEERING OFFICE

The twofold mission of the Defense Communications Engineering Office (DECEO) is (1) to translate approved plans into projects or tasks for improving, expanding, and modernizing DCS and (2) to provide management direction over implementation.

Some of the functions of DECEO are to—

- Provide engineering services and assist DCA in determining configuration of the DCS, and give systems engineering assistance to the DCA staff.
- Develop system implementation plans and furnish requisite management direction over their execution. These plans include—but are not limited to—guidance and criteria for funding, phasing, scheduling, site selection, site preparation, construction engineering, equipment fabrications, installation, test, system checkout, acceptance, maintenance, training, and logistical support.
- Develop and/or approve technical specifications for systems, subsystems, and equipment for integration into and utilization within the DCS to include detailed analysis of operational, economical, and technical tradeoffs.
- Exercise management direction over and monitor all procurement, including requests for proposals, contractor selection, and contract award, as assigned for execution by DCA in support of DCS.

DCA OPERATIONS CENTER COMPLEX

Operational direction of the DCS is accomplished through a complex of communication centers. Functions and tasks associated with operations centers are to tabulate, assemble, store, and display information on current conditions of system components; allocate channels and circuits to meet requirements of authorized users; and perform continuous system analysis and such other tasks as are necessary. The principal objective of the operations center system is to assure the greatest possible responsiveness of the DCS to the needs of its users.

Communication operations centers receive and process performance data based on hourly and spot reports made by various DCS reporting stations on networks, circuits, channels, and facilities of the DCS. These reports provide a knowledge of the status of the DCS at all times. The operations centers know of the traffic backlogs, if any; conditions of circuits; status of installed equipment at some 200 switching centers throughout the world; and the status of channels allocated to various users. With this knowledge and that of alternate route capabilities between any two points, spare capacity, and radio propagation conditions, the operations centers restore elements and reallocate channels according to needs and priorities of users.

Figure 4-2 shows the geographical areas and locations of the Defense Communications Agency Operations Center Complex. The DCA Operations Center Complex consists of Defense Communications Agency Operations Center (DCAOC), in Arlington, Va., Defense Area Communications Operations Centers (DACOC), and Defense Regional Communications Operations Centers (DRCOC).

Defense Area Communications Operations Centers serve Alaska at Elmendorf AFB; CONUS at Fort Carson, Colorado; Europe at Camp DesLoges, France; and Pacific at Kunia, Hawaii.

Defense Regional Communications Operations Centers serve the Far East at Camp Drake, Japan; Labrador at Goose Bay AB, Labrador; Middle East Africa, in the middle east; Panama at Corozal, C. Z.; South East Asia at Clark AB, P. I.; South East Asia Mainland at Saigon, Vietnam; Spain, Italy, and Africa at Torrejon AB, Spain; and the United Kingdom at Croughton AB, England.

Defense Communications Agency Operations Center

The Defense Communications Agency Operations Center (DCAOC) exercises operational direction over all elements of the DCS through Area Communications Operations Centers. It provides communication status information as required by the Joint Chiefs of Staff. The DCAOC maintains and displays the status of the worldwide DCS.

Internally, DCAOC consists of four major elements. These elements are input devices, a computer, displays, and control facilities. Input devices are standard teletypewriter machines used for the reception of Operational Immediate status messages from various reporting stations in the system. These status messages consist of information concerning the state of readiness of circuits and facilities comprising the DCS. Such messages include outage information, delays in transmission resulting from traffic backlogs, and important users affected by trouble in the system. Status information from teletypewriter messages is fed into an electronic computer previously programed with a data base consisting of a detailed inventory of system resources and operating rules. Current status information interacts on the data base in the computer to display, automatically, key information on electronic display boards. These displays reflect the current status of the system, showing whether conditions are good, marginal, or poor. One of the electronic display panels is an edge-lit map of the world. It is 8 feet high and 15 feet long. This panel shows the changing status of the system's major trunks and stations.

Information presented on display panels covers the full range of data required to analyze intelligently this worldwide communication system. Included in this information are trunk status, assignment, and availability of individual circuits, station status, and the scope, priority, and quantity of message backlog. When displays indicate a need for operational instructions to correct problem areas, the system supervisor issues instructions by telephone or teletypewriter message to the appropriate activity. The control area contains a series of operator consoles. Through these operator consoles the watch supervisor can obtain and display additional detailed information from the computer to assist in decision making.

Area Communications Operations Centers

In addition to the DCAOC, there are four Defense Area Communications Operations Centers

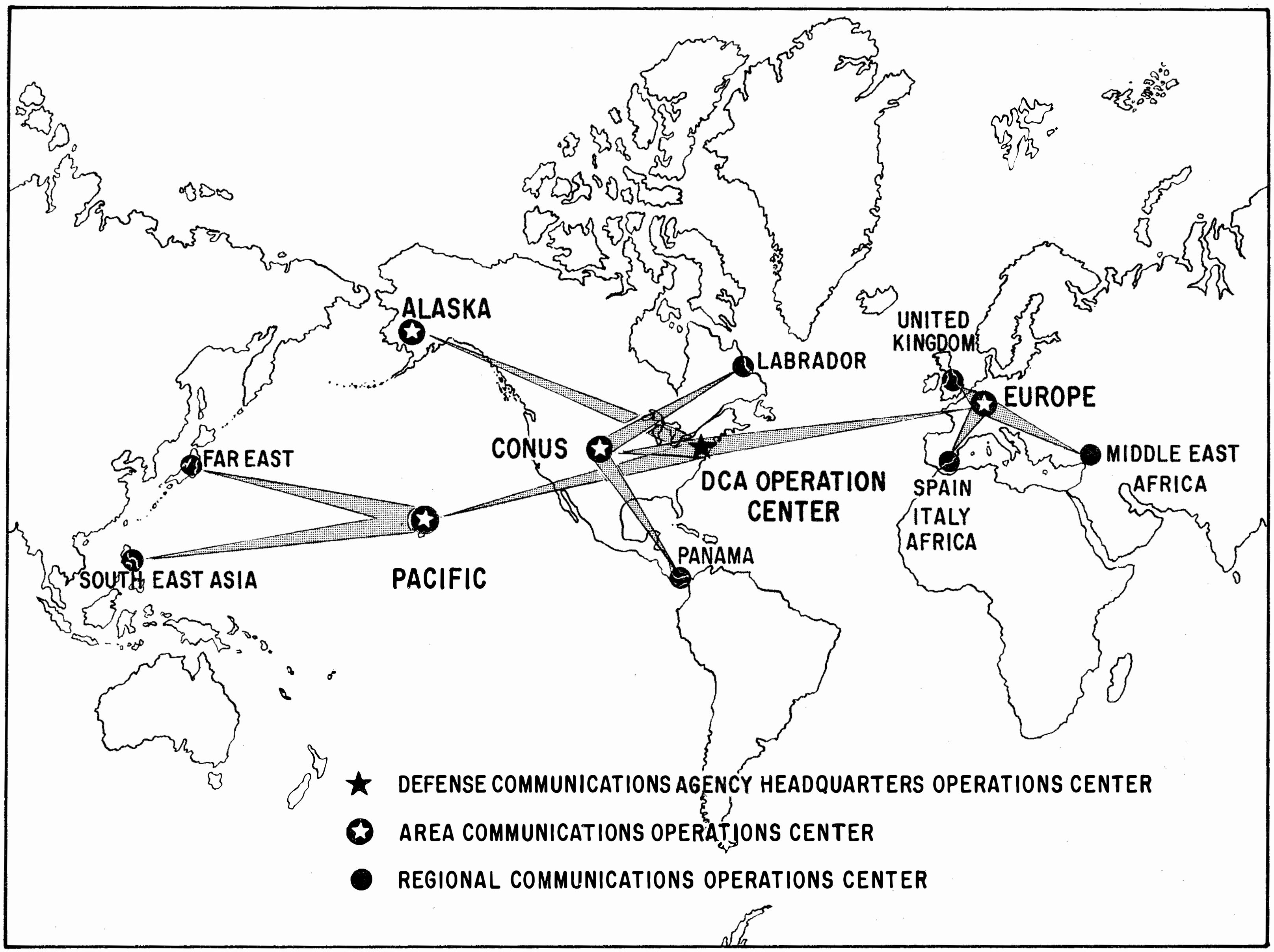

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Figure 4-2.—Defense Communications Agency Operations Center Complex.

(DACOC). These control centers are subordinate to the DCAOC and report to it. They exercise operational direction and supervision of DCS components in their geographical areas in the same manner that the DCACO covers the entire world. The Pacific DACOC is located in Hawaii; European DACOC at Camp DesLoges, France; Alaska DACOC at Elmendorf AFB, Anchorage; and Continental U. S. DACOC at Fort Carson, Colorado. Within the DCS, DACOC-CONUS increases the span of system control, and provides an alternate capability for DCAOC activities during emergency situations.

Establishment of these DACOCs provides control facilities that permit the DCS in their particular areas to be responsive to changing needs of area commanders. Although DCAOC has extensive computer capability, the degree of automation for Area Operations Centers is based chiefly on day-to-day, close control requirements.

Each of the four DACOCs is furnished teletypewriter and telephone circuits for status reporting, coordination and control, and administration.

Regional Communications Operations Centers

Subordinate to Area Communications Operations Centers are eight Regional Communications Operations Centers. Regional Communications Operations Center Far East (RCOC FE), Regional Communications Operations Center Southeast Asia Mainland (RCOC SAM) and Regional Communications Operations Center Southeast Asia (RCOC SEA) report to Area Communications Operations Center Pacific (ACOC PAC). Regional Communications Operations Center Middle East and Africa (RCOC MEA), Regional Communications Operations Center Spain Italy and Africa (RCOC SIA), and Regional Communications Operations Center United Kingdom (RCOC UK) report to Area Communications Operations Center Europe (ACOC EUR). Regional Communications Operations Center Labrador (RCOC LAB) and Regional Communications Operations Panama (RCOC PAN) report to Area Communications Operations Center Continental United States (ACOC CONUS). In the Alaska ACOC area, there is no RCOC.

Each RCOC takes care of the DCS within its own region, according to its needs, and makes status reports to the appropriate ACOC. The type and amount of automatic teletype and computer circuits and equipment depend on the needs of each particular region.

DEFENSE COMMUNICATIONS SYSTEM

The Defense Communications System (DCS) combines into a single system those elements that make up the Army's STARCOM, the Navy's Tape Relay System, the Air Force's AIRCOMNET, and the DCS AUTOVON and AUTODIN systems. An organizational chart of these elements is shown in figure 4-3.

The Defense Communications Agency (DCA) has operational direction over the DCS. This direction is set up by policy coordination with the commanders of each military service and by operational coordination with the communication headquarters of each service.

CIRCUIT CONTROL

Each military service has command of—and is responsible for—operation and maintenance of its stations within the DCS. Each DCS station operates under the circuit direction of a designated communications operations center.

Circuit control and operation are the responsibility of each relay station. Most relay stations usually have the necessary information for alt-routing or setting up new circuits. They normally handle these procedures without requesting help from DCA operations centers. If a relay station requires assistance in alt-routing a circuit or message traffic, it can call on the designated operations center for requisite data. The operations center supplies the information, but the relay station ensures that proper connections are made. If required by the local station, the operations center also provides coordination with distance stations.

Each communications operations center, in exercising operational direction of subordinate DCS stations, issues message or telephone instructions when required. As opposed to administrative messages entailing command and policy matters, these messages direct actions or request additional information calling for operational responsiveness of the DCS station. Normally, these messages require direct and immediate action by technical or traffic control elements of the DCS station. Messages involving operational direction are referred to as operational direction messages (ODMs). These

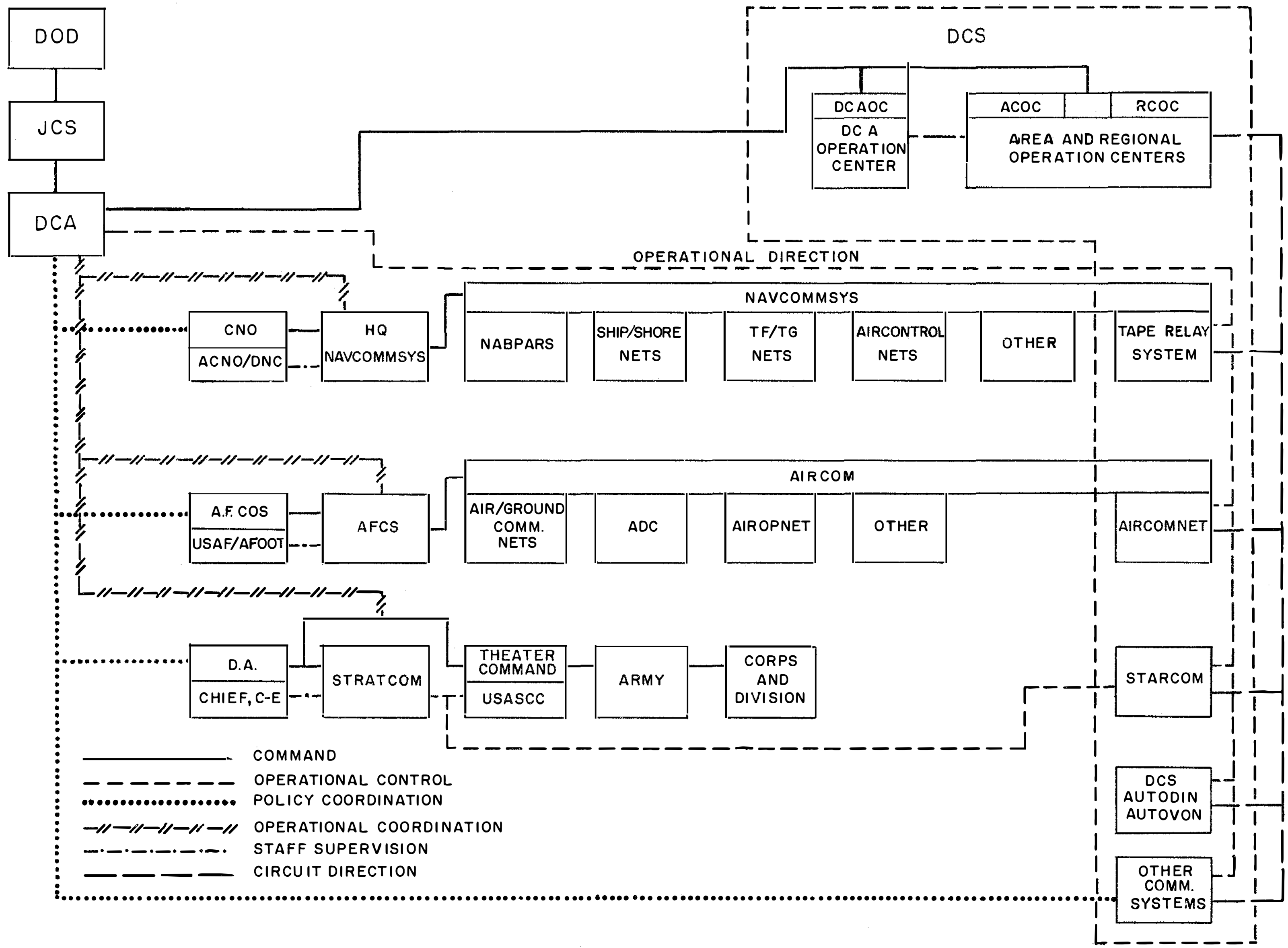

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Figure 4-3.—Military and Defense Communications System organizational chart.

messages are identified by the month in which originated, and are numbered serially from 010001Z January of each year. To illustrate, DCA-PACIFIC ODM 4-112 means that the message was originated in April and is the 112th ODM of the year. Operational direction messages are released only by the system control officer on duty in the operations center.

Each communications operations center functions as a central source in its area for technical and operational data on the DCS and the service it provides. Military commanders, DCS stations, DCS users, and local commercial communication companies must coordinate communication problems with the center in order to furnish the most effective communication service.

The chief of each Defense Operations Communications Complex (DOCC) must make arrangements to provide to senior military commanders served by his center the latest available communication status. Current status, warning, and long-term performance information on stations, facilities, networks, and the like, are provided, as required, to the military departments for fulfillment of their responsibilities.

The chief of each area center must ensure that the following functions are accomplished within his assigned area. Coordination functions indicated by an asterisk (*) may be performed by certain communication activities designated by the area center chiefs.

*DCS circuit coordination;
*DCS facility coordination;
*DCS network coordination;
DCS technical control;
DCS traffic control.

Effective control of each circuit, trunk, and facility of the DCS is achieved only if responsibility for each facet of the operation is clearly understood by all personnel concerned. To ensure better understanding, the DCAOC and each DCA area center is encouraged to develop plans for exercising control of each facility, trunk, and circuit in the DCS within their assigned responsibility. They also must distribute extracts to appropriate communication activities.

DCS REPORTING STATION REPORTS

Status information is required so that Director, DCA can maintain current information on circuits, channels, and resources of DCS.

An individual DCS reporting guide is prepared by the appropriate operations center for each DCS reporting and reported-on station. These guides contain only such information as pertains to preparing status reports by a reporting station.

A reporting station is a DCS station required to submit status reports in a prescribed format and accomplish other specific functions.

A reported-on station is a communication facility designated to have status reports submitted on it by a reporting station. Reports concerning these stations are put in the same form as though the reported-on station submitted the report.

Automatic data processing techniques are the basis for producing reporting guides. Information in the reporting guide is also programed in the computer. Information from status reports is fed into the computer, then is compared against information from the reporting guide programed previously. Any differences in the status of circuits and message traffic loads are shown automatically on the display panels.

Reports by DCS reporting stations for DCS operational direction are of two different forms: automated format and narrative form. These report forms fall into five categories. A description of various formats and categories follows.

Automated format: An automated format is required on specified information so that the ACOC automatic processing system can accept data to be used for operational direction and management of DCS.

Narrative form: The narrative form is used independently of automated format reports or to supplement them. Information submitted in this form is not processed by the computers. Voice reports follow the general format for the narrative form.

Regular reports: Regular reports are automated format reports of DCS performance that do not require special reports. Narrative remarks may be added. A regular report is required only when reportable information was not submitted by any other report category, and then at such time intervals as to preclude the information being unreported for more than 4 hours. An exception to this rule is the regular formatted report required at the end of each radio day.

Special reports: Automated format or narrative reports of DCS status are called special reports. They are required when facility or user service outage or restoral in special categories (normally related to restoration priority) is experienced. A special report is required when transmission paths supporting one or more priority 1 circuits sustain an outage, and it becomes apparent to the reporting station that circuit continuity cannot be restored within 10 minutes. The same requirement applies to any outage of circuits in this priority group, if the fact of outage is known but the cause and its location are unidentified.

Emergency report: Narrative reports of communication disruptions resulting from malicious interference with communications are known as emergency reports. An emergency report is required in the following circumstances: (1) when any physical damage or threat of damage occurs as a result of violence or warfare; (2) instances of sabotage, or attempted sabotage, to communication facilities; and (3) jamming, or suspected jamming, of electronic devices.

Recapitulation report: A recapitulation report summarizes the current status of a station, and is submitted upon request of a DOCC element. A recapitulation report (recap) is a complete summary of present status of a reporting/reported-on station in automated format. It provides for summary correction to suspected erroneous status indications at the ACOC. It is not a substitute, however, for internal corrections at the ACOC. Current outages or allocations, which began on the previous radio day, are reported as beginning at 0001Z of the current radio day.

Correction report: A correction report is a corrected version of a previously submitted automated format report. A correction report is submitted by a DCS reporting station upon request of cognizant DOCC element or upon discovery of a factual error in an earlier automated format.

DCS AUTOVON AND AUTODIN

The automated voice network (AUTOVON) and automatic digital integrated network (AUTODIN) systems are high-speed, fully automatic systems. They are designed for passing voice and teletype data over long distances. These systems, which are an integral part of DCS, are covered more fully in a later chapter.

NAVY COMMUNICATIONS

Because you already should be familiar with the Naval Communication System and its different types of networks, Navy communications is mentioned here only briefly.

For this chapter—whose purpose is to familiarize you with the Defense Communications System, communications of other military services, and how they all work together—the Naval Communication System is broken down into two groups: strategic and tactical.

Strategic communications cover a much wider scope than tactical.

By means of strategic communications, all forces are linked together on a worldwide network. The Navy Tape Relay System falls into this group. As explained previously, the Tape Relay System is part of the Defense Communications System. Tactical nets are not a part of DCS.

Tactical communications usually are limited to a specific area of operations, and are used to direct or report the movement of specific forces. Some tactical nets are utilized only for operational traffic; others may be used for operational and administrative traffic. For instance, the task force and task group nets and air control nets ordinarily are employed only for operational traffic. Ship-to-shore nets and broadcast nets can serve both types of traffic.

U. S. AIR FORCE COMMUNICATIONS

Air Force communications (AIRCOM) is organized into the Air Force Communications Service (AFCS). Both AIRCOM and AFCS are headed by the Director of Telecommunications. Actual operation of AIRCOM and its elements is the responsibility of AFCS. Additionally, AFCS develops and recommends practices and procedures for operating the entire system.

AIRCOM

The AIRCOM comprises all communication circuits and facilities—both leased and Government-owned—employed by the Air Force for transmitting intelligence to and between ground installations, air, and aerospace vehicles. Excluded are systems that are entirely self-contained; they do not exchange intelligence with AIRCOM, because they serve a single weapon system.

To understand the significance of the term AIRCOM, you should realize that this intricate communication system is composed of many integrated and related networks and facilities. Component networks, although they are operated independently, still are part of AIRCOM, and are described separately here.

Elements of AIRCOM include (1) specific support facilities (2) AIRCOMNET (3) AIROPNET (4) DCS AUTODIN (5) flight service network (6) weather networks, and (7) USAF air-ground communications network.

The types of interrelated circuits that make up AIRCOM are functional and common-user networks. A common-user network, for example, is designed for common use of all Air Force organizations and other authorized users. All types of messages are handled in a common-user network: command, operational, logistic, and administrative. Primary common-user networks of the Air Force are the AIRCOMNET and AIROPNET. The USAF air-ground network and flight service interphone network are representative of major command networks.

Functional networks are designed to handle a definite type of traffic in a specific manner. Included in this category are networks for controlling aircraft in flight and for exchanging weather information. Examples of functional networks are the weather teletype and weather facsimile networks.

STRATEGIC COMMUNICATIONS

Strategic communications normally are long-haul, point-to-point, fixed-station, and transportable facilities. Usually strategic communications support or significantly affect national strategy.

Air Force Communications Network

The Air Force Communications Network (AIRCOMNET) is used for passing official teletypewriter traffic on a global scale. It is a common-user network, to which every Air Force installation has access (if required). In the Air Force, AIRCOMNET is the primary means of communications, handling the vast bulk of teletype traffic. Major and minor relay stations, completely interconnected by quality-controlled wire and radio circuits, are employed by AIRCOMNET. These relay stations serve assigned tributary stations within a given area. Each relay station also acts as net control station (NCS) for tributary stations.

Support facilities and allocated channels of AIRCOM are utilized by AIRCOMNET. The AFCS operates AIRCOMNET relay stations and some tributary stations, besides having overall supervision of the network. Commands and subordinate units operate AIRCOMNET tributary stations. The AIRCOMNET is composed of the CONUS and overseas portions.

Five automatic switching centers are in the continental United States. Locations of these five relay stations—two of which are called gateway stations because they work directly with overseas relay stations—are as follows:

Andrews AFB (near Washington, D. C.); Atlantic overseas gateway station.
McClellan AFB (near San Francisco); Pacific overseas gateway station.
Wright-Patterson AFB, Ohio.
Robins AFB, Georgia.
Carswell AFB, Texas.

These five automatic switching centers are leased from Western Union. Numerous tributary stations, operated in conjunction with relay stations, provide communications with all Air Force installations.

Automatic relay stations overseas are at Fuchu, Japan; Hickam, Hawaii; Croughton, England; San Pablo, Spain; and Siegelbach, Germany.

Semiautomatic relay stations are located at Kadena, Okinawa; Elmendorf, Alaska; and Harmon, Newfoundland. At these semiautomatic stations, messages received on typing reperforators are switched to the desired outgoing channel by manually pressing a pushbutton on the equipment panel. This action shifts the messages directly to the desired channel without manual retyping or other handling.

In addition to the foregoing automatic and semiautomatic relay stations, other overseas relay stations are equipped for torn-tape relay operation.

Defense Communications System Element

The AIRCOMNET is the Air Force portion of DCS. It is closely integrated with communication systems of other DOD services and agencies. Like its counterparts, AIRCOMNET is operated in support of DOD and Joint Chiefs of Staff (JCS).

TACTICAL COMMUNICATIONS

Within the Air Force, tactical communications are used mostly to handle the movement of aircraft. For this purpose, different types of information are needed. These various types are handled on separate networks, which previously were mentioned as functional networks. Air Force tactical communication nets, as pointed out earlier, are not a part of DCS.

Air Operational Network

The air operational network (AIROPNET) is a worldwide teletypewriter network interconnecting all Air Force bases having a requirement for handling aircraft movement traffic.

Separate channels of AIRCOMNET relay system are utilized by AIROPNET. (Separate channels are discussed later in this chapter.) This network provides rapid communications between air traffic service facilities, flight service centers, transport control centers, and air operations agencies. Facilities of AIROPNET are used also by other military services. The AIROPNET is utilized for transmitting messages of the following types:

1. Aircraft emergency messages (distress, urgency, safety).
2. Air traffic control messages (arrival and departure requests, changes in flight plans, and the like).
3. Messages originated by aircraft or by agencies having operational control of aircraft, which require immediate action and pertain to initiation, continuation, diversion, or termination of a flight.
4. Departure and arrival reports.
5. Transfer of radio guard.
6. Meteorological information or Notices to Airmen (NOTAMs), of immediate concern to an aircraft awaiting departure or in flight.

Air-Ground Communications

The USAF air-ground communications network is a worldwide system that provides the link between ground stations and aircraft. Each air-ground station is a tributary of an AIRCOMNET/AIROPNET relay station. Air-ground stations are air extensions of point-to-point circuits operated by the Air Force in AIRCOM. This network is not intended as a primary network of any one command. It is available to all Air Force commands.

To meet requirements, chiefly in support of SAC and MATS, a number of air-ground stations are equipped with a patching capability. Such a facility permits direct electrical connection of air-ground voice channels into point-to-point landline or radio channels. By this means, controlling agencies can be put in direct voice communications, on a worldwide basis, with their aircraft.

Air Defense Communications

The purpose of Air Defense Command (ADC) Communication networks is to provide communication support for the primary mission of the Air Defense Command/North American Air Defense (ADC/NORAD). This mission encompasses detection, identification, interception, and destruction of enemy-manned air weapons. Within ADC, the types of communication networks, all of which are components of AIRCOM, are—

1. Surveillance teletypewriter network.
2. Alert teletypewriter network.
3. Command teletypewriter network.
4. Telephone network.

Army, Navy, and Canadian elements that are a part of the NORAD complex are also connected by ADC circuits.

Seaward extensions of the ADC network are supplied on both the east and west coasts of the United States. For communications with picket ships, airborne early warning aircraft, and control units in the air defense system, HF, VHF, and UHF radio is used.

Other Air Force Communications

Besides communication networks already described, the Air Force has several additional networks. These networks include—

1. Flight service interphone network.
2. Weather teletypewriter and facsimile networks.
3. Air Materiel Command networks.
4. Military Air Transport Service (MATS) communications.
5. Strategic Air Command (SAC) communications.
6. Tactical Air Command (TAC) communications.

Detailed descriptions of these additional networks are not given here.

ARMY COMMUNICATIONS

Army communications are operated by the Army Signal Corps, which is headed by the Chief, Communications-Electronics. His responsibilities to the Secretary of the Army and the Army Chief of Staff are equivalent to those of DNC to SECNAV and CNO.

STRATEGIC COMMUNICATIONS

The present strategic Army communication system, known as STARCOM (formed from the underlined letters of the term strategic Army communication system), is organized and operated to transmit and receive official messages and other traffic for the Department of Defense, Department of the Army, other military departments, and other agencies of the Government.

Most of the STARCOM system is under the management and operational control of the strategic Communications Command (STRATCOM). The long haul point-to-point system of STARCOM is part of the DCS.

The relay station at Fort Detrick, Maryland (near Washington) is the net control station for STARCOM and exercises operational control over the system. Operational control includes adherence to prescribed procedures, monitoring, circuit discipline, emergency routing, and determining priority in restoration of interrupted facilities.

STARCOM CONUS Portion

Within the continental U. S. portion of STARCOM are three primary relay stations. The stations are located at Fort Detrick, Md., Fort Davis (near San Francisco), and Fort Leavenworth, Kansas. These three relay stations complement one another's capabilities so that destruction or partial loss of one can immediately be compensated for by the other two.

The relay station at Fort Detrick is the largest automatic switching station in the STARCOM system. It can handle more than 275,000 messages a day. It has long-distance radio, cable and wire channels to provide teletypewriter, voice, data, and facsimile services throughout the United States and to vital overseas locations. Fort Detrick relay also serves as gateway station to Europe and the Caribbean. Fort Davis is the gateway station to the Pacific and Far East.

In addition to the three major relay centers, relay stations are located at Seattle, New York, Atlanta, Fort Houston, and Fort Bragg.

STARCOM Overseas Portion

The overseas portion of STARCOM is composed of a series of strategically spaced relay stations.

Major relay stations are in Japan; Oahu, Hawaii; Asmara, Ethiopia; and Pirmasens, Germany. Other relay stations are in Okinawa, Taiwan, Korea, Canal Zone, France, Germany, Turkey, and Italy.

Location of these overseas stations is dictated chiefly by the worldwide deployment of troops. Multichannel teletypewriter circuits connect the Department of the Army COMCEN in Washington with the Continental Army Headquarters. Tributary circuits reach out to all Army installations and other Government agencies, as required. Facilities of the overseas portion consist of fixed point-to-point radio and wire, and cable circuits. These circuit facilities are used with such equipment as single sideband, electronic time division multiplex, automatic and semiautomatic teletypewriter relay equipment, and high-speed tape reproduction equipment.

TACTICAL COMMUNICATIONS

Tactical communications within the Army usually starts at the theater level, down through the field armies, to the Army Corps, and to the lower echelons in the field.

Theater Communications

The form and extent of the signal communication system are determined by the type of command and the specific functional requirements. Because of the many differing operational environments of each locale, the situation varies.

The theater area communication system (TACS) is a high-capacity, high-quality, multimeans, multiaxis, integrated signal communication network. Circuits constituting the system extend forward from the theater rear boundary into the field army areas, where they interconnect with the field army area communication systems.

SIGNAL LONG LINES COMMAND.—The operating element of the theater army responsible for installation and operation of the TACS is the signal long lines command. Elements of this command are deployed throughout the theater of operations, as required. These elements are provided supply and maintenance support by the logistical command in whose area the elements are located.

The signal long lines command consists of a headquarters and headquarters company, plus construction and operating units, as required. Requirements are dictated by the mission and organization of the theater of operations, area of operations, theater plan of operations, theater troop composition and disposition, indigenous facilities, and enemy capabilities.

Field Army Communication System

The field army communication system organization is composed of the field army area communication system, communication systems of the subordinate corps, area communication systems of divisions, and other communication facilities of units integral to the field army.

FIELD ARMY AREA COMMUNICATION SYSTEM.—The field army area communication system is installed by signal troops assigned to the field army. Basically, the field army area communication system is composed of area signal centers interconnected by trunk circuits under centralized control. Each area signal center is assigned a geographical area for operations. The size of this area is determined by the location, disposition, and communications-electronics (COMMEL) requirements of the supported forces. Some army area signal centers may be located within division areas. Each signal center of the area system is interconnected with at least two other signal centers to provide alternate routing and to permit distribution of the traffic load.

Command signal centers are established to serve the echelons of field army headquarters. Each command signal center is connected with two or more area signal centers to provide alternate routing of circuits and flexibility of operations. Additionally, command signal centers may be directly interconnected when availability of facilities, distances, and other factors permit.

To provide the field army access to the TACS, theater army signal control centers are located to interconnect readily with army signal centers in the rear of the field army.

The field army messenger service is supervised and coordinated by the field army system control center for the systematic handling and expeditious delivery of messages, correspondence, and general distribution between the users of the field army area communication system. It consists of the messenger service provided by the army signal battalion and by the signal combat area battalions. It is integrated with the signal messenger service furnished by the corps and divisions.

Army Corps Communication System

The Army corps signal communication system is installed, operated, and maintained by the corps signal battalion. It provides direct communications from corps headquarters to each division, and from corps artillery headquarters to each division artillery headquarters, and to each artillery group attached to the corps.

The corps is not a fixed or permanent type of organization. Essentially, it is a tactical headquarters. It is organized mainly to execute tactical combat operations, normally as part of the field army. This system, integrated with the field army area communication system, provides a high degree of flexibility required in signal communications. The corps signal battalion is approximately 85 percent mobile.

Army Communication Units

Different types of communication units are made up to operate and maintain the communication systems. Some of these units are army signal groups, army signal battalions, army signal supply and maintenance battalions, signal communication center operation companies, combat area signal groups, signal combat battalions, and signal cable construction battalions.

COMMERCIAL COMMUNICATION SYSTEMS

The first transoceanic submarine cable, laid between Newfoundland and Ireland in 1858, marked the beginning of international commercial telecommunications. Radiotelegraph service between the United States and England started in 1899. It was not until 1927, however, that the first international radiotelephone circuit was established between New York and London. Since that time, telephone and telegraph facilities have, of course, expanded greatly. Today, almost every country in the world is linked to another by such means.

U. S. TELECOMMUNICATIONS FACILITIES

In the United States, telecommunication facilities are privately owned and operated. So are the industries supporting these facilities.

Telephone

Telephone facilities are provided by the various operating subsidiaries of the American Telephone and Telegraph Company, and by approximately 5300 independently owned companies that are members of the Independent Telephone Association. The Bell Telephone System, the name by which the AT&T is better known, operates about four-fifths of the more than 50 million telephones in the United States, making it the largest telephone system in the world.

Telegraph

Domestic telegraph service is furnished by the Western Union Telegraph Company. Western Union also operates an international submarine cable network between the United States and Europe, the United States and certain islands in the Caribbean, and by relay over foreign company facilities to South America.

Teletypewriter

The Bell Telephone System and Western Union supply facilities for private line teletypewriter service to industry and to the military services. Western Union (along with AT&T, Mackay Radio, Commercial Cables, and RCA) operates a form of teletypewriter service to London, and also press news channels.

Radiotelephone

The AT&T operates the major facilities for overseas radiotelephone service. In certain overseas and foreign areas, RCA Communications, the Radio Corporation of Puerto Rico, and Tropical Radio Telegraph Company provide radiotelephone service connecting with AT&T in the United States.

Cable

Submarine cable facilities are provided by Western Union and two subsidiaries of the International Telephone and Telegraph Corporation (IT&T). The subsidiary IT&T cable companies are the Commercial Cable Company (operating in the North Atlantic to Europe), and the All America Cables and Radio Company (operating in the Caribbean and the Atlantic and Pacific Oceans to Central and South America).

International Landlines

International landlines are operated by AT&T and Western Union for telephone and telegraph service, respectively, to Canada and Mexico. Telephone service to Alaska is supplied by AT&T in the United States, via facilities of the Alberta Government Telephone Company and the Northwest Communications System in Canada, and on the Alaska Communications System (ACS) lines in Alaska. Many private industries, such as petroleum, railroad, airline, lumber, mining, and shipping, operate private communication facilities. Some of these facilities are quite extensive and modern, such as the railroad communication systems and the microwave relay systems installed along petroleum pipelines.

Radio Broadcast

The radio broadcast field is dominated by four major networks, and is supplemented by many regional networks for program relaying. Comprising the four major networks are the National Broadcasting Company, the Columbia Broadcasting System, the Mutual Broadcasting System, and the American Broadcasting Company. Member stations of these networks are supplied with program material over the facilities of the AT&T landlines. Television stations associated with these networks have the video portion of the program material relayed by coaxial cable and microwave relay systems. The audio portion is carried over the regular radio program networks.

BELL SYSTEM

Basically, the Bell System is made up of the American Telephone and Telegraph Company and a group of 21 closely integrated associated telephone companies that own and operate telephone plants in their respective geographical territories. Each associated company therefore exists as a distinct corporate unit and is separated along territorial and functional lines.

Associated companies are not controlled by the AT&T company but, like other associated companies, have a license contract arrangement with it. Included in the Bell System organization are Western Electric Company, a manufacturing and supply organization, and Bell Telephone Laboratories.

AMERICAN TELEPHONE AND TELEGRAPH COMPANY

The AT&T performs an important interstate operating function through its Long Lines Department, which owns and operates long-distance lines interconnecting the 21 subsidiary operating companies. Moreover, AT&T coordinates the enterprise by planning and advising the associated companies on all phases of the business through its staff of specialists.

BELL TELEPHONE LABORATORIES

Bell Telephone Laboratories is responsible for all fundamental research and development work of the Bell System. Laboratories are composed of four chief development and research groups. These groups work in close cooperation, and the majority of the products of the laboratories represent the work of all. The continued ability of the Bell System to provide high-quality service depends largely on this organization. It is responsible for a number of new developments in the field of communications and electronics.

WESTERN ELECTRIC COMPANY

The Western Electric Company is the manufacturing and supply unit of the Bell System. Major functions of the company are manufacturing most of the apparatus and equipment, purchasing and distributing most of the supplies, and installing central office equipment. Western Electric maintains close supply sources for the operating companies at supply houses located throughout the country. These facilities provide a ready reserve of materials in the event of disaster.

Through ownership of Western Electric, it is possible for the Bell System to control adherence to rigid specifications. A centralized supply source also ensures the compatibility of the various systems. In large measure, Western Electric is responsible for standardizing and integrating the telephone network of this country.

DOMESTIC TELEPHONE FACILITIES

Supplying domestic telephone service is the Bell System's primary undertaking. With its 21 operating companies, and through interconnecting arrangements with the independent telephone companies, the System furnishes domestic, local, and long-distance telephone service to over 50 million United States telephones. This concentration of telephones is greater than the rest of the world combined.

The Bell System has four methods for interconnecting U. S. cities.

1. Open wire: A single pair of conductors is used to carry one voice channel; with multiplexing systems, 16 channels per pair.
2. Multiple pair cable: Multiple copper paired conductors transmit voice circuits on the individual pairs, or up to 12 telephone channels per pair with multiplexing systems.
3. Coaxial cable: Coaxial cable consists of a center conductor mounted within a concentric tube. The usual coaxial cable has eight of these tubes; six are for regular service, two for spares. The most recent design of voice-multiplex equipment enables each pair of tubes to handle 1800 two-way telephone circuits (one tube for each direction). A fully loaded coaxial cable can therefore handle 5400 two-way telephone circuits. Instead of the 1800 telephone circuits, each pair can be used to send two oppositely directed one-way TV channels and 600 telephone circuits. Thus, three pairs would carry six one-way TV channels (three in each direction), plus 1800 telephone circuits, with two coaxials held as spares.
4. Radio relay: Radio relay systems require towers at regular intervals (about 30 miles) for relaying telephone, teletype, or television signals from city to city. Carrier waves are relayed from tower to tower by means of high-gain antennas, coupled with extremely reliable transmitters and receivers. Sensory units are included within each station to detect faulty circuits, to inform maintenance crews of failure, and to switch to standby equipment in instances of outage. Radio relay stations handle at least 12 one-way communication channels, servicing a total of 3000 telephone circuits or 10 one-way television channels. Spare channels also are provided for maintenance or emergency use.

FOREIGN TELEPHONE FACILITIES

In addition to the telephone network covering the United States, telephone service is available to about 96 percent of the world's telephones through the overseas radiotelephone facilities of the Bell System. These facilities connect the United States with various parts of the world via radio channels originating at terminals near New York, Miami, and San Francisco. Connection is made with the Alaska Communication System of the Army at Seattle. Because the Bell System operates only within the CONUS, radiotelephone service is rendered in cooperation with the appropriate operating company in each country served.

The long-haul international radiotelephone circuits of the world normally use single sideband transmission. This feature results in improved intelligibility with narrow carrier bandwidths. More than 90 percent of the Bell System's direct radiotelephone circuits operate with single sideband transmissions.

Voice Cables

Despite technical advances in electronics, the reliability of communications over long-distance high-frequency radiotelephone circuits still leaves much to be desired. This deficiency is particularly true of the paths from the United States to northern Europe, where magnetic storms sometimes interrupt communications to some countries for hours at a time. A voice cable between the continents of America and Europe—under consideration for many years—now is in service.

Selection of the route was an important part of the construction plans for the North Atlantic telephone cable. Consideration of the many hazards led to the choice of a route from New York to Newfoundland to Scotland. It is the shortest practical route, is north of existing radiotelegraph cables, runs through a minimum of pack ice, and misses most of the trawling grounds. Two cables are provided, one for transmission in each direction. The main link is about 1800 miles long; overall length is 2250 miles. From Newfoundland to Nova Scotia the link runs underwater; but from Nova Scotia into Portland, Maine, it uses a conventional radio relay system.

The cable contains 36 voice circuits. To provide adequate communications, underwater repeaters are installed in the cable at intervals of about 40 miles. These repeaters have three low-power vacuum tubes that can operate for many years without attention. The cable itself is designed to last at least 20 years without attention.

Other underwater telephone cables in the Bell System include the Key West—Havana cable, two cables between the United States and Alaska, and the transpacific cable connecting mainland United States with Hawaii. This 2400-mile cable is similar in design and construction to the Atlantic and Alaskan cables. The twin-cable system is capable of carrying 36 simultaneous conversations, and is the first underwater cable to feature operator dialing. The Hawaiian cable substantially augments the 14 radio circuits operating between the mainland and Honolulu. This cable system is also used for teletypewriter service and for transmission of radio programs, but not television.

PRIVATE AND SPECIAL COMMUNICATION FACILITIES

The Bell System has an extensive network of private line telegraph facilities and TWX circuits. Most of the press wires and a large portion of the private line telegraph facilities of large business houses, brokers, and Government agencies are provided by the Bell System. Over 4000 TWX circuits and over 4,000,000 miles of private line telegraph circuits are now in service.

Among the special communication facilities of the Bell System are the mobile radiotelephone units. About half of these units are private systems, and the balance connect to the regular commercial telephone network.

Other special communication facilities include marine radiotelephone service, available to ships on the high seas and small craft operating in coastal and harbor waters and in the Great Lakes.

The Bell System also has a nationwide network of video channels that serve the television broadcasting industry.

SECURITY AND MOBILIZATION PLANS

The entire communication industry is faced with the problems of providing uninterrupted service, despite natural or manmade disasters. One of the best methods of assuring reliable service is diversification of circuits. In modern telephone facilities, diversification is realized by building new routes. As the United States telephone networks spread, it became a simple matter to route circuits between any two points over separate lines. With the advent of possible nuclear bombing of large cities, it is realized that long-distance telephone facilities might be seriously disrupted. Bypass and express routes are now constructed to protect service from interruption.

Alternate switching facilities now ensure that intercity telephone traffic is not wiped out completely if enemy attack or natural disaster occurs. Alternate switching centers, at considerable distance from the main switching centers, afford this protection. By use of this alternate routing, the Bell System offers relief for congested traffic situations in daily operations. This arrangement is working daily; it is not a standby plan. In other words, a sizeable percentage of traffic in and out of a city is handled by dispersed offices every day. Consequently, in an emergency, no time would be required to put them into service.

The matter of bypassing cities is important. The Bell System, with its many alternate routes, provides this capability in eight transcontinental routes. Of this number, four are open wire; one is a cable equipped with the paired cable type of long-haul carrier; another is of the coaxial cable type; and finally, two radio relay routes span the country from coast to coast.

As standby equipment, the Bell System has available throughout the country 100 radio systems that can be used in emergencies. They also may serve to bridge the gap that may have occurred in wire lines or cable as a result of disaster. Currently the Bell System is adding newly designed portable equipment to its emergency radio facilities. This equipment includes portable aluminum towers that can be erected within an hour where circuits suffer damage.

Trained personnel with large stocks of material available to them are located in many areas. All associated companies, as part of their regular service provision, have developed plans for restoration of essential service in emergencies.

INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION

The wide geographical extent and varied activities of the International Telephone and Telegraph Corporation are backed by experience nearly as old as the electrical communication industry itself. Long a major supplier of telephone and telegraph equipment overseas, the IT&T system has expanded its research and manufacturing activities in the United States so that it now ranks among the leaders in electronics and telecommunications.

The IT&T supplied South America with its first radiotelephone service to Europe and North America, Europe with its first multichannel commercial radiotelephone link and its longest coaxial cable network, Belgium and Switzerland with pioneer nationwide telephone dialing equipment, and the world with its first commercial microwave system.

IT&T Operating Subsidiaries

Telephone operating subsidiaries of IT&T furnish telephone service in Chile, Puerto Rico, Virgin Islands, and to certain areas of Brazil and Peru. Radio operating subsidiaries of IT&T in Argentina, Bolivia, Brazil, Chile, and Puerto Rico provide international radiotelegraph service and, except in Puerto Rico, international radiotelephone service as well.

AMERICAN CABLE AND RADIO CORP.—Principal subsidiary of IT&T is the American Cable and Radio (AC&R) Corporation. It is the largest American international telegraph system, owning and operating both cable and radio facilities. The AC&R was formed in 1940 upon consolidation of the operations of three IT&T affiliates—All America Cables and Radio, the Commercial Cable Company, and Mackay Radio and Telegraph Company.

A complete global communication service is offered by AC&R for the use of Government agencies, the general public, and the press. It operates more than 80 international radiotelegraph circuits, more than 15,000 miles of landlines, and approximately 48,000 miles of submarine cable. Main types of service supplied by AC&R are point-to-point, ship-to-shore, radiotelephone, multiple-addressed press, and telex. (The telex system enables a subscriber to obtain a direct teleprinter connection to any other telex subscriber merely by dialing as one does with a telephone.) In addition to its numerous branch offices and main operating centers located in the gateway cities of New York, San Francisco, and Washington, AC&R maintains and staffs more than 140 overseas traffic offices. Six powerful marine stations are located on the Atlantic, Pacific, and Gulf coasts of the United States. The system owns and operates a fleet of four cableships for laying and repairing its vast cable network.

ALL AMERICA CABLES AND RADIO.—The IT&T affiliate, All America Cables and Radio, was first to bridge the Americas with its submarine cable, connecting the United States with Mexico, Central America, and South America. The company entered the radiotelegraph field in 1929, establishing its first radio station at Lima, Peru. Its radio network since has been expanded to interconnect several other Latin American countries, the United States, numerous European countries, and the Far East. It also owns and operates an international radiotelephone service in Ecuador, Peru, and the Virgin Islands. Multiplexed circuits, both cable and radio, provide the necessary channels for international telex and leased channel services. In 1960 All America commenced operation of 36 duplex telegraph channels in the Miami/San Juan telephone cable. These outlets are for message traffic, telex, leased teleprinter, and data channels for private customer use.

COMMERCIAL CABLE COMPANY.—Submarine cable service between North America and Europe is maintained by the Commercial Cable Company, another AC&R carrier. The company owns six transatlantic cables, the first two of which connected Nova Scotia with Ireland. From these terminals the cables were extended to the eastern United States and to several cities in Great Britain. Later, the company extended service to France, Belgium, and the Netherlands. Two of the company's six cables follow a southerly course from Nova Scotia to the Azores before swinging northeast to Ireland. At the Azores, the cables connect with foreign-owned cables to Europe, Africa, and Asia.

MACKAY RADIO AND TELEGRAPH COMPANY.—The Federal Telegraph Company, predecessor of Mackay Radio, began operations in 1911 as a domestic radiotelegraph carrier on the west coast. With initiation of service between San Francisco and Honolulu in 1912, Federal became the first American company to operate a successful transocean radiotelegraph circuit.

Today, Mackay Radio owns and operates powerful long-distance transmitting and receiving stations on the east and west coasts of the United States and in Honolulu, Manila, and Tangier. Point-to-point telex and leased channel services are provided, through these facilities, between the United States and numerous countries throughout Eruope, the Middle and Near East, Africa, Latin America, the Far East, and islands in the Pacific.

Mackay's service to Latin America, connecting in some instances with foreign telegraph administrations, is further augmented through integration of the company's facilities with those of eight other AC&R and IT&T communication companies that operate throughout this area.

Communication with ships at sea is effected through Mackay's six marine stations located on the east, west, and gulf coasts of the United States. The company also designs, manufactures, sells, rents, installs, and services shipboard communication equipment and electronic aids to navigation.

OTHER IT&T SUBSIDIARIES.—In addition to the commercial communication companies already described, the IT&T has several other subsidiaries. These subsidiaries are located in Argentina, Bolivia, Brazil, Chile, Peru, and Puerto Rico.

RADIO CORPORATION OF AMERICA

The Radio Corporation of America (RCA) was organized in 1919. Its creation was the result of both a patent tangle and a desire that American radio communications should not be under foreign control. Before it was established, the British Marconi Company tried to obtain exclusive rights to radio equipment made by the General Electric Company. Negotiations were near completion when the U.S. Navy Department voiced its objections to the ownership of this and other radio patents by a foreign interest. Thus, RCA was organized, and immediately purchased the assets and patent rights held by the British-controlled American Marconi Company.

Within the next few years RCA established direct radiotelegraph circuits between the United States and England, Hawaii, Japan, Norway, Germany, France, Italy, Poland, and Sweden. By 1937 RCA had long-distance high-frequency circuits to Java, Indo-China, Hong Kong, and the Philippines. To conduct the public radiotelegraph business formerly taken care of by other departments, RCA launched two subsidiaries—Radiomarine Corporation of America, and RCA Communications, Inc. Operations of RCAC are confined largely to point-to-point service between land stations. Radiomarine Corporation handles service to and from ships almost exclusively.

Today, the RCA communication network is made up of more than 250 radio channels. With them the company provides radiotelegraph service between the United States and 68 countries, telex facilities to and from 45 foreign countries, and radiophoto service with 45 foreign terminals. Also the company operates the terminals of 14 radiotelephone circuits in the Pacific area, affording broadcasters two-way program transmission with almost any point on the globe. Extensive facilities for communications with oceangoing vessels and ships on U. S. inland waterways are also maintained by RCA.

The New York terminal of RCAC is linked by microwave radio with remote transmitter and receiver stations on Long Island. Together, these installations constitute the east coast gateway from which radio circuits fan out to reach 50 countries in Europe, Africa, the Middle East, and South America. For communications with transpacific points, the gateway is at San Francisco, with transmitting and receiving stations at Bolinas and Point Reyes, California.

The RCAC operates its own international communication facilities in Guam, Morocco, Hawaii, Haiti, Puerto Rico, the Dominican Republic, and the Philippines. Elsewhere abroad, the distant terminals of RCAS circuits are managed by local agencies, usually government-owned.

The company has pursued a long-range program of utilizing more efficiently its allocated radiofrequencies. Through the use of frequency and time division multiplex, radio circuits that previously could provide a single radioteletypewriter channel of 60 wpm now carries as many as 16 channels at 100 wpm. The additional available channels provide for an increased volume of traffic and make available such new communication services as telex and leased channel service.

WESTERN UNION TELEGRAPH COMPANY

The Western Union Telegraph Company started business in 1851, just 7 years after Samuel Morse sent the first telegram. Over the years, properties of over 500 other companies have been acquired by Western Union or merged with the company.

Western Union provides service through more than 2000 offices and 20,000 agencies across the Nation. Moreover, Western Union owns, leases, and operates (or has arrangements with connecting companies for operating) a network of submarine cables. These cables make available communication for all of Western Europe, the Middle East, and Central and South America.

The introduction of fixed and portable carrier telegraph terminals, electronic repeaters, microwave systems, modern terminal equipment, automatic switching centers, and other modern transmission equipment has led to highly reliable networks for public message services and private wire (leased line) systems. In recent years, Western Union's own staff of engineers and scientists pioneered in developing and installing modern telegraph equipment. Nearly all the pole lines have been retired, and the manual relaying of messages has been eliminated. Western Union has 15 reperforator relay centers throughout the United States. By means of this high-speed switching system, telegrams are dispatched and relayed without manual retransmission.

Western Union owns over 4 million miles of carrier-equipped telegraph circuits, including 560,000 miles of microwave radio circuits. These channels are less subject to atmospheric disturbances than other radio circuits. All trunk circuits bypass major cities by approximately 30 miles so that the basic system should be little affected in the event of disaster.

Aside from telephone and messenger delivery of messages, Western Union provides large-volume users with direct teleprinter and facsimile connections. Teleprinter connections from patrons' offices direct to Western Union afford a rapid method of pickup and delivery. When the traffic volume warrants, patrons are provided with direct connections to automatic or semiautomatic reperforator switching centers. Approximately 20,000 customers are supplied with teleprinters. Western Union also furnishes to 37,000 customers a compact facsimile machine, called Desk-Fax. Transmission is made directly from typed or handwritten copy, and reception is recorded on electrosensitive paper.

Telex, long used overseas and in Canada, was introduced in the United States by Western Union. This teleprinter direct dialing system is available in and between New York, Chicago, San Francisco, Los Angeles, and 21 other major cities in the United States, including Honolulu.

Commercial Departments

Western Union's Government Contract Sales Division handles the leasing of systems to

Government and military organizations. It also conducts the outright sale of equipment and engineering services to all organizations. A separate Private Wire Services department has cognizance over leasing systems to commercial companies.

Cable Facilities

Western Union's cable system is the largest of the North Atlantic cable facilities. Several cables are leased from the Anglo-American Telegraph Company of England on a long-term basis. The balance, owned by Western Union, include the world's fastest telegraph cable as well as those of the standard, nonloaded, ocean-cable type.

All the nonloaded type now have installed electronic amplifiers, increasing their capacity about threefold. These transoceanic facilities consist of seven cables between North America and Europe, with a total capacity of 1950 wpm; two cables to the Azores, with a capacity of 560 wpm; three to the West Indies, of 2178 wpm capacity; and one to Barbados, with a capacity of 104 wpm in each direction. Western Union's submarine cable system totals about 26,600 miles.

FEDERAL COMMUNICATIONS COMMISSION

The Federal Communications Commission is the agency charged with regulating interstate and foreign commerce in communications by wire and radio. Jurisdiction of the FCC extends not only to private radio broadcasters and to common telecommunication carriers engaged in interstate and foreign commerce, but to communication activities of State and local governments as well.

The purposes of regulation by the FCC are (1) to make available to the people of the United States a rapid, efficient, nationwide, and worldwide wire and radio communication service, with adequate facilities at reasonable charges; (2) for the national defense; and (3) for the purpose of promoting safety of life and property through the use of wire and radio communications.

The FCC is not a part of any Government department. It is a separate agency, created by an Act of Congress (Communications Act of 1934), and reports directly to Congress. Formerly, jurisdiction over electrical communications was shared by the Commerce Department, Post Office Department, Interstate Commerce Commission, and (later) the Federal Radio Commission. With the Communications Act, all supervisory and regulatory functions were assigned to the FCC.

The FCC is administered by seven commissioners appointed by the President and subject to confirmation by the Senate. One of the commissioners is designated chairman by the President. Not more than four commissioners may be members of the same political party. Except for filling an unexpired term, the term of a commissioner is 7 years. Organization of the FCC is shown in chart form in figure 4-4.

In national and international communication matters, the FCC cooperates with various Government agencies. Included are the Department of Defense, Departments of State, Treasury, Interior, and Commerce, and other users of radio in the Federal establishment. It also cooperates with State regulatory commissions in matters of mutual interest.

The Communications Act applies to all the 50 states, Puerto Rico, and other U. S. possessions. Functioning within these areas, the FCC has 24 radio district offices, six suboffices, and one ship office. Various monitoring stations also are included in the organizational structure, together with a field engineering laboratory. Field duties include monitoring and inspecting all classes of radio stations, examining radio operators, making various radio measurements and field intensity recordings, and conducting related investigations. In addition to the foregoing offices, there are three common carrier engineering field offices. (A common carrier is a company furnishing wire or radio communication to the public for hire, with the exception of broadcasters.) Because broadcasting stations are not deemed common carriers, the FCC does not regulate charges for program time. Even though the Commission monitors broadcasts, it has no power to censor radio or television programs.

Licensing

Only a limited number of radio transmissions can be on the air at the same time without causing interference, hence the Communications Act requires all non-Government radio operations to be licensed. Courts have held that radio transmission anywhere within the United States

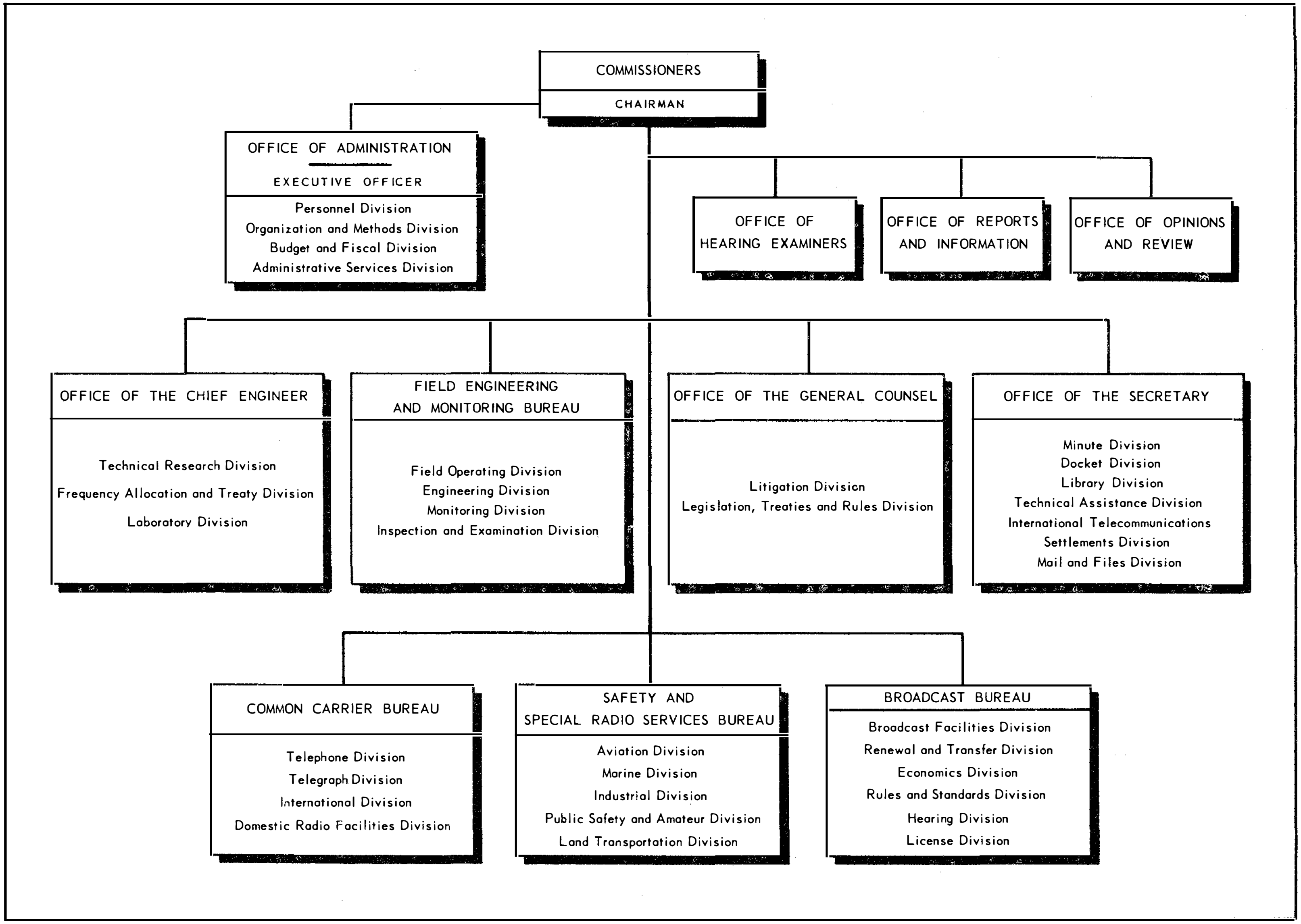

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Figure 4-4.—Organization of Federal Communications Commission.

or its possessions calls for licensing both the transmitter and its operator.

Although the FCC issues licenses to both operators and transmitting stations, the Commission collects no fee nor charge of any kind in connection with this licensing. When the FCC issues a license, it first makes sure the license will serve the "public interest, convenience, or necessity." This standard governs the granting of licenses. Because channels are limited and are a part of the public domain, it is essential that they be entrusted to licensees who have a high sense of public responsibility. The license privilege is extended by the Communications Act to citizens of the United States only. It is denied to corporations wherein any officer or director is an alien, or if more than a fifth of the capital stock of the corporation is owned or voted by aliens or their representatives.

Monitoring

One of the important functions of the FCC is "policing the ether." Monitoring is done by field stations, which monitor transmissions to see that they are in accordance with treaties, laws, and regulations. There are 10 primary monitoring stations and 18 secondary monitoring stations. If necessary, mobile equipment can trace illegal operation or sources of interference. Monitoring stations also furnish emergency directions to Government and civil aircraft.

Periodically, the Commission inspects radio equipment on United States ocean vessels and on foreign ships calling at U.S. ports. The FCC ascertains that radiotelegraph installations comply with the International Convention for the Safety of Life at Sea, and the shipboard radio requirements of the Communications Act. About 14,000 such inspections are made each year.

FCC in Wartime

During World War II, the FCC cooperated with the Air Force in maintaining a constant vigil on the coasts, ready to close down radio transmissions that might furnish bearings for enemy aircraft. With the Office of Civil Defense, it worked to guard vital communication facilities against sabotage. The Board of War Communications, headed by the chairman of the FCC, coordinated communication activities for emergency purposes. The FCC established a foreign intelligence service to monitor foreign broadcasts for the military services and other Government agencies. Its own radio intelligence division policed the domestic ether and helped furnish bearings to U. S. aircraft.

FCC Regulations Pertaining to Naval Communications

The FCC has no jurisdiction over naval communications. There are only two areas where the FCC comes in contact with naval communications: frequency monitoring, and licensing of amateur radio stations aboard Navy ships and stations.

Several FCC field stations police the ether to make sure that commercial and amateur radio station transmitters are on proper frequencies and within specified tolerances. While checking through the frequency spectrum, if monitoring stations find that a Navy transmitter is not operating properly or that a Navy circuit is interfering with a commercial circuit, they notify the Navy. In turn, the Navy notifies the Navy communication station operating the transmitter so that corrective action can be taken. When a Navy circuit interferes with a commercial circuit, the problem can be resolved by cooperative efforts of both the FCC and the Navy.

All amateur operators and stations are licensed by the FCC. Many Navy ships and stations operate amateur radio stations, with approval from the commanding officer of the ship or station and CNO. Although these amateur stations may be operated by Navy personnel and on occasion use Navy equipment, they must be licensed by the FCC. Regulations governing licensing of amateur naval radio stations are explained more fully in OpNav Instruction 2070.2G.

Emergency Broadcast System

The Emergency Broadcast System (EBS) has been devised to provide the President and the Federal Government, as well as State and local governments, with a means of communicating with the general public through non-Government broadcast stations preceding, during, and after an enemy attack.

ORGANIZATION.—The Emergency Broadcast System consists of broadcast stations holding FCC National Defense Emergency Authorizations (NDEA), facilities and personnel of networks, and other groups engaged in communications, as well as appropriate Government agencies.

Advisory committees have been set up on a national, regional , State, and local scale. (See fig. 4-5.)

The National Industry Advisory Committee provides advice and assistance to the FCC in technical programing, guidance, production, and other operations of the facilities provided to the EBS by networks and other broadcasters.

The Regional Industry Advisory Committee maintains liaison with the appropriate Federal, national, and State authorities within the respective regions. Also, the committee establishes such plans as may be required for coordinating the regional EBS operations with those of the appropriate State Industry Advisory Committees.

The State Industry Advisory Committees act as liaison between State Civil Defense officials and broadcasters. They operate a State network capable of delivering State programing to each NDEA station assigned to a designated operational area within a State.

Local Industry Advisory Committees act as liaison between appropriate Civil Defense officials and broadcasters. They are responsible for continuous programing of their facilities. All plans established by these committees are subject to concurrence and approval by appropriate Federal Government agencies.

TESTS.—Periodically, closed circuit tests are conducted of the national program distribution channels, national program origination facilities, and regional, State, and local program source interconnecting facilities.

MILITARY USE OF COMMERCIAL FACILITIES

The Department of Defense has made the following statement regarding use of commercial facilities:

> It is impracticable to employ similar concepts and standards in assessing military and commercial communication requirements. In the development of commercial facilities, expected revenue must be a prime consideration. Military communications, on the other hand, as an essential element of command, must first satisfy military needs, with economy of force or funds an important but secondary consideration. As a result of this fundamental difference, it is impossible for the military to enunciate a policy which will, under all conditions, prescribe the specific degree to which it will utilize or depend on commercial communication facilities. It is incumbent on all military commanders, in compliance with the basic principle of economy of force, to make maximum possible use of all existing facilities available to them, including commercial service. Before reaching a decision to employ other than strictly military facilities, each commander, based on the conditions prevailing in his area, must weigh any advantages from the standpoint of economy against the resulting effect on military security and control, dependability of service, and the rapid flow of military messages. As general policy, therefore, it may be stated that the Military Services will, whenever practicable, utilize commercial facilities and service in the interest of economy of force or funds, provided that acceptable military standards of security control and service can be maintained.

Use of Commercial Facilities in the United States

During the early period in the development of national communication systems, it was necessary for the military services to construct and operate their own communication facilities. Today, extensive and dependable commercial communication networks cover the length and breadth of the United States. From the standpoint of security, the risk normally involved in partial military control of its communications is considered as relatively low within the continental United States. This condition is a result of (1) the close working relationship that exists between the military services and the commercial communication organizations, and (2) the existence of adequate laws to permit prompt Government operation and control if deemed advisable in the national interest.

Under these conditions, the construction and maintenance of completely separate communication systems within the United States for exclusively military use would entail unjustifiable outlay of funds, manpower, and equipment. Military policy concerning use of commercial facilities in the continental U. S. may, therefore, be summarized as follows: Within the continental

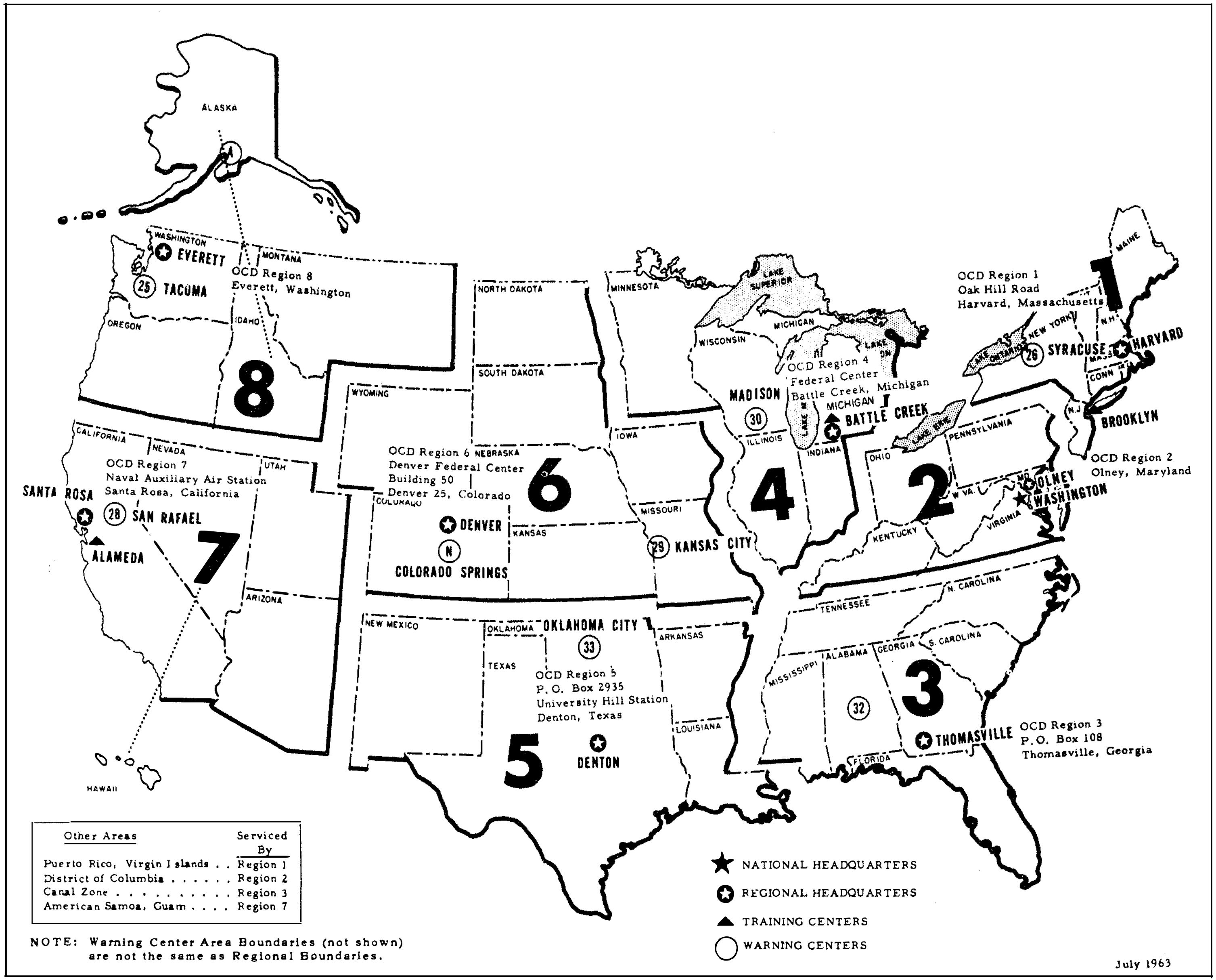

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Figure 4-5.—Regional boundaries and field installations.

United States, the military services, in establishing communication networks for the purpose of interconnecting their various headquarters, installations, and activities, will, by lease or other contractual arrangement, utilize commercial facilities and services when available and feasible. An exception is where unusual security or operational conditions are required. Terminal facilities, including communication centers and relay stations of these networks, will be operated and controlled by the military services.

Commercial Networks as a Source of Trained Personnel for Military Service

In peacetime, the military services can maintain only the nucleus of a wartime communication system. It is also known that the impact of a state of war or national emergency on military communication systems is instantaneous, and can be met only through immediate expansion of both trunkline and terminal facilities.

Modern communication facilities, although extremely efficient, require a comparatively long lead time in training operators and maintenancemen. Hence, in the critical period between the outbreak of hostilities and the time military training programs can meet overall demands, commercial systems of the United States represent an important source of additional trained communication personnel for military service.

Legislation now exists whereby, in time of war or national emergency, the total telecommunication resources of the Nation can be placed at the disposal of the Government. To this end, the military services encourage domestic communication systems of the United States to be as efficient and dependable as allowable through sound engineering, reasonable economy, and good operating practices. Their capacity should reflect the ability to handle greatly increased wartime traffic volumes. Many alternate routings and types of facilities must be available, consistent with the ability of the commercial companies to realize a reasonable profit from their investments.

CHAPTER 5

ELECTRONICS ADMINISTRATION

A First Class or Chief Radioman probably will be either fully or partially in charge of operation and maintenance of radio equipment in his division. This chapter discusses preventive maintenance and various records and reports required of electronics installations by the cognizant authority. Contributions of certain of these records and reports to enforcement of guarantees and to development of improved equipment are also touched on in this chapter. It describes various electronics reports, and mentions certain publications and the manner in which their proper use contributes to increased equipment efficiency.

MAINTENANCE AND MATERIAL MANAGEMENT

Maintenance of ships is divided into two broad categories: preventive maintenance and corrective maintenance. Preventive maintenance consists of routine shipboard procedures designed to increase the effective life of equipment or forewarn of impending troubles. Corrective maintenance includes procedures for analyzing and correcting material defects and troubles. The main objective of shipboard preventive maintenance is prevention of breakdown, deterioration, and malfunction of equipment. If this objective is not reached, however, the alternative objective of repairing or replacing failed equipment—corrective maintenance—must be accomplished.

Shipboard preventive maintenance programs in the past have varied from one command to another, resulting in various degrees of operational readiness. A relatively new, uniform system of scheduling, recording, reporting, and managing ship maintenance is now in use. This system is called the Standard Navy Maintenance and Material Management (3-M) System. It is intended to upgrade the operational readiness of ships.

The 3-M System is not to be considered a cure-all for all equipment and maintenance problems. The system does, however, envision a logical, efficient approach to these problems by launching a forthright attack on electrical, mechanical, and electronic disorders. Moreover, the system produces a large reservoir of knowledge about equipment disorders, which, when fed back to appropriate sources, should result in corrective steps to prevent recurrences.

The 3-M System consists primarily of a Planned Maintenance System (PMS), which provides a uniform system of planned preventive maintenance; and a Maintenance Data Collection System (MDCS), which affords a means of collecting necessary maintenance and supply data, suitable for rapid machine processing. A manhour accounting system, also called exception time accounting (ETA), is installed in the repair department of repair type ships in conjunction with the MDCS.

Like any other system or program, the 3-M System is only as good as the personnel who make it work. The Radioman's role in the system, as RM1 or RMC, includes training lower rated personnel in its use, as well as scheduling and supervising maintenance. General information concerning all aspects of the system is included in this chapter, but a leading petty officer should keep abreast of all developments and changes to the system. Details on the system and changes related to it are available in the Maintenance and Material Management (3-M) Manual, OpNav 43P2. Other sources of information include OpNav Instruction 4700.16, The Naval Ship Systems Command Technical News, and directives issued by type commanders.

PLANNED MAINTENANCE SYSTEM OPERATION

Planning and scheduling of planned maintenance is accomplished through the Planned

Maintenance System (PMS). Additionally, the PMS defines the minimum preventive maintenance required, controls its performance, describes methods and tools to be used, and aids in prevention and detection of impending casualties. These factors should prove to be a definite asset to the leading petty officer in forecasting future material requirements and in properly utilizing available manpower.

The planned maintenance system was developed to provide the means by which each ship, each department, and each supervisor is enabled to plan, schedule, and effectively control shipboard maintenance. When PMS is implemented aboard ship, it replaces Part II of POMSEE, Preventive Maintenance Checkoff. Part I of POMSEE, Reference standards and Performance Standard Sheets, remains in effect.

In establishing minimum planned maintenance requirements for each piece of equipment, the Bureau of Ships Technical Manual, manufacturers' technical manuals, and applicable drawings are critically examined. If preventive maintenance requirements are found to be unrealistic or unclear, they are modified or revised before being incorporated into the PMS.

It is possible that planned maintenance prescribed in the PMS may conflict with that prescribed in other documents such as the Bureau of Ships Technical Manual. In such an eventuality, the PMS supersedes and takes precedence over any and all documentation that may be in conflict with it. All tests, inspections, and planned maintenance actions should ultimately be incorporated in the PMS.

The planned maintenance system is based upon the proper utilization of planned maintenance system manuals, maintenance requirement cards (MRCs), and schedules for accomplishment of planned maintenance actions.

PLANNED MAINTENANCE SYSTEM MANUAL

The planned maintenance system manual contains minimum planned maintenance requirements for each component installed for a particular shipboard department. A separate section of the PMS manual is furnished for each department. Manuals are compiled individually for each ship, thereby assuring a tailored system. The Operations Department Manual (OpNav 43P1) has a green cover for electronics, and is kept in the operations office. This manual is used by the planning officer and maintenance group supervisors to plan and schedule maintenance for each group. The manual contains a list of effective pages and a section for each division or maintenance group within the operations department. Each divisional section contains index pages for each system, subsystem, or component that requires a planned maintenance action. These pages are referred to as maintenance index pages (MIPs). Each MIP gives a brief description of maintenance requirements and the frequency with which maintenance is to be effected. The frequency code is as follows: D-daily, W-weekly, M-monthly, Q-quarterly, S-semiannually, A-annually, C-once each overhaul cycle, and R-situation requirement (e.g. 100 hours of operation).

An index page also includes the rate(s) recommended to perform a task, as well as average time required. A sample maintenance index page (OpNav 4700-3) is shown in figure 5-1.

Manpower available for performing maintenance varies from one ship to another. For this reason, information found on MIPs regarding rates recommended to perform a maintenance task and the average time required for the task must have certain clarification. Maintenance tasks are actually performed by personnel available and capable, regardless of the rating listed on the MIP. The average time required, as listed on the MIP, does not take into consideration the time required to assemble tools and materials to do the maintenance action nor the time required to clean the area and put away tools at the end of the task.

That portion of the PMS manual containing maintenance index pages applicable to equipment under a specific division or maintenance group is called the group maintenance manual. A copy of the group maintenance manual, in addition to the one in the departmental PMS manual, is kept in each working space as a ready reference to maintenance personnel.

MAINTENANCE REQUIREMENT CARD

The maintenance requirement card (MRC) (fig. 5-2) defines a planned maintenance task in sufficient detail so that assigned personnel can perform the task with little difficulty. Each maintenance requirement card lists the rating of personnel recommended to perform that particular task; safety precautions that

System, Subsystem, or Component	Reference Publications
R-390A/URR Radio Receiver	NAVSHIPS 93053

Bureau Card Control No.					Maintenance Requirement	M.R. No.	Rate Req'd.	Man Hours	Related Maintenance
CK	037CRG2	A5	BE78	M	1. Test the calibration oscillator. 2. Test tuning system and signal strength. 3. Test bandwidth and audio response. 4. Test limiter action.	M-1	RM3	0.9	None
CK	037CRG2	A5	BE79	Q	1. Test IF gain. 2. Measure overall receiver gain. 3. Test audio gain.	Q-1	RM3	0.9	S-1
CK	037CRG2	A5	BE80	S	1. Measure receiver sensitivity.	S-1	RM3	1.2	None
CK	037CRG2	A5	BE81	S	1. Clean and inspect the radio receiver.	S-2	RMSN	0.6	M-1
CK	037CRG2	A5	BE82	A	1. Lubricate mechanical tuning system.	A-1	ETSN	1.0	Q-1, S-1
					These maintenance cards were prepared for this equipment in which the following field changes have been accomplished: 1 through 5 Of these, the following field changes affect the maintenance actions: 4, 5 New maintenance requirement cards and maintenance index pages will be made available as future field changes are accomplished that affect the prescribed planned maintenance.				

MAINTENANCE INDEX PAGE
OPNAV FORM 4700-3 (4-64)

BUREAU PAGE CONTROL NUMBER C-20/2-A5

98.171

Figure 5-1.—Maintenance index page.

SYSTEM	COMPONENT	M.R. NUMBER	
Communication & Control	R390A/URR Radio Receiver	C-20 M-1	
	MAINT. SIGNIFICANT NO.		
SUB-SYSTEM	RELATED M.R.	RATES	M/H
Radio Communication Systems		RM3	0.3
M.R. DESCRIPTION		TOTAL M/H: 0.3	
1. Check receiver operation.		ELAPSED TIME: 0.3	

SAFETY PRECAUTIONS

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

1. Headphones.

PROCEDURE

Preliminary Control Settings:

1.	RF gain	5
2.	Function switch	Cal
3.	BFO switch	ON
4.	BFO pitch	0
5.	Line gain	5
6.	Line meter switch	+10
7.	Local gain	5
8.	Bandwidth	4 KC
9.	Audio response	WIDE
10.	AGC switch	MED.
11.	Limiter switch	OFF.

1. Check receiver operation:

a. Connect headphones in receiver phone jack, turn megacycle change knob counter-clockwise until the first two counter digits read "00".

b. Turn kilocycle knob counter-clockwise until the last three digits read "000".

c. Turn ZERO ADJ. completely clockwise.

d. Increase RF GAIN to 10. (Cont.)

LOCATION

Page 1 of 2 | CK | 037C | RG2 | A3 | AA05 | M

Procedure Continued

e. While listening in phones and observing carrier level meter, vary kilocycle change knob for zero beat in phones coincident with minimum deflection on line level meter.

f. Turn "ZERO ADJ." maximum counterclockwise.

g. Turn "BFO PITCH" to +2. Beat note will be heard in phones.

h. Turn megacycle change knob clockwise, one position at a time from 00 to 31.

i. Observe carrier level meter while listening for beat note in each position.

j. Carrier level should indicate a minimum of 10 DB and beat note should be clearly audible in phones in each position.

k. Return "MC" change knob counterclockwise until counters are again 00.

l. Turn kilocycle change knob clockwise until last three digits of counter read 000.

m. Counters should read 00+000. This is equivalent to 1 MC.

n. Turn "BFO PITCH" control to "0" and RF gain to 5.

o. Repeat steps 1. c through 1. j.

Page 2 of 2 | CK | 037C | RG2 | A3 | AA05 | M

98.176

Figure 5-2.—Maintenance requirement card.

must be observed; time, tools, parts, and materials required for the task; and detailed procedures for performing the task. A complete set of applicable MRCs is maintained in each working space with the group maintenance manual. A master set of all MRCs is kept on file in the departmental office. If a card becomes lost, torn, or soiled, it can be replaced by typing a duplicate card from the master set or by ordering one through proper channels.

The maintenance requirement card is one of the primary tools of the PMS system to be used by personnel actually performing maintenance tasks. Personnel assigned to maintenance tasks must remove pertinent cards from the set maintained in the working space; obtain stated tools, parts, and material; perform the maintenance requirement specified on the card; correct and report any deficiencies noted during the performance of the maintenance requirement; and return the card to its proper place after completing the task.

Maintenance requirement cards represent minimum planned maintenance requirements of the cognizant systems command. To meet local conditions, each command has the prerogative to increase minimum requirements. If changes are of a continuing nature, recommended changes in the system should be submitted to the cognizant systems command.

SCHEDULING PLANNED MAINTENANCE

Through the use of a cycle schedule (fig. 5-3), the planned maintenance system is designed to simplify planned maintenance scheduling. All required planned maintenance actions are programed throughout the overhaul cycle of a ship. Further, the system is flexible enough to readily accommodate any changes in a ship's employment schedule. Cycle schedules contain a list of components for each division or maintenance group, and indicate the quarter after overhaul in which semiannual, annual, and overhaul cycle maintenance requirements are to be scheduled. Cycle schedules also list quarterly, monthly, and situation requirements that must be scheduled every quarter. In conjunction with division officers and leading petty officers, the department head utilizes a cycle schedule in making out a quarterly schedule.

By definition, the day a ship leaves the shipyard is in the first quarter after overhaul. A ship is not necessarily expected to perform all planned maintenance listed for the first quarter after overhaul, but the amount performed must be in proportion to the time remaining in that particular quarter. Steps to follow in using the cycle schedule can best be explained by reference to figure 5-3. Consider, for example, planned maintenance required for the R390/URR receiver. As indicated on the cycle schedule, a short description of maintenance required may be found on page C-20 of the PMS manual. From the cycle schedule it is apparent that maintenance must be scheduled as follows:

M 1—each month.
Q 1—each quarter.
S 1—1st, 3rd, 5th, 7th, 9th, and 11th quarters after overhaul.
A 1—4th, 8th, and 12th quarters after overhaul.

A quarterly schedule is a visual display consisting of two identical quarterly schedule forms (fig. 5-4), one for the current quarter and one for the subsequent quarter. The cycle schedule and both quarterly schedule forms are contained in the same visual display holder, and correspond line for line. The entire display, called the maintenance control board, is maintained in the departmental office. Maintenance control boards show the overall status of planned maintenance within a department. A quarterly schedule has 13 columns, one for each week in the quarter, for scheduling maintenance throughout a 3-month period. Each week is divided into days by tick marks (see fig. 5-4) to depict more accurately the operating schedule, thus allowing maintenance requirements to be scheduled in conjunction with ship operations. A suggested procedure for preparing a quarterly planned maintenance schedule is to first black out the dates a ship is expected to be underway during the quarter, then, with the aid of the cycle schedule and PMS manual, fill out the quarterly schedule accordingly. Monthly planned maintenance requirements should be scheduled at approximately the same time each month, and other planned maintenance actions should be scheduled at equal intervals insofar as practicable. After the quarterly schedule is completely filled in, it is a good practice to look it over closely to see if the workload is balanced throughout the quarter. If less work appears to be scheduled during one week of a quarter than in other weeks, some maintenance requirements should be rescheduled to balance the workload throughout the quarter.

TYPE

CLASS

MAINTENANCE GROUP: COMMUNICATIONS

EQUIP PAGE	COMPONENT	SCHEDULE AS INDICATED — QUARTER AFTER OVERHAUL 1 5 9	2 6 10	3 7 11	4 8 12	EACH QUARTER
C-1	AN/URR-35					M1, M2, Q1
C-2	TED-9					M1, M2, Q1
C-3	AM-1365/URT		S1		S1	M1, M2,
C-5	AN/WRT-2	A1				M1, M2
C-6	AN/CRT-3					Q1
C-7	AN/URC-4					Q1
C-8	AN/SRR-11A					M1
C-10	AN/WRT-1		A1			M1
C-13	SCR-536	S1		S1		Q1
C-14	AM-215/U			A1		
C-16	AN/URT-7C					M1, M2, Q1
C-17	CU-692/U					Q
C-18	CU-691/U					Q1
C-19	AN/URA-8A				61(8)	M1
C-19	AN/URA-8B		C1(2)			M1, Q1
C-20	R390/URR	S1		S1	A1	M1, Q1
C-21	AN/GRC-27A					M1, M2,
C-25	AN/URC-32		A1			M1, Q1, Q2
C-25	AN/URC-32A			A1		M1, Q1, Q2
C-26	AN/SRA-22					Q1

CYCLE SCHEDULE OPNAV FORM 4700-4 (4-64) 0107-766-4000 C-40996

98.172

Figure 5-3.—Cycle schedule.

MAINTENANCE GROUP COMMUNICATIONS	YEAR 1966	QUARTER AFTER OVERHAUL 2
MONTH JULY	MONTH AUGUST	MONTH SEPTEMBER

EMPLOYMENT SCHEDULE

	2	9	16	23	30	6	13	20	27	3	10	17	24
1.	~~M1~~	~~M2~~			~~M1~~, ~~Q1~~	M2				M1	M2		
2.		~~M1~~, ~~M2~~				M1,M2,Q1					M1, M2		
3.			~~M1~~	~~M2~~	~~S1~~		M1	M2				M1	M2
4.	~~M1~~			~~M2~~		M1			M2	M1			M2
5.		~~Q1~~											
6.								Q1					
7.			~~M1~~				M1			M1			
8.		~~M1~~			(M1) →	A1	M1		M1				
9.									Q1				
10.													
11.		(M1) ~~M2~~ →	~~M1~~, ~~Q1~~		~~M1~~, ~~M2~~					M1,M2			
12.												Q1	
13.	~~Q1~~												
14.		~~M1~~				M1					M1		
15.	~~M1~~				~~M1~~				C1, M1				Q1
16.	~~M1~~				~~M1~~	Q1			M1				
37.													

QUARTERLY MAINTENANCE SCHEDULE OPNAV FORM 4700-5 (4-64)

98.173

Figure 5-4.—Quarter or subsequent quarter schedule.

Quarterly schedules are updated weekly. The leading petty officer of the division or maintenance group must cross out all maintenance requirements that have been accomplished and must circle all requirements scheduled for that week but not accomplished. All circled requirements are rescheduled by drawing an arrow to a later week as indicated in figure 5-4. A quarterly schedule is retained on board as a record of all completed maintenance actions. This record may be destroyed at the beginning of the second quarter after the next shipyard overhaul period. A quarterly schedule is also used by the leading petty officer of each division or maintenance group to prepare a weekly planned maintenance schedule (fig. 5-5). Weekly schedules are posted in each working space and are used by the leading petty officer to assign specific maintenance tasks to specific personnel.

A weekly schedule provides a list of components, appropriate page number of the PMS manual, and spaces for assignments of maintenance tasks to specific personnel. Daily and weekly planned maintenance actions are preprinted on the weekly schedule forms. All other planned maintenance requirements to be performed during a specific week are obtained from the current quarterly schedule. A weekly schedule offers flexibility for all planned maintenance actions except those required to be performed daily. When a planned maintenance task is completed, the leading petty officer should cross out the requirement on the schedule. Maintenance that cannot be completed on time is circled and rescheduled on the basis of workload and ship operations.

The weekly schedule is designed for convenient preparation and effective reuse. At the end of each week it is the responsibility of the leading petty officer of the division or maintenance group to take the weekly schedule to the departmental office, update the quarterly schedule, erase the weekly schedule, and prepare a schedule for the following week. Preparation of a weekly planned maintenance schedule necessitates consideration of available manpower, time expended on each maintenance task, and ship's operations. In assigning specific personnel to maintenance tasks, it must be remembered that the average time required to perform a task (as listed on the maintenance index page and maintenance requirement card) does not take into account the time required to assemble tools and material to do the maintenance action or to clean the area and put away the tools at the end of the task. Related maintenance requirements (see figs. 5-1 and 5-2), which are due, should be scheduled and performed together to conserve time. Any corrective maintenance, cleaning, or upkeep to be performed is in addition to planned maintenance prescribed by the PMS.

FEEDBACK REPORT

Through the use of a feedback report (fig. 5-6), the planned maintenance system enables correction of discrepancies in the system. A feedback report should be originated immediately by the person who discovers a discrepancy, if one is found in the system as installed aboard ship.

A feedback report is useful only if all information concerning the discrepancy is correct and complete, including the reason for any recommended change. Before forwarding a feedback report to the appropriate systems command maintenance management field office, it should be checked for completeness and accuracy by the leading petty officer of the division.

RECORDING MAINTENANCE ACTIONS

The Maintenance Data Collection System (MDCS) is designed to provide a means of recording information concerning planned and corrective maintenance actions. Maintenance performed is recorded by code in sufficient detail to permit collection of a variety of information concerning maintenance actions and equipment performance. Use of codes in recording and reporting maintenance actions permits machine processing with automatic data processing equipment. The system also furnishes data pertaining to initial discovery of a malfunction, how equipment malfunctioned, how many hours equipment was in operation, equipment involved, repair parts and materials used, delays incurred, reasons for delay, and the technical specialty or work center that performed the maintenance. Except for routine preservation actions (chipping, painting, and cleaning) and daily or weekly planned maintenance system actions, each maintenance action is reported in this manner.

Shipboard installation of the maintenance data collection system includes a central functional

GROUP COMMUNICATIONS WORK SCHEDULE FOR WEEK OF 6 AUGUST 1966

COMPONENT	MAINTENANCE RESPONSIBILITY	PAGE	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT/SUN	OUTSTANDING REPAIRS AND P.M. CHECKS DUE IN NEXT 4 WEEKS
AN/URR-35	ABLE	C1			M2				
TED-9	BAKER	C2		~~M1, M2, Q1~~					
AM-1365/URT	CHARLES	C3							
AN/WRT-2	DOW	C5		(M1) →	M1		W1		
AN/URC-4	GREENE	C7							
AN/SRR-11A	HAPP	C8				W1			
AN/WRT-1	INTRYE	C10		~~A1~~	W1		W2		
SCR-536	JUSTICE	C13							
AM-215/U	KIDD	C14							
AN/URT-7C	LORNE	C16							
CU-692/U	MAYS	C17							
CU-691/U	NAYLOR	C18							
AN/URA-8A	O BRIEN	C19	~~W1~~		M1				
AN/URA-8B	PETERS	C19				W1			
R390/URR	QUINN	C20		~~Q1~~					
R390A/URR	RUSK	C20							
AN/GRC-27A	SIMPSON	C21	~~W1~~						
AN/URC-32	TODD	C25			W1				
AN/URC-32A	USTE	C25	~~W1~~						
AN/SRA-22	VICTOR	C26							

WEEKLY WORK SCHEDULE OPNAV FORM 4700-6

98.175

Figure 5-5.—Weekly work schedule.

INSTRUCTIONS ON BACK OF GREEN PAGE

FROM: INDICATE SHIP HULL NUMBER OR ORIGINATING ACTIVITY, IF OTHER THAN SHIP.

SERIAL #: NO. IN SEQUENCE

DATE: DATE WRITTEN

TO: BUSHIPS/BUWEPS MAINTENANCE MANAGEMENT FIELD OFFICE NORFOLK, VIRGINIA 23511

VIA:

SUBJECT: PLANNED MAINTENANCE SYSTEM FEEDBACK REPORT

SYSTEM SAME AS ON MRC	COMPONENT SAME AS ON MRC
SUB-SYSTEM SAME AS ON MRC	M.R. NUMBER SAME AS ON MRC BU. CONTROL NO. VERTICLE NO. ON R.H. SIDE OF MRC

DISCREPANCY

- ☐ M. R. Description
- ☐ Safety Precautions
- ☐ Tools, Etc.
- ☐ Missing Maintainance Requirement Card (MRC)
- ☐ Equipment Change
- ☐ Missing Maintainance Index Page (MIP)
- ☐ Technical
- ☐ Procedure
- ☐ Typographical
- ☐ Technical Publications
- ☐ Miscellaneous

1. HANDWRITTEN COPIES ACCEPTABLE. USE BALLPOINT PEN.
2. CHECK APPROPRIATE BOX.
3. USE THIS SPACE FOR ALL COMMENTS. STATE WHAT IS WRONG AND RECOMMENDED CORRECTION. GIVE REASON FOR RECOMMENDED CHANGE (UNLESS COMMENT IS OBVIOUS).
4. FOR MISSING MRC, MIP & WHEN BU CONTROL NUMBER IS NOT AVAILABLE IDENTIFY EQUIPMENT BY NOUN NAME AND APL/CID OR AN NUMBER.
5. FOR EQUIPMENT CHANGE REPORT, IDENTIFY EQUIPMENT REMOVED AND THAT INSTALLED BY NOUN NAME AND APL/CID OR AN NUMBER.
6. "TECH PUBLICATIONS" BLOCK INCLUDES ALL BUWEPS AND BUSHIPS PUBLICATIONS. IDENTIFY PUBLICATION NUMBER, VOLUME, REVISION, DATE, CHANGE NUMBER, PAGE, PARAGRAPH AND/OR FIGURE. WHEN REFERRING TO PMS/SMS EQUIPMENT VOLUMES 2 OR 4, THE "M.R. NUMBER" AND "BU. CONTROL NO." BLOCKS SHOULD ALSO BE COMPLETED.
7. DISTRIBUTION: AS SHOWN ON BOTTOM OF EACH PAGE.
   INSTALLATION TEAM: FORWARD REPORTS WITHIN 10 DAYS OF INSTALLATION.
   SHIP: FORWARD REPORTS WITHIN 90 DAYS AFTER INSTALLATION AND AS REQUIRED THEREAFTER, VIA APPROPRIATE TYCOM.
8. REQUEST ADDITIONAL FORMS FROM TYCOM.

SIGNATURE OF C. O. OR DESIGNATED REPRESENTATIVE

THIS COPY FOR: **ADDRESSEE** **1**

OPNAV Form 4700/7 (10-65)

40.101

Figure 5-6.—PMS feedback report.

data collection center. Principal function of the shipboard data collection center is to screen all documents for completeness and accuracy before they are forwarded to the data processing center. During the screening process, the data collection center adds a 4-digit maintenance control number to each document.

Effectiveness of the MDCS depends initially upon personnel performing the maintenance action and the accuracy with which it is reported. Leading petty officers are responsible for ensuring that all forms used in connection with the MDCS are complete and accurate. Leading POs should also ensure that a form is submitted for each applicable action and that no action is reported more than once.

EQUIPMENT IDENTIFICATION CODE MANUAL

It is essential that all personnel charged with any responsibility for maintenance actions be indoctrinated in the proper use of the equipment identification code (EIC) manual, because it contains many of the codes used in reporting maintenance actions. Each major system is coded, and codes are broken down to the lowest part necessary for positive equipment identification. The manner in which the EIC is obtained from the manual is described in the following example.

Assume it is desired to determine the code for the voltage regulator of an AN/WRR-2 receiver. By referring to the index pages of the EIC manual, it is found that communication systems are identified by the code F, and the subsystem (in this example, communication receivers) is identified by the code FF. Next, turn to the pages of the manual with the FF codes, and go down the list of equipment until the listing for the AN/WRR-2 appears. Under this listing are the 7-digit codes for the voltage regulator. The first digit of the code identifies the system; the second digit, the subsystem; the third and fourth, the equipment; and the last three digits, the assembly. If the assembly requires further breakdown, the last digit identifies the subassembly.

Besides equipment identification codes, the EIC manual contains other codes and information of equal importance. Section I of the manual contains general instructions governing preparation of forms when reporting maintenance actions. Other sections of the manual deal with additional codes, as follows: Section II, Administrative Organization; Section III, Work Center; Section IV, How Malfunctioned; Section V, When Discovered; Section VI, Action Taken; Section VII, Service; Section VIII, Source; and Section IX, Type Availability.

A variety of information may be recorded in a relatively small space as a result of the foregoing codes. At the data processing level, these codes permit use of automatic data processing operations, which provide pertinent direct reading information summaries. Summaries can be employed profitably only if information recorded is accurate. Familiarity with the coding systems is a must, therefore; and the importance of accuracy in the recording of codes cannot be overstressed.

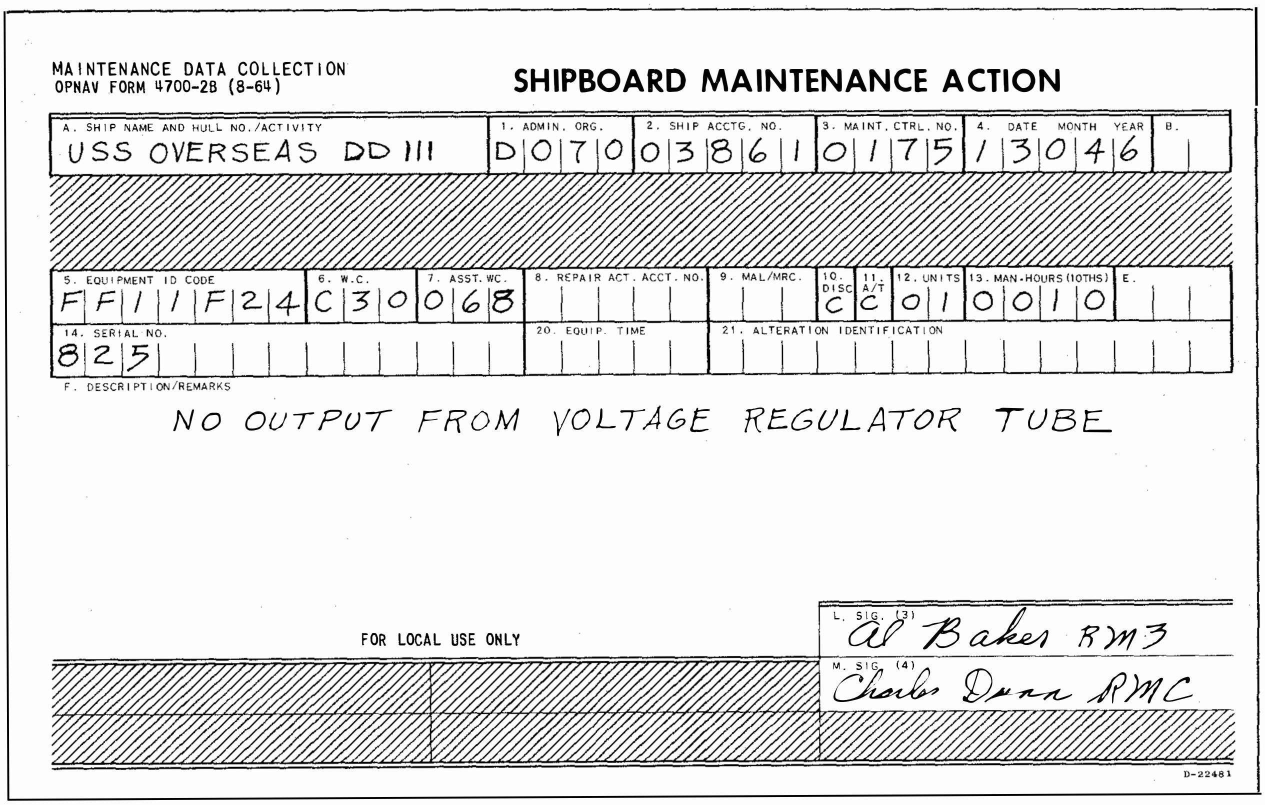
MDCS DOCUMENTATION

Documentation in the maintenance data collection system is accomplished by completion, as applicable, of one or more standard forms. Forms used to record and report information related to maintenance actions aboard ship and within repair activities include OpNav form 4700-2B (shipboard maintenance action), OpNav form 4700-2D (deferred action), OpNav form 4700-2C (work request), and OpNav form 4700-2F (work supplement card). Detailed descriptions of entries to be made on these forms are listed in section I of the EIC manual and in chapter 3 of the <u>3-M Manual</u>.

Shipboard Maintenance Action Form

A sample shipboard maintenance action form (OpNav 4700-2B) is shown in figure 5-7. This form is a single-sheet document used to record completion of planned maintenance actions, corrective maintenance actions, and authorized alterations already performed at the shipboard level by shipboard personnel. All planned maintenance actions except daily and weekly actions must be recorded on this form, as well as on the weekly and quarterly schedules. Routine preservation such as chipping, painting, and cleaning should not be reported.

The shipboard maintenance action form is also used to report work done aboard ship by any outside activity that does not report under the maintenance data collection system. Duplicate 4700-2B documents are prepared for ship maintenance assistance provided when a repair activity, such as a civilian contractor or a shipyard (except for regular overhauls), is


MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2B (8-64)

SHIPBOARD MAINTENANCE ACTION

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE MONTH YEAR	B.
USS OVERSEAS DD 111	D0070	038611	01175	13046	

5. EQUIPMENT ID CODE	6. W.C.	7. ASST. WC.	8. REPAIR ACT. ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MAN-HOURS (10THS)	E.
FF111F24	C30	068			C	C	01	00010	

14. SERIAL NO.	20. EQUIP. TIME	21. ALTERATION IDENTIFICATION
825		

F. DESCRIPTION/REMARKS

NO OUTPUT FROM VOLTAGE REGULATOR TUBE

FOR LOCAL USE ONLY

L. SIG. (3) Al Baker RM3

M. SIG. (4) Charles Dunn RMC

D-22481

17.81B

Figure 5-7.— Shipboard maintenance action form.

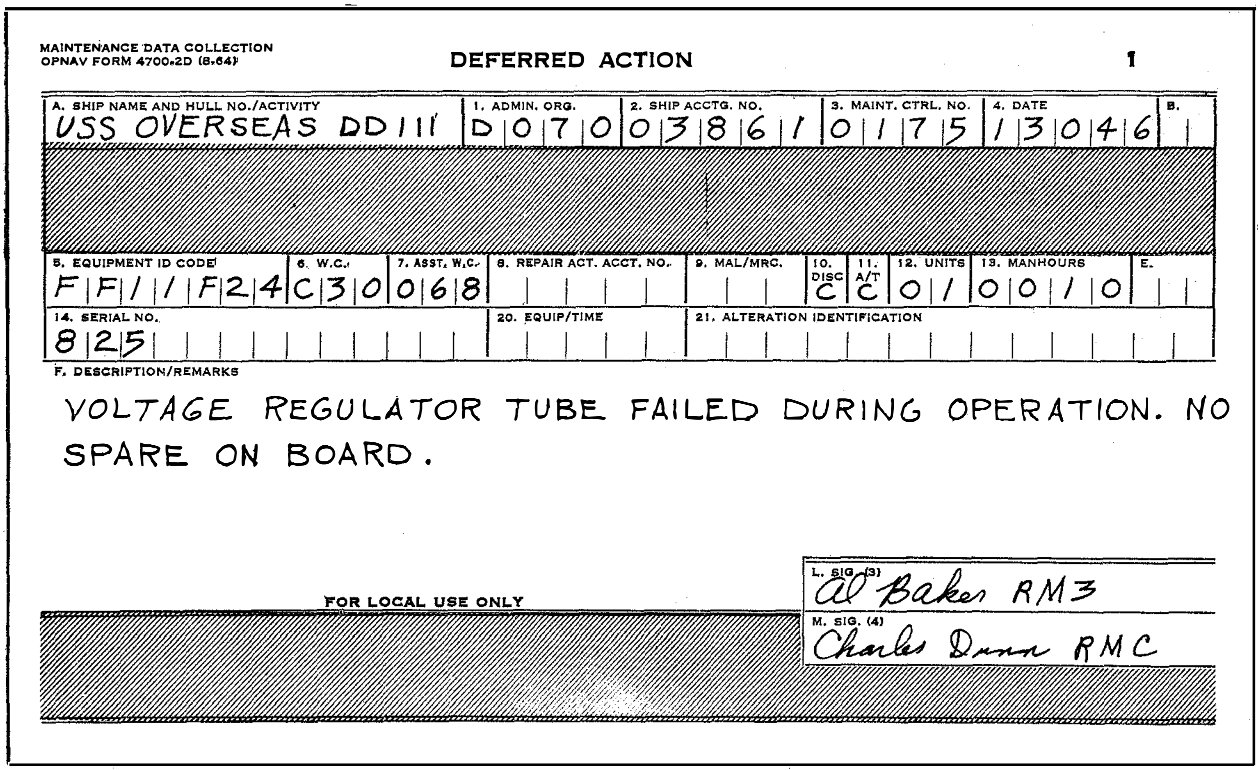
not under the MDCS. Block 7 of the original document is left blank, and the code for the assisting work center is entered on the duplicate. Only the time actually spent by shipboard personnel in assisting an outside activity is recorded in block 13 of the original. Man-hours spent by an outside activity in assisting the shipboard work center are documented in block 13 of the duplicate.

Deferred Action Form

The deferred action form (OpNav 4700-2D) is a two-sheet form used to report corrective maintenance actions that are deferred because of ship's operations, lack of repair parts, or necessity for outside assistance. The first sheet (fig. 5-8) is used to record and report the reason for deferral. The second sheet (fig. 5-9) is for reporting completion of a deferred action.

If a corrective maintenance action is beyond ship's force capability, and outside assistance is required, a work request is prepared and forwarded. This situation always requires submitting an OpNav form 4700-2D. Man-hours expended (if any) by ship's force in connection with the maintenance action are documented on OpNav form 4700-2D. Man-hours concerned with investigation and removal of equipment are documented on the first sheet of the document. Man-hours involved in reinstallation of equipment are documented on the second sheet of the forms.

If a shipboard maintenance action must be deferred because of lack of necessary repair parts or because of ship's operations, an OpNav form 4700-2D is prepared; the first sheet is submitted, using the appropriate action taken code from section VI of the EIC manual; and the man-hours expended (if any) are entered in block 13. When the maintenance action is



MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2D (8-64)

DEFERRED ACTION 1

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE	B.
USS OVERSEAS DD 111	D070	03861	0175	13046	

5. EQUIPMENT ID CODE	6. W.C.	7. ASST. W.C.	8. REPAIR ACT. ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MANHOURS	E.
FF111F24	C30	068			C	C	01	0010	

14. SERIAL NO.	20. EQUIP/TIME	21. ALTERATION IDENTIFICATION
825		

F. DESCRIPTION/REMARKS

VOLTAGE REGULATOR TUBE FAILED DURING OPERATION. NO SPARE ON BOARD.

FOR LOCAL USE ONLY

L. SIG. (3) Al Baker RM3

M. SIG. (4) Charles Dunn RMC

17.81D

Figure 5-8.—Deferred action form, sheet 1.

completed, the second sheet is submitted, using the appropriate action taken code; man-hours expended in completing the action are entered in block 13.

Work Request

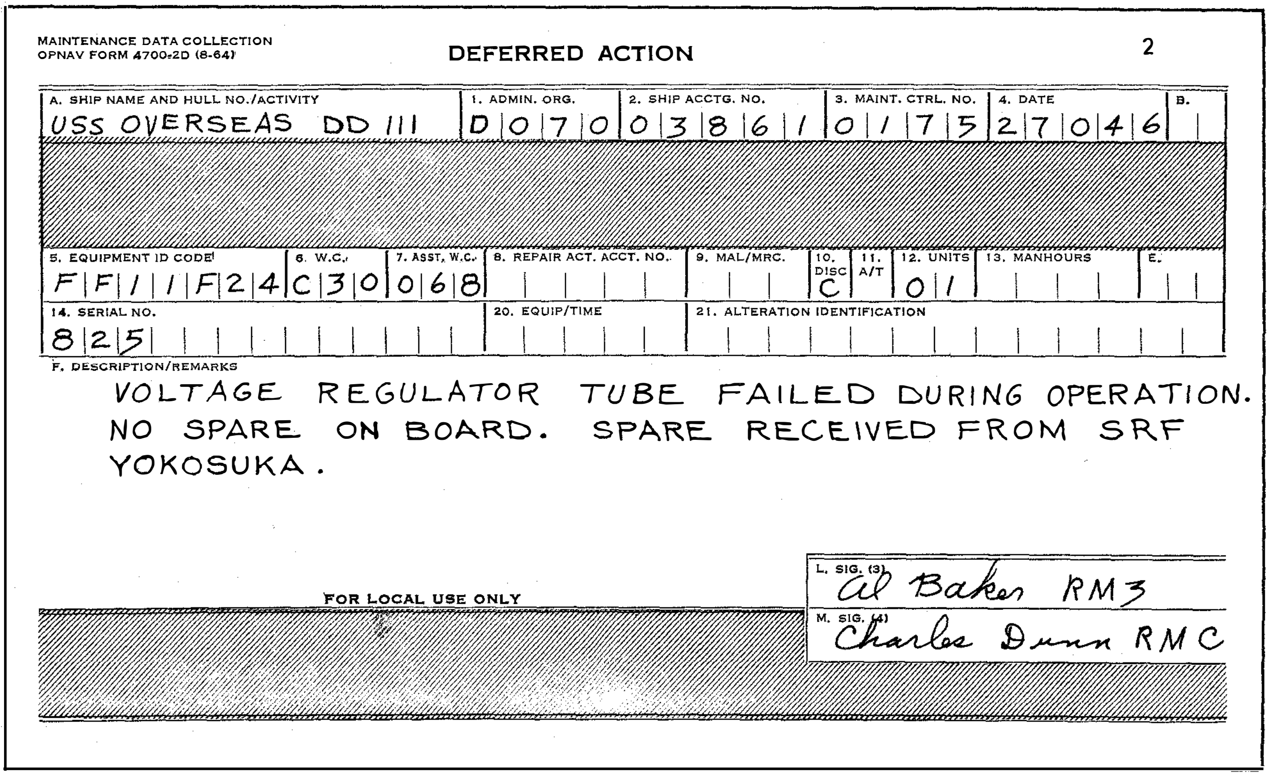
The work request form (OpNav 4700-2C) is a 4-sheet document presently used to request outside assistance from repair ships and tenders. It is planned that OpNav 4700-2C also will be used, at a later date, for requesting assistance from shipyards. Part I of the work request is shown in figure 5-10. Part II of the work request (fig. 5-11) is a continuation of part I and provides additional space for written descriptions, diagrams, and sketches.

Information to be given in block F (Description/Remarks) of the work request includes name of component, CID number of component, and alteration number. If the alteration number is not applicable, it must be listed as N/A. Block F should also contain a description of existing defects and any repairs required on the component.

The original sheet of the work request is retained by the requesting activity; copies 2, 3, and 4 are forwarded to the assigned repair activity via the designated chain of command. Information concerning administrative procedures to be taken on work requests by repair activities is given in chapter 4 of the 3-M Manual.

When the work request is accepted by a repair activity, sheet 3 of the document is used as a job order and is sent to the assigned work center. Prepunched work supplement cards (OpNav 4700-2F) are also sent to the assigned work center. A sample OpNav 4700-2F is shown in figure 5-12.

The assigned work center performing the job records maintenance data on work supplement cards. Any material obtained outside of normal supply channels is recorded on the reverse side


MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2D (8-64)

DEFERRED ACTION 2

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO.	3. MAINT. CTRL. NO.	4. DATE	B.
USS OVERSEAS DD 111	D070	03861	0175	27046	

5. EQUIPMENT ID CODE	6. W.C.	7. ASST. W.C.	8. REPAIR ACT. ACCT. NO.	9. MAL/MRC.	10. DISC	11. A/T	12. UNITS	13. MANHOURS	E.
FF111F24	C30	068			C		01		

14. SERIAL NO.	20. EQUIP/TIME	21. ALTERATION IDENTIFICATION
825		

F. DESCRIPTION/REMARKS

VOLTAGE REGULATOR TUBE FAILED DURING OPERATION. NO SPARE ON BOARD. SPARE RECEIVED FROM SRF YOKOSUKA.

FOR LOCAL USE ONLY

L. SIG. (3) Al Baker RM3

M. SIG. (4) Charles Dunn RMC

17.81D

Figure 5-9.—Deferred action form, sheet 2.

of the card. If more than one work day is required to complete the action, or if assisting work centers are needed, the lead work center utilizes additional work supplement cards provided for recording daily man-hours expended. (The lead work center has primary responsibility for completion of the task described on the work request.)

On completion of a repair job, sheet 3 of the work request is completed by the lead work center and is signed by the man who performed the maintenance. An inspector from the requesting activity is contacted for final inspection and signs off the work request. After obtaining the signature of the inspector, the lead work center supervisor forwards the completed work request to his division officer.

Material Usage and Cost Data

Documentation of material usage and cost data on maintenance transactions requires the joint effort of supply and maintenance personnel aboard ship. The form used to document material usage and cost data depends on the action involved and the source of material.

The reverse side of the appropriate OpNav form of the 4700 series is used by maintenance personnel to report material obtained from outside normal supply channels. (The reverse sides of OpNav forms 4700-2D and 4700-2F are essentially the same as the 4700-2B, which is shown in figure 5-13.) Examples of material reported are parts and material obtained from preexpended material bins; items obtained by cannibalization or from salvage, which can be identified by a part number or Federal stock number; and consumable materials such as lumber, sheet metal, and bar stock, used for manufacture work. Economy of effort and elimination of duplicate recording are highly desirable. When there is doubt about reporting an item, however, it should be reported.

MAINTENANCE DATA COLLECTION
OPNAV 4700-2C (8-64)

WORK REQUEST 1

A. SHIP NAME AND HULL NO./ACTIVITY	USS OVERSEAS DD 111
1. ADMIN. ORG.	D0710
2. SHIP ACCTG. NO	038611
3. MAINT. CTRL. NO	01175
4. DATE	13046
B.	
5. EQUIPMENT ID CODE	FF11F24
8. REPAIR ACT. ACCT. NO.	
9. MAL/MRC.	
10. DISC	
12. UNITS	
C.	
14. SERIAL NO.	825
15. T/A	
16. REQ. W.C.	C30
17. DESIRED CMPLN. DATE	27046
18. SERV	A
D	

F. DESCRIPTION/REMARKS

AN/WRR-2 VOLTAGE REGULATOR OUTPUT VARIES.

FOR LOCAL USE ONLY

G. NO. 1 CONTACT	Al Baker RM3	J. SIG (1)	Charles Dunn RMC
H. NO. 2 CONTACT	Earl Franklin RM2	K. SIG (2)	Lt G.H. Jinter

17.81C

Figure 5-10.—Work request, part I.

Existing supply forms are used to document material usage and cost data of repair parts or materials obtained through normal supply channels. Choice of document is determined by availability of automatic data processing equipment. If a ship has automatic data processing equipment, DD form 1348 is used. If a ship does not have automatic data processing equipment, NavSandA form 1250 is used. Maintenance personnel are required to furnish the work center code, equipment identification code, CID number, maintenance control number, name of part, and stock number when submitting form 1250 or 1348 to the supply department.

MAN-HOUR ACCOUNTING SYSTEM

The man-hour accounting system, sometimes referred to as exception time accounting (ETA), is designed and intended for use by the repair department of repair activities in conjunction with the maintenance data collection system. Basically, the ETA is a management tool, and records all deviations from a normal 7-hour working day.

The mechanics of exception time accounting includes the use of codes, preparation of a master roster listing, and preparation and submission of daily exception cards (OpNav form 4700-2E). A sample daily exception card is shown in figure 5-14.

ELECTRONICS RECORDS

Details about electronics records are given in the Bureau of Ships Technical Manual. As a rule, these records are kept in the electronics workshop. Aboard ship, the electronics material officer usually assigns responsibility for the major portion of electronics recordkeeping to ETs. There are two reasons why the leading Radioman should have a working knowledge of these records. First, a thorough acquaintance

MAINTENANCE DATA COLLECTION
OPNAV FORM 4700-2C (9-64) PART II

WORK REQUEST

A. SHIP NAME AND HULL NO./ACTIVITY	1. ADMIN. ORG.	2. SHIP ACCTG. NO	3. MAINT. CTRL. NO.	4. DATE MONTH YEAR	8.
USS OVERSEAS DD111	D070	03861	0175	13046	

F. DESCRIPTION/REMARKS (Continued)

PAGE 1

17.81C

Figure 5-11.—Work request, part II.

1 ADM ORG	2 SHIP	3 MCN	8 T/A	5 EIC	6 WC	9 MAL	10 DISC
D070	0386	0175	C	FF11F24	C30	068	C

REMARKS:

* - DO NOT ENTER IF SAME AS ABOVE

4.	DATE	27046
5.	EIC *	
7.	AWC	
9.	HOW MAL *	
10.	WHEN DISCOVERED *	
11.	ACTION TAKEN	C
12.	UNITS COMPLETED	01
13.	MANHOURS (TENTHS)	0010
	READY TO PICK UP (√)	✓
	DELIVERED (√)	

WORK SUPPLEMENT OPNAV FORM 4700-2F (7-65)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

17.81F

Figure 5-12.—Work supplement card.

CID/APL/AEL/AN
55376101

SOURCE CODE	COG.	FEDERAL STOCK NO./PART NO.	REFERENCE SYMBOL/NOUN	MATERIAL REQ. UNITS	MATERIAL REQ. QUANTITY	MATERIAL USED UNITS	MATERIAL USED QUANTITY	UNIT PRICE
1	IN	5905-258-0034	R1445			EA	2	.38

OPNAV FORM 4700-2B (8-64) BACK

17.81B

Figure 5-13.—Reverse side of OpNav 4700-2B.

DAILY EXCEPTION CARD OPNAV FORM 4700-2E(1-65)

A. WORK CENTER CODE	B. NAME (LAST & INITIALS)	C. GRADE CODE	D. ASSIGNED LABOR CODE
	JUSTICE K.L.	003	01

E. TYPE OF CHANGE (✓)

- [✓] X SHORT TERM LOAN TO: 31A (WORK CENTER CODE)
- [ ] 1. ASSIGNED
- [ ] 2. TRANSFERRED
- [✓] 3. LABOR CODE
- [ ] 8. OVERTIME

F. DATE OF CHANGE: 09 (DAY) 04 (MO) 6 (YR)

G. HOURS OF CHANGE: 1 (HOURS) 3 (TENTHS)

H. CHANGE LABOR CODE TO: (✓)

PRODUCTIVE DIRECT

- [ ] 01 DIRECT LABOR

PRODUCTIVE SUPPORT

- [✓] 10 MAINTENANCE ADMIN. & SUPERVISION
- [ ] 11 MATERIAL CONTROL
- [ ] 12 TENDER EQUIPMENT MAINTENANCE
- [ ] ____ SUB CODE

TENTHS OF HOUR KEY

MINUTES	TENTHS
1-2	0
3-8	1
9-14	2
15-20	3
21-26	4
27-33	5
34-39	6
40-45	7
46-51	8
52-57	9
58-60	FULL HR

NON-PRODUCTIVE

- [ ] 20 DELAYS
- [ ] 21 DUTY ABSENCE
- [ ] 22 NON DUTY ABSENCE
- [ ] ____ SUB CODE

A. WORK CENTER ASSIGNED	ACCURACY HELPS MAINTENANCE	D. ASSIGNED LABOR CODE (CODE, SUB)	E. CHANGE	F. DATE OF CHANGE (DAY, MONTH, YR)	G. HOURS OF CHANGE (HOURS, TENTHS)	I. WORK CENTER WORKED	H. LABOR CODE WORKED (CODE, SUB)	B. NAME (LAST & INITIALS)	C. GRADE CODE

685760-0 BSC

17.81E

Figure 5-14.—Daily exception card.

with the necessary records and the proper way to keep them is helpful in understanding capabilities and limitations of equipment, determining its reliability, and ensuring that it is maintained in peak operating condition. Second—and equally important—Radiomen quite often are called upon to perform maintenance and repairs on their own equipment.

Due to the implementation of the 3-M system previously described, many of the records and reports discussed in the remainder of this chapter are being phased out. Some of these records and reports are being replaced by a monthly report sent to the ships from the maintenance data collection (MDC) center.

The MDC report contains information furnished by the activity on the 4700-2 series forms. In order for the MDC report to be complete and for each activity to have a complete record on each piece of its equipment, every maintenance action taken by the activity must be reported.

The MDC report must be kept by each activity in place of the records under the Current Ships Maintenance Project (CSMP), such as the Electronic Equipment History Card (NavShips 536), Repair Record Card (NavShips 529), Alteration Record Card (NavShips 530), and the Record of Field Changes (NavShips 537). The CSMP is discussed briefly for those activities that have not yet incorporated the 3-M system (or are in the process).

CURRENT SHIP'S MAINTENANCE PROJECT

The purpose of the CSMP has been to provide an up-to-date record of maintenance, modifications, and repairs yet to be accomplished by ship's personnel or during availabilities. Some ships may only be using part of the CSMP because of the implementation of the 3-M system. The CSMP is comprised essentially of the following three card forms: repair record card (NavShips 529), a blue card; alteration record card (NavShips 530), which is pink; and the white record of field changes (NavShips 537). As a repair is required, an alteration approved, or a field change authorized, the applicable card should be completed and filed in the material binder behind the appropriate history card. The cards are of distinctive colors, and readily direct attention to work outstanding.

Repair Record Card

When a required repair cannot be accomplished immediately or is beyond the capacity of ship's force, a repair record card (NavShips 529) should be filled out and filed behind the appropriate history card. Repair cards for work beyond the capacity of ship's force should contain information that will be needed later for repair requests for shipyard or tender work. Entering complete data at the time the need for repair becomes evident helps to guarantee successful shipyard and tender availabilities.

Electronic Equipment History Card

The electronic equipment history card (NavShips 536) is the basic material history card for electronic equipment (where the 3-M System is not installed). It provides for recording failures and other pertinent information about equipment. A separate card is prepared for each unit on board; additional cards are added, if required. All cards for a particular unit are transferred with the unit when it is removed from the ship.

The heading of the card is so designed that when the card is filled in properly, all necessary information is readily available for completing the upper part of the electronic equipment failure/replacement report (DD-787). The heading of the card should be typed, but entries on the body of the card may be either typed or written in ink or indelible pencil. Instructions must be followed closely in filling in the form, a sample of which is shown in figure 5-15.

Alteration Record Card

When an alteration is approved, an alteration record card (NavShips 530) is filled out and filed behind the history card for the equipment that the alteration is to modify or replace. If the alteration includes installation of new equipment, the card should be placed in the binder where the new history card eventually is to be inserted. Usually, information to be supplied is self-explanatory. An important consideration is adequate description of the alteration in the Work Required section of the card.

Record of Field Changes

Information on field changes for electronic equipment is recorded on the record of field

NAVSHIPS 536 (Rev. 9-48) ELECTRONIC EQUIPMENT HISTORY CARD

Equipment Model Designation: AN/SRR-13A | Equip. Ser. No.: 596 | Name of Unit and Type No.: Radio Receiver Set, R-441A/SRR-13 | Card No.: 1

Name of Contractor: Radio Corp. of America | Contract No.: NObsr-67134 | Date Installed: 5 Mar 58 | Serial No. of Unit: 596

Location: Radio Central 01-52-0-C | Installing Activity: NavShipYd Phila.

Spare Parts — Box No. and Location: Bin stowage | Instr. Bk. On Board (Check): X

Date	Nature of Trouble (Or F. C. No. and Title)	Cause of Failure Brief Description of Work Done	Name of Part	Circuit Symbol	Navy Stock No.	Life Hours	Date NavShips-383 Mailed
1/6/59	F. C. #1	AS DIRECTED IN E.I.B. 499					
	REDUCTION OF						
	POWER INPUT						
	VOLTAGE.						
3/3/61	LOW SENSITIVITY	OPEN RESISTOR	RESISTOR	R-1605			

Stocked in CDS

16—52956-3

1.2

Figure 5-15.—Electronic equipment history card (NavShips 536).

changes (NavShips 537). One of these cards is prepared for each equipment and is filed in the material history binder next to the history card for that equipment. Without modification, an equipment may be dangerously out of date and subject to numerous serious difficulties. Lacking a record of field changes, it is difficult to determine what modifications (if any) have been made. Information recorded on these cards is therefore essential for routine maintenance, for troubleshooting, and for ordering parts for improved equipment.

Figure 5-16 illustrates a record of field changes (NavShips 537). Spaces for equipment model designation, serial number, date installed, and card number are filled out by typing or writing with ink or indelible pencil. The official name and Navy type number (or other official identification) of each component affected by a field change should be shown parenthetically after the title of a change.

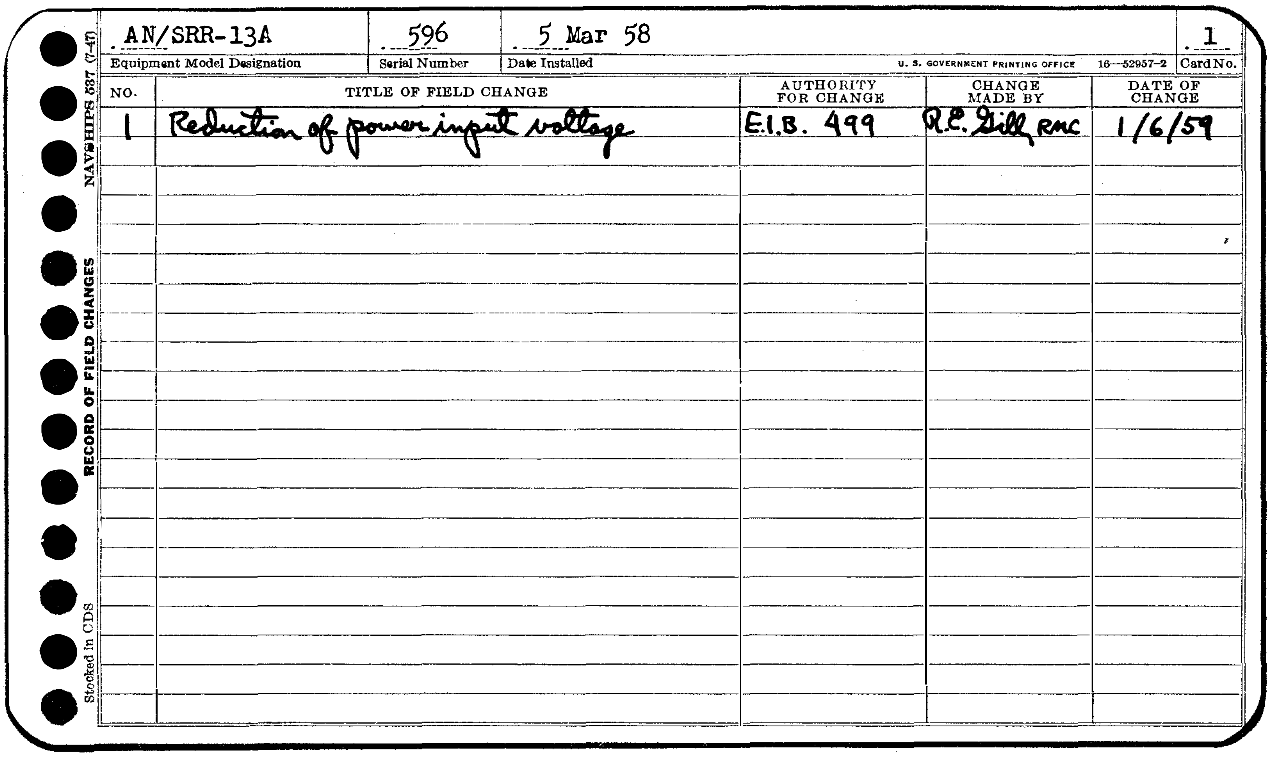
Record Retention Procedures

When CSMP work is completed, notations to this effect should be entered on the material history card and applicable CSMP cards. The latter, with the exception of the record of field changes, then should be removed and placed in a completed work section of the CSMP.

Electronic equipment history cards and records of field changes remain with the equipment referred to on the cards. If equipment is transferred, these cards are transferred with it. The history card must remain with the equipment throughout its normal service life. If an equipment is processed through equipment restoration procedures, a new history card replaces the previous card.

ELECTRONICS REPORTS

Type commanders call for certain reports such as ShipAlt completion reports, for purposes of maintaining accurate data on equipment



NAVSHIPS 537 (7-43) RECORD OF FIELD CHANGES Stocked in CDS

Equipment Model Designation	Serial Number	Date Installed	U. S. GOVERNMENT PRINTING OFFICE 16—52957-2	Card No.
AN/SRR-13A	596	5 Mar 58		1

NO.	TITLE OF FIELD CHANGE	AUTHORITY FOR CHANGE	CHANGE MADE BY	DATE OF CHANGE
1	Reduction of power input voltage	E.I.B. 499	R.E. Dill RMC	1/6/59

1.4

Figure 5-16.—Record of field changes (NavShips 537).

installed on the ships of a command. This information serves as the basis for a ship's improvement program, operational data, and for shipyard scheduling. The Naval Ship Systems Command requires similar data, plus other reports described here, which reveal the performance of equipments, especially directed at failures. From these data the Naval Ship Systems Command can predict required stock levels of parts to be maintained, parts allowances for individual ships, and changes to equipment to improve performance and operation. The 3-M system will eventually take over the function of these reports.

Requirements for electronics reports and instructions for their use are listed in the following references: type commander instructions and directives; BuShips Technical Manual; Electronics Installation and Maintenance Book (EIMB); and Reporting Electronics Equipment Installations (NavShips 900,135).

Ship Electronics Installation Record

The ship electronic installation record (NavShips 4110), shown in figure 5-17, is an inventory of a ship's electronic equipment. It furnishes the Naval Electronics Systems Command a complete and current record of shipboard electronics installations and is a means of informing the Office of the Chief of Naval Operations, fleet and type commanders, Electronic Supply Office, and naval shipyards of electronics installations in the fleet. It serves as a basis for determining electronics repair parts allowance lists (ERPAL), and constitutes one of the factors entering into analyses of the fleet's electronic equipment and maintenance requirements. It also is used in planning future overhauls; in budgeting for, procuring, and distributing equipment; and in planning deployment of ships.

It is obvious that an error in the inventory (listing a wrong serial number, for example) is reflected as a mistake in the ERPAL, resulting

NAVSHIPS 4110 (REV. 2-59)

SHIP ELECTRONICS INSTALLATION RECORD

DATE REVISED BY SHIP 6 Dec 61

BUSHIPS REPORT-9670-2

SHIP TYPE	SHIP NUMBER	SHIP NAME	STATUS	AREA	FLT. FRON.	DIST. COMM.	BERTH AREA	PLAN. YARD	SHIP VOLT.	DATE MO.	DATE DAY	DATE YR.	DIST.	OVHL. YARD
DDG	10	SAMPSON	B	A	50			BS					05	

S.C.C. CODE FOR BUREAU USE ONLY	CAT.	LOCATION	EQUIPMENT MODEL	SERIAL NUMBER	EQUIPT. VOLTAGE 1	EQUIPT. VOLTAGE 2	REMARKS
	1	010	49546	21576		0	
	1	010	AM-215D-U	194		8	
	1	010	AN-SGC-1A	717		8	
	1	010	AN-SRA-12A	499		0	
	1	010	AN-SRR-11A	A-11		8	
	1	010	AN-URA-8B	1377		8	
	1	010	C-1004B-SG	120		8	
	1	010	CV-591A-URR	2855		8	
	1	010	R-390A-URR	4877		8	
	1	010	RE-156A-SR	39		8	
	1	010	SB-82-SRR	QTY 18		0	
	1	010	SB-83-SRT	QTY 1		0	
	1	010	SB-315B-U	2228		8	
	1	010	SB-863-SRT	QTY 3		0	
	1	010	TT-23F-SG	53		0	
	1	010	TT-69A-UG	364		8	
	1	010	TT-187-UG	546		8	
	1	010	TT-192-UG	427		8	
	1	010	TT-253-UG	205		8	
	1	010	TT-253-UG	224		8	
	1	020	AN-GRC-27A	844		8	
	1	020	AN-SRA-13	234		8	
	1	020	AN-URC-32	136		8	
	1	020	AN-URR-27	90		8	
	1	020	AN-URR-35C	27		8	
	1	020	AN-URT-7C	196		8	
	1	020	AN-WRT-1	73		11	
	1	020	AN-WRT-2	104		11	
	1	020	CU-691-U	42		0	
	1	020	SA-597-SRT	46		0	
	1	020	TED-9	179		8	
	1	030	AN-SRR-11A	A-19		8	
	1	030	AN-SRW-4	CJ-34		8	
	1	030	TCS-12	14108		8	

PAGE 1 OF 16

35.82

Figure 5-17.—Ship electronics installation record (NavShips 4110).

first in inadequate or wrong repair parts support and, second, in improper test equipment allowance. Inasmuch as the report is originated by individual ships, the Naval Electronics Systems Command can do little, except during regularly scheduled overhauls, to verify accuracy of the report. Responsibility therefore rests with the ship, and it is to the ship's benefit to have changes and corrections submitted as soon as they occur.

Details for preparing NavShips 4110 reports are contained in Reporting Electronic Equipment Installations, NavShips 900,135. Only pertinent extracts are given here. The person making the report must use the referenced publication to ensure complete adherence to procedures.

Whenever a major change is made in a ship's electronic installation, a corrected NavShips 4110 is submitted to the Naval Electronics Systems Command in order that its tabulations may be transferred readily to the latest electronic tabulating system. The record information is punched on cards in such a manner that it shows not only what equipment is installed in each ship, but also what military requirement the equipment fills or partly fills, and whether there still are unfilled or partly filled military requirements. The system has been expanded to show also what equipment has been allocated but not yet installed.

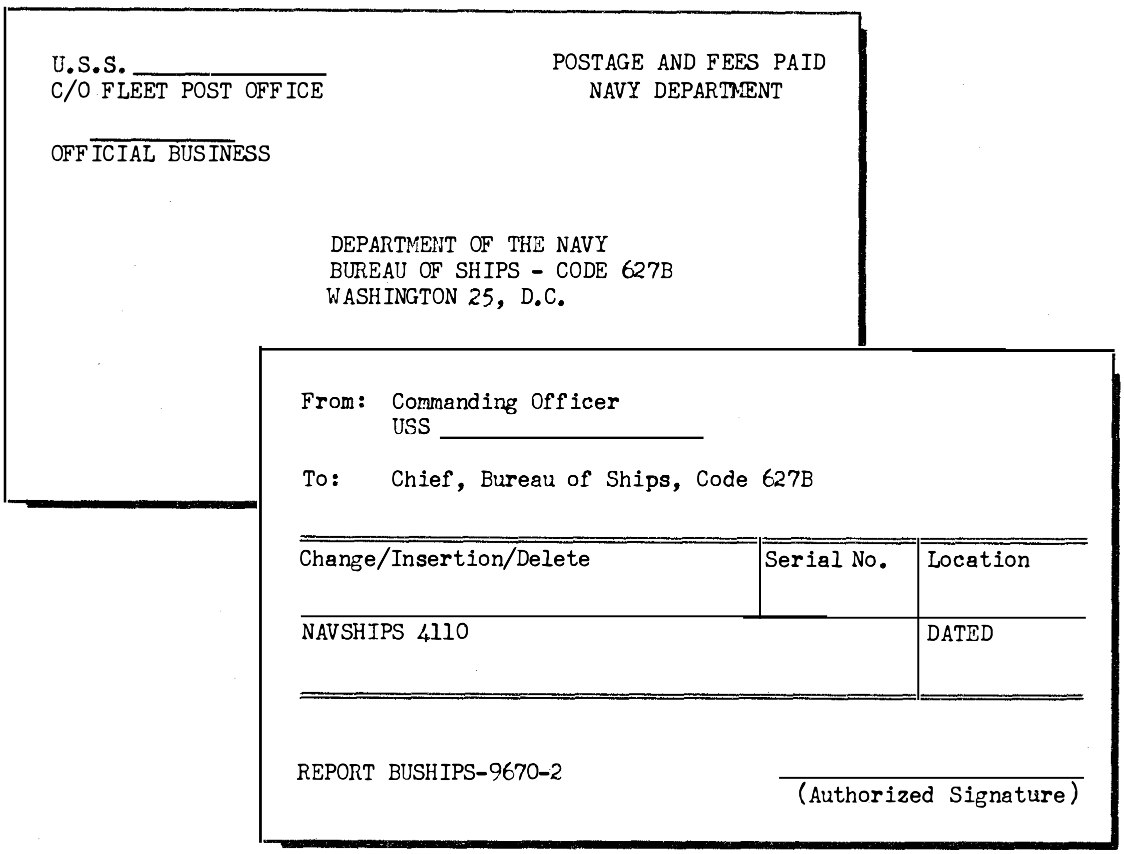
In a concise manner, NavShips 4110 reveals what equipment is on board, where it is located, and identifies its operating voltages, along with other important information. For identification purposes, coded letter and figures are used in the several data columns. Meanings of these codes (for each column) are given in the previously referenced NavShips 900,135.

Minor changes may be reported on NavShips 4263, a post card form (fig. 5-18). A minor change is defined by the Naval Electronics Systems Command as one that does not affect military characteristics of the ship, such as relocation of equipment or change in operating voltage.

When a change in the electronics installation is made by ship's force, a tender, or shipyard, the 4110 report must be revised to agree with the changed installation. Necessary changes must be noted on all copies, in red pencil or red ink, and the date of the revision must be indicated at the top of the form. One revised copy is mailed to the Naval Electronics Systems Command, Washington, D.C. Other revised copies are returned to the ship's files pending receipt of reprinted copies. Upon receipt of the reprinted copies, the filed revised copies are destroyed after they are rechecked carefully for accuracy by the ship.

In general, the cognizant systems command does not reprint NavShips 4110 after receiving a single minor change report from the ship, but uses and files them until several are accumulated.

A postoverhaul NavShips 4110 report is required 1 week before completion of a scheduled



U.S.S. ______________
C/O FLEET POST OFFICE

POSTAGE AND FEES PAID
NAVY DEPARTMENT

OFFICIAL BUSINESS

DEPARTMENT OF THE NAVY
BUREAU OF SHIPS - CODE 627B
WASHINGTON 25, D.C.

From: Commanding Officer
USS ______________

To: Chief, Bureau of Ships, Code 627B

Change/Insertion/Delete	Serial No.	Location
NAVSHIPS 4110		DATED

REPORT BUSHIPS-9670-2

____
(Authorized Signature)

50.21

Figure 5-18.—NavShips 4263, indicating minor change in ship electronic installation.

overhaul. The ship forwards to the cognizant systems command a revised copy of the latest NavShips 4110 report.

In summary, then, a ship's responsibility is to submit a corrected NavShips 4110 at least 1 week before completing an overhaul, as well as when a major installation or removal is made between overhauls. Minor changes occurring between overhauls must be reported promptly on the NavShips 4263 post card form.

The Naval Electronics Systems Command is responsible for publishing and distributing a revised NavShips 4110 upon receipt of a post-overhaul report from the ship, upon receipt of reports of major changes made between overhauls, and 6 months before a regularly scheduled overhaul. In preparing this preoverhaul issue, the Naval Electronics Systems Command uses the latest NavShips 4110 on file, consolidating with it all minor changes reported to date. The Command forwards the completed preoverhaul NavShips 4110 to the ship, type commander, overhaul shipyard, and the Electronics Supply Office.

Electronic Performance and Operational Report

The Naval Electronics Systems Command must keep tabs on new (and modified) equipments to evaluate their usefulness. This procedure is accomplished with the electronic performance and operational report (NavShips 3878), shown in figure 5-19. Reports are not required to be submitted on all equipments. Only those equipments currently listed in the Material Command Instruction 9670.20 (as corrected by the EIB) are to be reported. Equipment listings in the EIB are changed periodically to delete certain equipments and add others. At present this report is made on only a few equipments. All newly installed equipment must be reported for 1 year: The 3-M system will eventually do away with the need for this report.

Electronic Failure Reporting System

The electronic failure reporting system to overcome serious shortcomings in data collected under the system formerly used. Two major advantages of the new failure reporting system are reduction in fleet and shore station workload, and improved statistical and engineering value of reports.

Reports of failures in electronic equipments, serve several excellent purposes. (1) They provide the Systems Command with a comprehensive presentation of the overall performance of electronic material. (2) They point out the weakest circuit components of particular equipment. (3) They are useful for calculating load lists and repair parts requirements. (4) Because new models (or modifications of older models) usually are in some stage of development, prompt receipt of failure reports enables the Systems Command to initiate immediate corrective action to eliminate similar or related deficiencies in subsequent production.

An efficient reporting system, sensitive to failure or replacement trends of parts and equipments, is required to provide information needed to measure and improve equipment reliability and maintainability. More reliable and maintainable Navy electronic equipment can result from data derived from this failure reporting program. Success of the program depends, however, on basic data being presented accurately and submitted rapidly by Navy personnel operating and maintaining the equipment.

The importance of reporting failures and their causes cannot be stressed too highly, particularly circumstances existing when failures occur under actual operating conditions. Failure reports must be filled in completely and in conformity with instructions accompanying report forms. Many reports received by the systems command are valueless because they do not give essential information required by the form or because information given is incomplete. When indicating the model or type of equipment, include all significant nomenclature, modification, letters, and numbers. To avoid forwarding an incorrect stock number, check the number against the FOCSL or allowance parts list (APL).

GUARANTEES

An additional and important purpose served by the failure reporting system is supplying information for use in enforcing guarantees on electronic material. When purchasing electronic equipment, it is the practice of the Electronics System Command in most instances to include in the contract a guarantee covering design, material, and manufacture of each set and their components and parts. In recent contracts the procedure has been to require a 1-year guarantee, to become effective upon the date of acceptance by the Inspector of Naval Material. This acceptance date (when available) and date of installation should be entered in appropriate logs, installation records, and equipment history cards.

To obtain maximum protection and effectiveness under terms of contractual guarantee, it is essential to report all failures promptly to the appropriate systems command. Information forwarded should be complete and described fully so that the systems command can conduct an analysis that will provide a basis for claim under the guarantee. An activity reporting a defect or failure may be requested to furnish additional facts to enable the systems command to pursue claims under contractual guarantees. The systems command provides instructions requiring such information after analyzing the defects reported.

Guarantees apply to replacements for parts, units and sets, as well as to the originals. Replacements must therefore receive the same consideration as original items regarding recording dates of acceptance and periods of service and reporting failures and defects promptly.

REPAIR PROCEDURES FOR REPAIR SHIPS AND TENDERS

Whenever practicable, between regular overhauls, type commanders arrange routine upkeep periods for their ships alongside a repair ship or tender. (Normally they are of 2 weeks' duration.) These intervals vary according to different types of ships. Small ships, such as destroyers, usually have an upkeep period every 6 months. Upkeep periods are planned to agree with quarterly employment schedules of ships concerned. Under normal conditions a ship knows in advance when and where she will go alongside a repair ship or tender.

Arrival Conference

When a ship arrives at a repair activity, an arrival conference must be held promptly to discuss work requested by the ship. This conference is attended by representatives of the ship, repair department, and (usually) type commander. Relative needs of the ship and the urgency of each job are discussed. Jobs that are indefinitely stated in work requests are specifically defined and priorities are established. In other words, the arrival conference serves to clarify all uncertain items for the repair activity, which receives and studies work requests in advance.

PROGRESS OF WORK

As soon as work requests are approved at an arrival conference, jobs requiring delivery to a tender should be started immediately. Getting repair work started early is important for completion on schedule of all repair work.

Progress of repair work should be checked to be certain that (1) jobs are not delayed, (2) no job is overlooked or forgotten, and (3) all jobs undertaken are completed satisfactorily by the end of an upkeep period.

Progress of repair work in radio spaces should be known at all times by the leading Radioman. He should keep a careful check and estimate on the progress of ship's force repair work, and check on the progress of the tender or repair ship detail.

Repair ships and tenders usually assign a chief petty officer to be ship's superintendent. His duties regarding repair jobs are to act as liaison between ships alongside and the tender and coordinator of shop work for assigned ships; report daily to a representative of the commanding officer of the ship to ensure that work is progressing satisfactorily as far as the ship is concerned; maintain a running daily progress report or chart for each job, notify the ship to pick up completed material on the tender; notify ship's personnel to witness tests on repaired equipment; and, on completion of job orders, obtain signatures from cognizant officers.

PROCEDURES FOR SUBMITTING WORK REQUESTS

Procedures for submitting shipyard work requests preceding a regular overhaul are laid down (in general) in Navy Regulations and (in detail) in fleet and type commander regulations. In this topic, the method adopted by the Atlantic Fleet is used as an example. (In the Pacific Fleet, the procedure for submitting shipyard work requests differs somewhat in detail. Each item of work is submitted on a separate work request form, with sufficient copies. The sheaf of work requests is accompanied by a priority list.)

ELECTRONIC PERFORMANCE & OPERATIONAL REPORT
NAVSHIPS 3878 (Rev. 4-60) *Submit original only to Bureau - No forwarding letter required* REPORT-BUSHIPS-9670-1

FROM: USS RANGER (CVA-61)
(Ship name, type and hull no.)

☐ LANT
FLEET
☒ PAC

TO: CHIEF, BUREAU OF SHIPS (CODE)

REPORT CLASSIFICATION	DATE
UNCLASSIFIED	1 Sep 61
REPORTING PERIOD FROM 1 Aug 61	TO 31 Aug 61

TYPE AND MODEL OF EQUIPMENT: AM-1365/URT Amplifier

SERIAL NUMBER: 383

FIELD CHANGES TO DATE	ACCOMPLISHED	NOT ACCOMPLISHED
	None	None

HOURS DURING PERIOD OF THIS REPORT: OPERATED 180 NOT IN OPERATING CONDITION 564

PERFORMANCE FIGURE (PF) & TECHNICAL EVALUATION: ☐ OUTSTANDING ☐ GOOD ☐ SATISFACTORY ☒ UNSATISFACTORY

OPERATIONAL EVALUATION: ☐ OUTSTANDING ☐ GOOD ☐ SATISFACTORY ☒ UNSATISFACTORY

RADAR

PEAK POWER OUTPUT (PT)	AVER. VSWR IN TRANSMISSION LINE	AVER. ECHO BOX RING TIME	MIN. DISCERNIBLE SIGNAL (PMDS)
dbm		YDS	dbm

MAX. RANGE TARGETS DETECTED	MI	MI	MI	MAX. ALTITUDE AT RANGE DETECTED	MI	MI	MI
MAX. ALTITUDE TARGETS DETECTED	FT	FT	FT	RANGE AT MAX. ALTITUDE DETECTED	FT	FT	FT
TARGET CLASS. TYPE - DETAIL (SEE REVERSE)				TARGET CLASS. TYPE - DETAIL (SEE REVERSE)			

MAXIMUM RELIABLE RADAR RANGE: MI
MINIMUM RELIABLE RADAR RANGE: YDS

SONAR

SOURCE LEVEL (LS) db//μBAR	RECEIVING SENSITIVITY db//VOLT/μBAR	SEA STATE	PROCEDURE USED

NOISE LEVEL db//VOLT	5 KNOTS	10 KNOTS	15 KNOTS	20 KNOTS	25 KNOTS	30 KNOTS

	RANGING	LISTENING	SOUNDING
MAXIMUM RANGE SONAR TARGETS DETECTED AND TRACKED	YDS	YDS	FATHOMS
TARGET CLASSIFICATION TYPE AND DETAIL			
BT PATTERN			
OWN SHIP'S SPEED.	KTS	KTS	KTS

COMMUNICATIONS

PERCENT OF TIME OUT OF CONTACT WHILE WITHIN RANGE (IF ANY)	ANTENNA SYSTEMS	INTERFERENCE (Frequencies, intensity, and sources)
0 %	No problems	No problems

POWER OUTPUT	AVERAGE VSWR	REL RANGE	RECEIVER SENSITIVITY
Voice 100 WATTS	1.5:1	40 miles	NA UVOLTS

ELECTRONIC WARFARE

MAXIMUM RANGE AND ALTITUDE TARGETS ... DETECTED	MI	FT	MI	FT	MI	FT
TARGET CLASSIFICATION TYPE AND DETAIL (SEE REVERSE SIDE)						
MAXIMUM RELIABLE RANGE AND ALTITUDE	MI	FT	MI	FT	MI	FT
TARGET CLASSIFICATION TYPE AND DETAIL (SEE REVERSE SIDE)						

MAX. RANGE SONAR TARGETS DETECTED	BT PATTERN	MAX. RELIABLE SONAR RANGE	BT PATTERN
YDS		YDS	

35.83

Figure 5-19.—Electronic performance and operational report (NavShips 3878).

TARGET CLASSIFICATION

TYPE

1. Large Plane (Bomber)
2. Small Plane (Jet Fighter)
3. Group of Planes
4. Merchant Ship
5. Warship
6. Formation of Ships
7. Submarine
8. Buoy
9. Weather Front
10. Land
11. Other (Explain)
12. Unknown

DETAIL

a. Own Ship's controlled aircraft
b. An alerted aircraft approach or contact (An aircraft whose existence and location is known prior to being picked up on own radar)
c. An unalerted aircraft approach or contact (An aircraft whose existence was not previously known)
d. An opening aircraft contact
e. An anticipated surface contact
f. An unanticipated surface contact
g. Snorkling
h. Submerged
i. Other (Explain)
j. Unknown

OUTAGE REMARKS: (Account for time equipment was NOT in operating condition. Show casualty, corrective action, outage time and comments. Include time inoperative for preventive maintenance and POMSEE. Reference Casualty Report, if one submitted on this equipment during this reporting period).

Equipment was in use for about 180 hours when C8, P.A. plate feed through capacitor, shorted, causing overload relay to kick out. Repair part not available on board, was ordered and not yet received. Three failures of this type have occurred among the eight units installed.

GENERAL REMARKS: (Comment on any problems or inadequacies encountered in the equipment. Comment is also desired on any item above or any item not covered by this report. When detailed tracking data is available and the equipment can be evaluated operationally, comment on such items as reliability, target discrimination and clarity. If overheating occurs report ambient and equipment temperature in degree. If equipment is considered to be operating satisfactorily, so state.) (Problem areas listed below are for convenience.)

Antenna
Cabling (including wave guides)
Design
Electrical
Interference
Lubrication
Maintenance
Mechanical
Overheating
Power input
Physical operation
Safety devices
Spare parts
Test equipment
Test points
Transducer
Tube failures
Vibration
Logistic support (Manuals, repair activities, overhaul, etc)

While equipment was operating properly, 40 mile range was consistent.

The failure of C8 is considered a design problem.

Experience to date has indicated that the AM-1365/URT is saving the 4X150A output tubes in the TED-8 transmitter. Longer tube life is gained through reduced drive required from the TED-8. Ten watts output is sufficient, compared with the attempt to drive the transmitter at 30 watts before the AM-1365/URT amplifier was installed.

SIGNATURE: C. O. Holt
C. O. HOLT, CDR USN By direction

CLASSIFICATION (Of this report): UNCLASSIFIED

8-43867

35.83

Figure 5-19.—Electronic performance and operational report (NavShips 3878)—Continued.

Commanding officers are required to submit their naval shipyard work lists to the type commander 60 days before a scheduled overhaul. After the type commander carefully inspects these lists, various items are approved, disapproved, changed, or corrected in accordance with standard repair policies. Lists then are forwarded to the shipyard no less than 30 days before starting the overhaul.

Ships having mimeograph machines are required to submit 30 copies of the work lists; others, an original and 6 copies. A separate (departmental) work list is made out for each of the following headings: hull, engineering (mechanical), engineering (electrical), electronics, and ordnance.

Items of work are recorded in relative order of priority for each work list of groups listed. After work lists are completed, a ship's priority index is prepared. Usually this priority indexis made up in a conference of all heads of departments and the executive officer. From individual repair lists various items are selected and are assigned in an overall order of priority for the ship.

Certain procedures are observed in making out a departmental work request list. Some type commanders require that each work item be submitted in the following form and contain information designated.

1. Description of item, including location, nameplate data, and (where applicable) plan numbers.
2. Report of existing defects in the item to be repaired.
3. Complete and full description of repairs required to place item in satisfactory operating condition.
4. Reference to authorizing correspondence, where applicable.
5. Stipulation whether ship-to-shop or other assistance is to be provided by ship's force.
6. Ship's inspecting officer or petty officer. (Persons named should have detailed information concerning repair item.)

SUPPLEMENTARY WORK REQUESTS

Supplementary work requests sometimes must be prepared in order to include items that arise after submitting original lists. Additional repairs may be required because of recent voyage casualties or because of conditions discovered during shipyard tests and inspections. In submitting a supplementary list, the same procedure must be followed as for original lists. Supplements are dovetailed into a ship's priority index.

In the period (approximately 3 months) between submitting original work lists and ship's arrival at a shipyard, unforeseen difficulties might arise, necessitating shipyard repairs. In such situations, an additional repair list, called the first supplement, must be prepared ahead of ship's arrival at the yard (if possible).

In accordance with an established procedure, and as requested by the ship, a naval shipyard holds numerous tests and inspections of equipment. These tests and inspections may disclose some additional repair items. When these initial tests and inspections are completed, a supplementary repair list is made out to cover any defects discovered. This repair list is called (as applicable) the first or second supplement.

Except the two instances mentioned, there ordinarily should be no further need for submitting supplementary repair items. In other words, all items requiring shipyard repairs should be written up and submitted before a ship arrives in the yard—not after she is in the yard for some period of time. In most instances, other last-minute repair jobs indicate a ship's maintenance program is inadequate, her CSMP recordkeeping is incomplete or not up to date, or that there is a lack of experience or knowledge in submitting a complete list of repair items for a shipyard overhaul.

Supplementary work lists sometimes are needed when many repair jobs are assigned for ship's force accomplishment, because of limitation of funds available for an overhaul period. After starting a repair job, for example, it may become evident that satisfactory repairs are beyond ship's force capacity. A request must then be made for the yard to make the repairs. To avoid such a difficulty, jobs of this type are written up preferably as ship-to-shop jobs. To illustrate, ship's force disassembles, assembles, and tests equipment, and the shipyard performs the needed repair work.

120-Day Letter

Alterations for accomplishment are authorized through the medium of the 120-day letter. The term "120-day letter" is derived from the requirement that directs its issue in sufficient time to be received by action addressees 120 days in advance of the scheduled beginning date for overhaul of a ship.

The 120-day letter is issued by Naval Ship Systems Command. It notifies the cognizant type commander, planning yard, and other interested activities of the specific ship alterations, under material command cognizance, to be accomplished during the overhaul period. It normally includes the following information: work authorized; available funds; materials required; plans for accomplishing specified work; operating schedule of ship; and status of ShipAlts that already may have been started and if any material is aboard for the ShipAlts authorized.

INSPECTION DUTIES OF SHIP'S FORCE

Inspection of work performed by a repair activity for a ship is the responsibility of both repair activity and ship. A repair activity makes inspections that will ensure proper execution of the work and adherence to prescribed specifications and methods. A ship makes any inspections that are necessary, both during its progress and upon completion, to determine if work is satisfactory.

The leading Radioman should schedule his work in such a manner that he is free at all times to inspect and check progress of shipyard work going on in his spaces or being performed on equipment for which he has responsibility of maintenance and upkeep. Before the job is considered fully completed, a check should be made to see if any required tests are made by the shipyard. Any tests that must be made by yard personnel are listed on the naval shipyard job order.

If any unsatisfactory work is being performed by shipyard personnel, leading RMs should follow instructions put out by the ship's engineer officer. Talking over the problem in a friendly manner with workmen usually solves any difficulty. It it doesn't, the division officer should be notified, and he should request the operations officer to take up problems of unsatisfactory work with the ship's superintendent.

In many ships it is customary for the division officer or operations officer to check with the leading petty officer before he signs off a job order as completed. By continuous inspection of shipyard work and checking off jobs completed satisfactorily, required information can be supplied promptly.

YOUR JOB IN SUPPLY

All naval personnel should possess a general knowledge of principles of the Navy's present supply system, in order to utilize the system fully and correctly. Of primary significance, also, administrative and supervisory personnel must have a sound working knowledge of methods used to obtain and properly account for their particular supplies.

A Radioman First or Chief is instrumental in seeing that repair parts and other material are available in adequate supply. He also helps in planning for future needs. In general, these are main responsibilities concerning supply. Military Requirements for Petty Officers 1 & C has an entire chapter on supply, and tells what the leading RM should know and be able to do in fulfilling this part of his job. Coverage includes departmental budgets, material identification, estimating needs, procurement, receiving and inspecting, custody and storage, inventory, and expenditure of material—including surveys.

CHAPTER 6

TYPES OF COMMUNICATION LINKS

This chapter is designed to show how the Naval Communication System links its various ships and stations in order to provide a continuous flow of information from the smallest unit at sea to major commands ashore. All methods employed in setting up a complex communication system are discussed.

NARROWBAND AND WIDEBAND TRANSMISSION SYSTEMS

The terms "narrowband" and "wideband" refer to the bandwidth of a transmission system and the number of channels utilized in transmitting messages—in other words, the information-carrying capacity of a transmission system.

Narrowband transmission systems consist of a group of facilities (or subsystems) whose information-carrying bandwidth is 4 voice channels or fewer. Narrowband systems include high-frequency radio (single sideband and independent sideband) and landlines.

Wideband transmission systems consist of a group of transmission facilities having an information-carrying bandwidth of more than 4 voice channels, regardless of transmission means or frequency utilized. Bandwidth and number of voice channels used depend on the type of system. Links carrying 1800 voice channels through a single transmitter and receiver are available. Included in wideband systems are forward propagation tropospheric scatter (FPTS), microwave, and cable systems.

In the past and, to a large degree, in the present, narrowband systems are (and have been) the main link between communication facilities. Although wideband systems are more desirable than narrowband systems, their usage is limited because of an overcrowded frequency spectrum. As technical advances in equipment and systems are devised and economical use of the frequency spectrum is solved, increased use of wideband systems is expected.

The rest of this chapter is concerned with different types of links in use today, and how they are used within the overall communication system. These links fall into one of the systems mentioned earlier. Most often the primary link between communication facilities is audio cable, microwave, or HF radio circuits. The type of link used is determined by service desired, amount of message traffic to be handled, and overall cost to the Navy.

LANDLINES

Seldom is a Radioman called on to work directly with landlines. Almost all landlines used by the Navy are leased. When it is determined to link one place with another, the telephone company serving the area is notified regarding the type of circuit and kind of service desired. Proper selection of landlines (if used) is made by the telephone company.

Perhaps the only time a Radioman encounters landlines is when he has to patch teletype circuits from one pair of lines to another. Depending on the type of installation, these circuits may either be d-c lines or audio lines. Patching usually is accomplished at a control center of a Navy communication station or in the communication control link (CCL) of a tributary station.

DIRECT CURRENT (D-C) LANDLINES

A d-c landline circuit (as it appears in a CCL) consists of a pair of wires between two terminals. A d-c battery, supplied by either the terminal equipment or a separated d-c line power supply, is connected in series with the circuit. These lines are used for controlling different types of equipment, such as keying a transmitter, and for short-haul teletype circuits. In some instances they are used as secondary or backup circuits for primary microwave circuits that link different sites of a naval communication station. Some tributary stations of a NavComm-Sta may have d-c landlines as their primary teletype circuit and also may have them for remote keying of CommSta transmitters.

AUDIOFREQUENCY LANDLINES

Audiofrequency landlines (as they appear in a CCL) are pairs of wire used for handling tone teletype equipment. Each end of a line is terminated to an audio transformer to give the circuit a 600-ohm impedance with a 3-kc bandpass. One pair of lines is capable of carrying up to 16 teletype channels. Because these lines are engineered to handle a 3-kc bandpass at audiofrequencies, they are considered to be in the narrowband system. When telephone companies pick up these lines, they usually are transferred to a carrier system.

LEASED LINES AND CIRCUITS

Telephone companies use many types of circuits and systems in handling their vast telephone and telegraph network. Each circuit is engineered to meet specifications of individual users. In general, these circuits and systems can be classified as landline types, two-wire and four-wire circuits, audio systems, and carrier systems.

Landline Types

Landline systems that carry various circuits are further broken down into four types of lines; open wire, wire cable pairs, coaxial cable, and submarine cable. All four of these lines are capable of handling all circuits and systems in use today.

OPEN WIRE.—Open-wire lines are the familiar wires seen on telephone pole crossarms along highways. Wires of each pair and each pair of wires are spaced a certain distance apart, depending on the type of circuit and system used. If more than one crossarm is used, distance between them is also made to a certain length. These distances are determined by frequency (audio and/or carrier systems) of circuits, and are set to certain specifications to help eliminate crosstalk.

WIRE CABLE PAIRS.—Use of cables came about because of unsightly congestion resulting from overhead wires, especially in cities. Underground wire cables are less vulnerable to storms and other weather conditions. During wartime they also are less susceptible to sabotage and enemy attack.

Wire cables are made up of many pairs of wires insulated in such a way as to prevent crosstalk between various circuits in the cable. Insulation covering each wire (or each pair of wires) is a different color. This color coding makes it easy to keep circuits separated when connecting them to terminal points.

Open-wire systems are terminated at a pole on the outskirts of towns and cities. They are connected to cable conductors extending from the terminal pole to the central office of the city. Because of difference in size of wire used on the two types of systems, cable conductors are designed so that their impedance matches open wire impedance. In numerous situations, such as river crossings, it is necessary to insert relatively short lengths of cable in long open-wire line.

COAXIAL CABLE.—Today, nearly 30 percent of all communication services flow over a coast-to-coast coaxial cable network. This percentage is destined to increase in the future, along with usage of its newer companion, microwave (discussed later). Together, they will replace older open-wire and cable circuits. Coaxial cable falls into the wideband group of communication systems.

Modern coaxial conductors are constructed chiefly of 3/8-inch copper tubing. Exactly in the center, a No. 10 gage copper wire is held by small plastic disk insulators spaced about 1 inch apart. Both the outer conducting tube and the wire have the same center or axis, hence the name coaxial. In some types of coaxial conductors, insulation between these two conductors is made of a solid dielectric material. Both types of conductors are shown in figure 6-1.

Coaxial conductors are made up into cables, with eight or more coaxials arranged in a tight ring. Also contained within the cable are a number of paper- or polyethylene-insulated wires used for control, maintenance, and short-distance communications. Air or nitrogen gas is introduced under pressure into coaxial cable in spaces between tubes and wires. The air or gas keeps out moisture and also aids in detecting any damage that may occur to the cable. Figure 6-2 shows an 8-tube coaxial cable. New systems use cables containing 20 coaxial tubes.

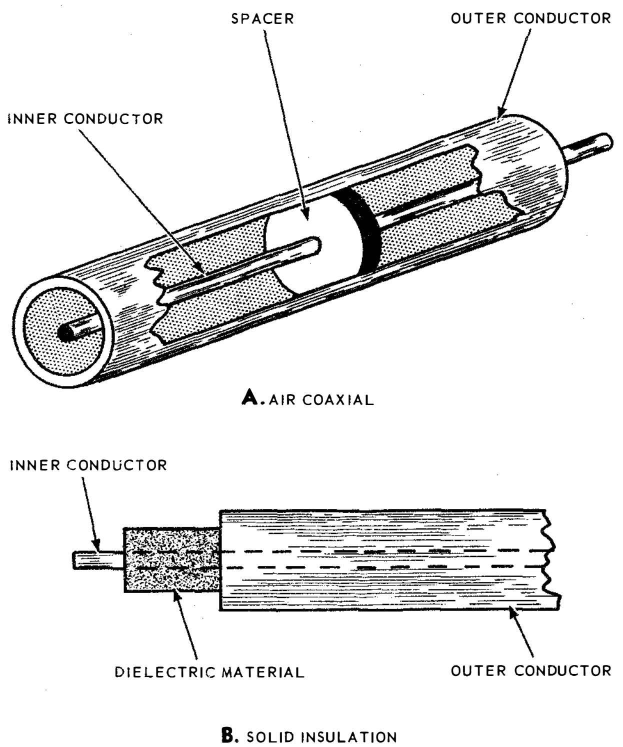


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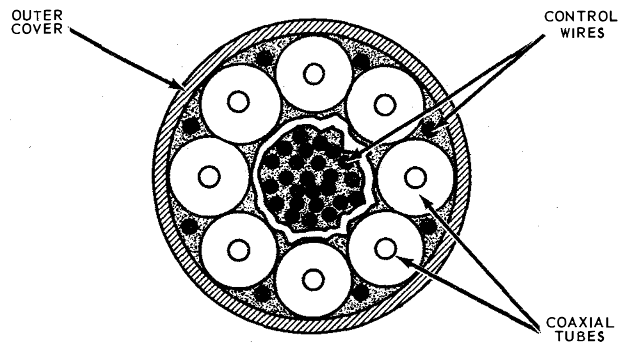
Figure 6-1.—Coaxial conductors.

SUBMARINE CABLE.—Because submarine cable now reaches almost every continent, it is possible to contact nearly every part of the world without using radio as a link. Until 1956 existing telegraph cables could not carry voice circuits. Since 1956 several cables have been laid that can carry up to 128 voice channels. Figure 6-3 shows telephone cables that now are operating and some that are planned or under construction.

The first telephone cable had external armor for strength and protection, and its flexible one-way amplifiers or repeaters were spaced about 40 miles apart. Power for these repeaters was fed from terminals. Improvements in this system increased its capacity from 36 to 48 circuits.

A newer type of cable and improved amplifiers brought circuit capacity up to 128 circuits. New cable, constructed in a manner that makes it stronger, employs two-way amplifiers spaced about 20 miles apart. Both types of cable are shown in figure 6-4.



29.226
Figure 6-2.—Eight-tube coaxial cable.

Types of Telephone Transmission Systems

The various kinds of line facilities and apparatus described so far are, in practice, applied to developing several distinct types of long-distance circuits. Such circuits may be broadly classified as between those operating at voice frequencies and circuits that operate at higher (carrier or radio) frequencies. In the former group are ordinary two-wire circuits, which employ a single pair of open-wire or cable conductors as their transmitting medium, as is the general practice with most local and short-haul service. These two-wire circuits are comparable to the Navy's simplex or half-duplex circuits. The voice frequency group also includes the four-wire cable circuits in which a separate pair of cable conductors is used for transmission in each direction. These four-wire circuits can be compared to the Navy's full duplex circuits.

Except where coaxial cable is used, carrier circuits employ the same (or similar) kinds of wire facilities for transmission as do voice frequency circuits. Both circuits must have amplifiers or repeaters at regular intervals along the line.

It is impossible to make an unqualified statement concerning particular situations in which each type of circuit may be best applied in practice. In general, however, two-wire circuits commonly are used for relatively short distances—not more than a few hundred miles. Four-wire cable circuits are for somewhat longer distances. Landline carrier or microwave circuits ordinarily are utilized for longest

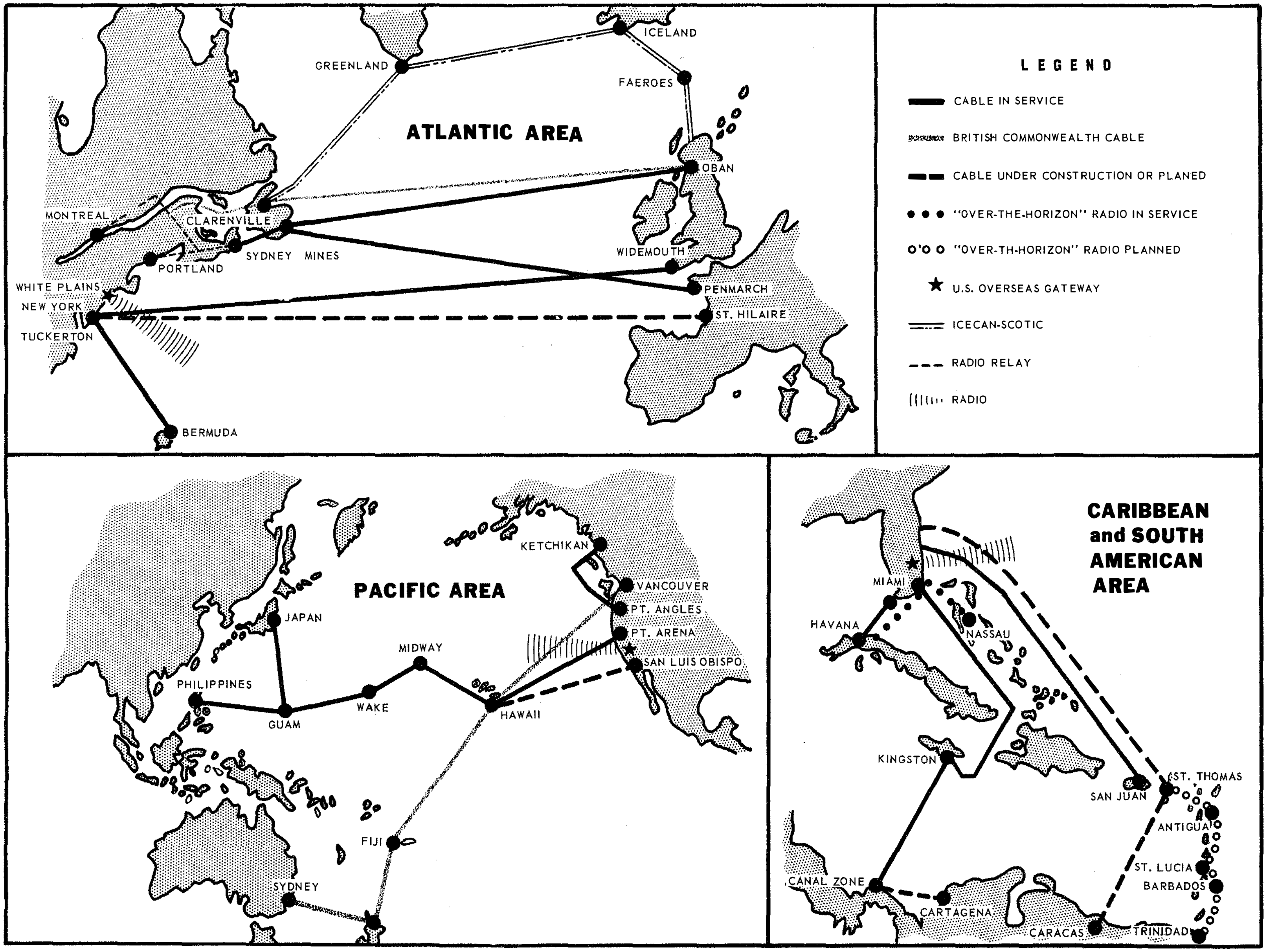


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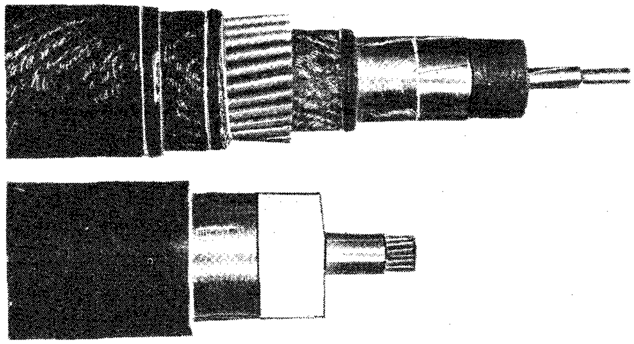
Figure 6-3.—Submarine cable in operation and planned or under construction.



TOP—A SECTION OF DEEP SEA CABLE USED IN THE TRANSATLANTIC SYSTEM PLACED IN 1956.

BELOW—THE TYPE UTILIZED IN THE SYSTEMS LAID IN 1963.

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Figure 6-4.—Two types of submarine cable.

distances, although their use is not limited to such application.

AUDIO SYSTEMS.—Audio systems used by telephone companies can be compared to audio lines terminating in a CCL. Each pair of lines carries a telephone conversation at the frequency of the participants, i.e. audiofrequencies. By using terminal equipment similar to the Navy's equipment, telephone companies can put twelve 100-wpm teletype circuits on one voice or audio channel.

An early development, called a phantom circuit, was used on open-wire lines. It enabled use of three circuits on one pair of lines. Figure 6-5 shows a phantom group. A key to proper operation of a phantom group is the precision with which line wires and coils are balanced. Any unbalance permits currents from side circuits to leak into the phantom (and vice versa). These unwanted currents make circuits noisy. In severe cases, they actually allow a conversation on one circuit to be heard on others. This phenomenon is called crosstalk.

Audio systems are not used to a great extent in present-day communications except for some local and short-haul circuits.

CARRIER SYSTEMS.—Carrier systems used by telephone companies are carrier frequencies that are modulated by information to be transmitted. Various modulation means used, that a Radioman is already familiar with, include amplitude modulation (a-m) and frequency modulation (f-m).

When carrier systems were first used, cost of equipment and installations was high. For economy of use, therefore, it had to be used on long circuits where equipment costs were less than the price of additional wires on the line.

As new techniques were developed and better equipment was built, the number of carrier systems increased. They were progressively used for shorter distances.

Many types of carrier systems are in use today. The time division multiplex process and frequency division multiplex equipment used on these carrier systems are similar to systems used by the Navy. Some of the Navy's carrier equipment is discussed in chapter 10.

RADIO

Until comparatively recently, the term "radio communications" brought to mind one of two or even three types of circuits: telegraphy, or c-w as it is commonly called by communicators, using the ever-reliable Morse code; a-m voice communications, for short-haul voice circuits; and possibly teletypewriter communications. Anyone passing a radio shack heard the familiar sound of Morse code; a Radioman sitting at an operating position with a pair of earphones on his head was a common sight.

Communications has come a long way since then—no longer is Morse code a familiar sound; it has been replaced by teletypewriter clatter and the buzz of Radiomen handling an ever-increasing volume of message traffic. Instead of talking about telegraph keys and earphones, a Radioman now speaks of TDs, reperfs, and teletype channels. Although c-w circuits have been pushed to the background in favor of single sideband circuits, microwave, and even satellite circuits, they still are in use today, and at times afford the most reliable means of communications.

CONTINUOUS-WAVE TRANSMISSION

Continuous-wave (c-w) is the on-off keying of a carrier frequency of a transmitter in such a way as to form a code that can be translated into a readable intelligence. International Morse code is the most common type of c-w transmission.

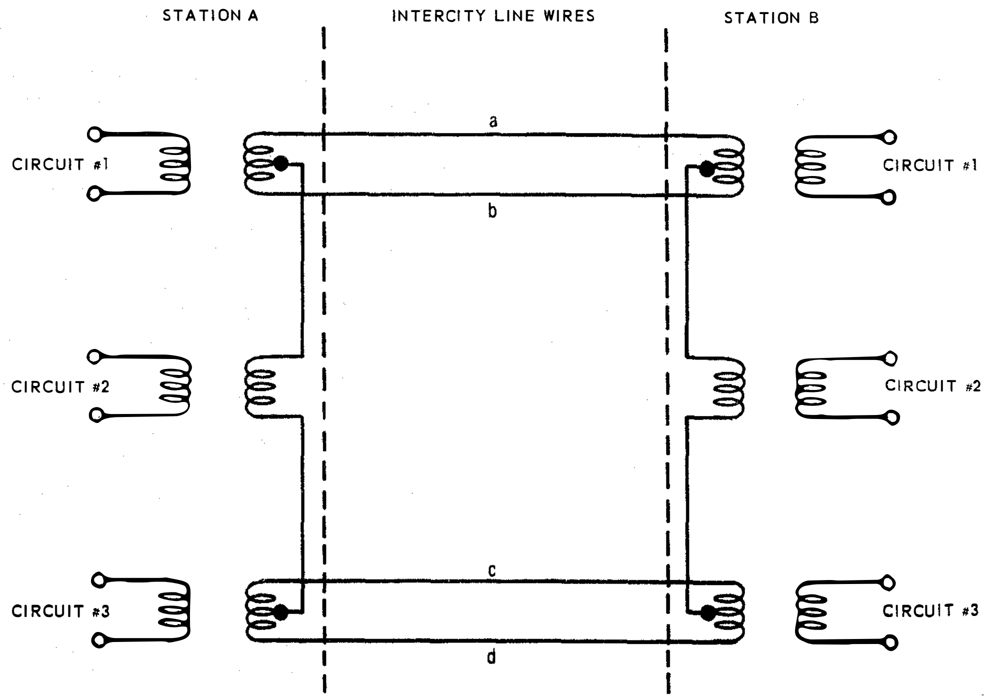

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Figure 6-5.—Phantom group circuit. Two physical circuits (1) and (3) on either side of phantom circuit (2).

Many ship-shore and broadcast circuits still use the c-w system. It still is considered the best method for penetrating heavy atmospheric disturbances, especially in the far northern and southern hemispheres. Occasionally the c-w method is used for order-wire circuits between communication stations. Practically all communication plans make provision for at least one c-w circuit for emergency backup of primary teletype circuits.

AMPLITUDE-MODULATED TRANSMISSION

Amplitude-modulation (a-m) transmission is used with all four major means of communications—c-w, voice, teletype, and facsimile.

Amplitude modulation is a process of varying amplitude of a carrier frequency by other frequencies (usually audio) or by applying varying amounts of d-c voltage. The a-m voice circuits are used for UHF tactical nets and for harbor common nets. Occasionally, amplitude-modulation is used for long-haul voice circuits.

In tactical situations, commanders of different units find that UHF a-m nets are an effective means of communications. These nets give direct communications between commanders, assuring speed and accuracy in handling tactical maneuvers.

Some teletype circuits also use UHF a-m for short-distance communications. Amplitude modulation is also used on many single-channel ship-to-shore circuits. By using time division multiplex (MUX) equipment, up to four teletype channels can be transmitted by amplitude modulation.

Current/no-current teletype signals are fed into a keyer unit, which changes them to tone signals. These tone signals are sent to a transmitter where they modulate the carrier, from which they are sent out on the air.

Facsimile modulates the carrier by using varying amounts of d-c voltage. Zero volts is white, with no modulation of the carrier; approximately 12 volts is black, and gives maximum modulation of the carrier. Different amounts of d-c voltage between 0 and 12 volts furnish the shades between black and white.

SINGLE-SIDEBAND TRANSMISSION

Single-sideband (SSB) transmission is the most common link used today. It is being applied to many circuits that previously operated on amplitude modulation. Many UHF circuits are expected to utilize SSB in the near future. Chapter 11 tells what SSB is and how it operates. This chapter discusses where and how it works.

SSB Voice Circuits

Single sideband communications are gradually replacing many voice circuits that have been using amplitude modulation.

The high command net (HICOM) uses SSB as a means of communications between fleet commanders, and between fleet commanders and subordinate and adjacent commands.

Whenever special voice circuits are necessary, either between shore activities or ships and shore activities, SSB is selected because it is less susceptible to atmospheric interference than amplitude modulation. Often, SSB is used for voice order-wire circuits between NavComm Stas.

As mentioned earlier, UHF circuits are starting to use SSB as the means of transmission. Moreover, SSB circuits are being adapted to existing UHF equipment. Other applications of UHF SSB circuits, besides voice circuits, are discussed later.

SSB Teletype Circuits

With few exceptions, SSB is used on all existing long-haul teletype circuits. It is also used on ship-shore circuits, as well as on ship-ship teletype circuits. Most of these systems are now covered circuits; that is, an electronic cryptodevice on either end of the circuit automatically encrypts and decrypts message traffic. These devices are used on point-to-point, ship-shore, ship-ship, and broadcast circuits.

SHIP-SHIP SSB TELETYPE CIRCUITS.—Although ship-ship SSB teletype circuits are not in wide use, they will be used more often as equipment becomes available and as their advantages become known. Their main application is for task force or task group nets or several ships in company. By using this type of net, ships can send their outgoing messages to a guardship from which traffic can be relayed ashore. This procedure saves manpower, circuit time, prevents individual ships from overcrowding ship-shore circuits, and saves usage of the frequency spectrum. Depending on the number and types of ships in company, the guard can be shifted to other ships from time to time. A major advantage of these circuits is that electronic cryptodevices can be used so that classified messages can be sent without need for manual encryption. These circuits are used for incoming as well as outgoing traffic, and they can use either HF or UHF.

SHIP-SHORE SSB TELETYPE CIRCUITS.—Many ships handle enough message traffic that a continuous ship-shore teletype circuit is justified. Depending on traffic load, these circuits can be from one to four teletype channels on one SSB circuit. If the traffic load warrants more than one teletype channel, usually time division multiplex (MUX) or frequency division multiplex is used. This equipment handles up to four incoming and four outgoing channels. One channel normally is used as an order-wire circuit for handling operator-to-operator procedure messages and for making frequency changes when necessary. Three remaining channels are available for handling official message traffic.

POINT-TO-POINT TELETYPE CIRCUITS.—Most point-to-point long-haul circuits between naval communication stations need more channels than SSB can provide. To compensate for the deficiency, independent sideband (ISB) transmission, which is similar to SSB, is used. In ISB, instead of suppressing the carrier and filtering out a sideband, only the carrier is suppressed. Both sidebands are used, and are split into two 3-kc audio channels, as shown in figure 6-6. Each audio channel may carry different intelligence.

By using frequency division multiplex equipment, 16 teletype channels can be put into each of the 3-kc audio channels, giving a possible total of 64 teletype channels on one ISB circuit. Usually, only one or two audio channels are

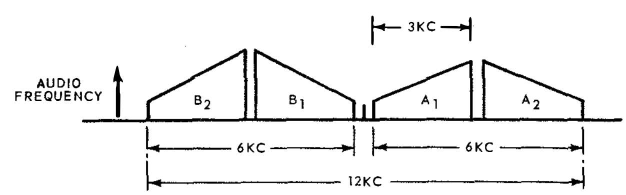

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Figure 6-6.—Radiofrequency—ISB channel and frequency bandwidth.

used for teletype. Other channels are available for voice and/or facsimile, depending on the needs of participating stations. Figure 6-7 is a simplified diagram of how one ISB circuit may be used. Chapter 11 briefly describes one of the frequency division multiplex equipments, the UCC-1.

MICROWAVE TRANSMISSION

Microwave is a line-of-sight radio transmission system. Line-of-sight systems are made up of one or more links having a clear path between antennas at the ends of a link. Usually frequencies used are above 900 mc. In the Naval Communication System, three equipments currently in use are the UQ, operating between 1700 and 1850 mc; AN/FRC-37 system, operating between 1700 and 2400 mc; and AN/FRC-84 system, operating between 7125 and 7750 mc. Wideband transmission, suitable for 24 to 600 voice channels, has been obtained by proper system planning.

At frequencies mentioned, wavelengths become short, and propagation of the r-f energy becomes remarkably similar to that of light energy. It thus becomes practicable at microwave frequencies to use high-gain antennas that resemble reflectors used in searchlights. These antennas concentrate energy into a narrow beam in the same manner as light energy. With the beam directed in the desired direction, it can be seen that a much larger signal arrives at the receiving antenna than would happen with a nondirectional antenna. Figure 6-8 depicts a parabolic antenna that is used for transmission and reception of microwave electromagnetic energy.

Terrain determines the length of a single link. In actual practice, transmit and receive antennas can be separated by a slightly greater distance than the actual horizon-to-horizon line-of-sight distance, due to refraction of the microwave

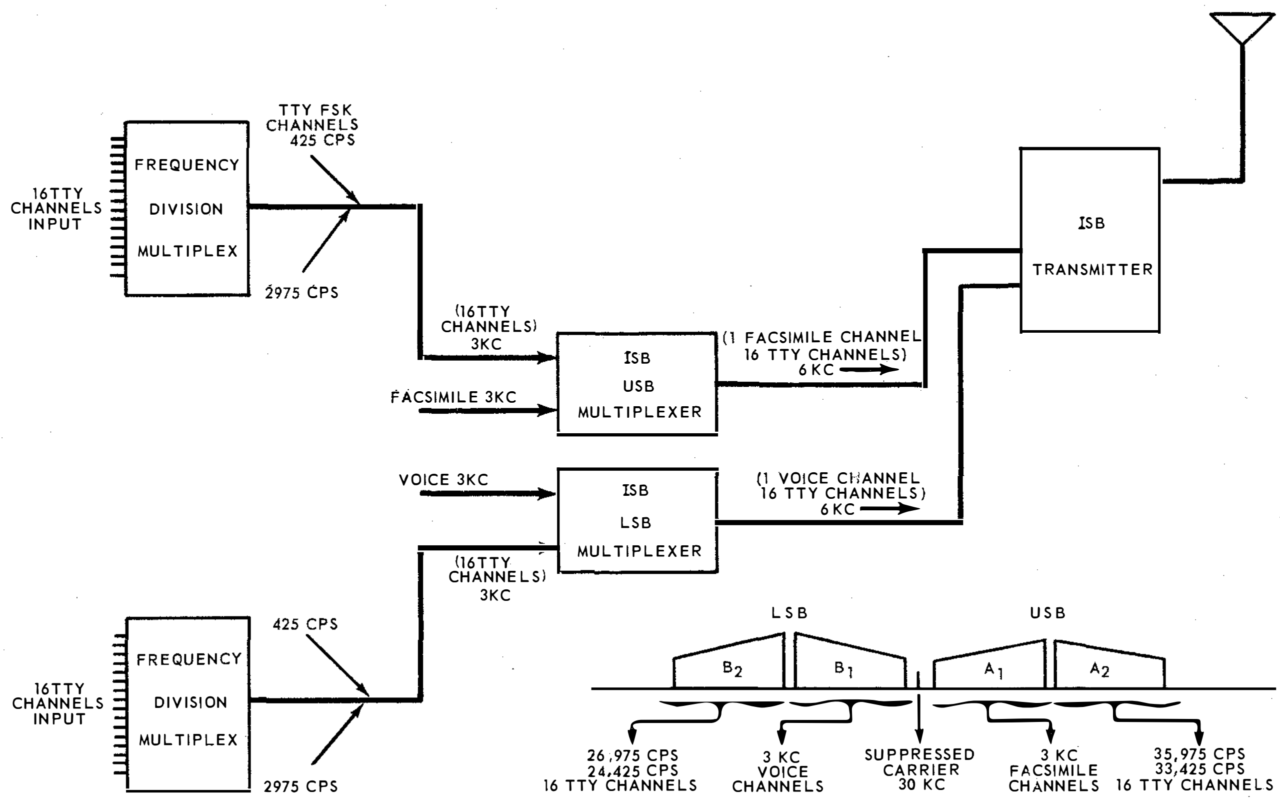

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Figure 6-7.—Typical ISB circuit.

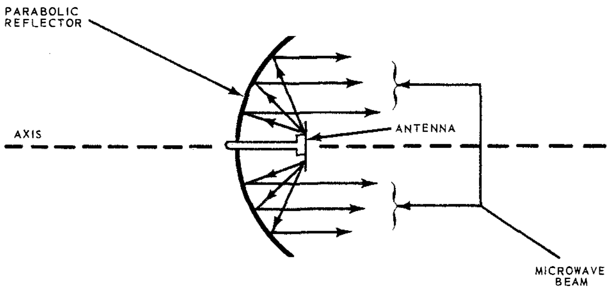

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Figure 6-8.—Microwave antenna.

beam by the atmosphere. Most systems are composed of links of 30 miles or less, except where especially favorable sites can be found. Repeater stations may be used to connect one link to another to form long chains, thereby setting up long paths for many voice channels where needed. Chains of more than 40 links, for example, cross the United States carrying voice, teletype, and television signals.

Microwave links are often used for carrying signals from a portion of a naval communication station to another; from and to the transmitter and receiver sites to the main station, for example.

Some of the long-haul circuits the Navy leases from AT&T may go by microwave from one part of the United States to another.

Microwave radio link systems have the advantage of greater flexibility, economy of operation, and almost complete independence over weather conditions. They have excellent reliability (over 99 percent), extremely wide information-carrying bandwidth, good resistance to interference, and low power requirements. Limitations are that they require a relatively large portion of the frequency spectrum, and a short range.

Usually microwave radio is used where large channel capacity is required, links are relatively short, and where it is more difficult or costly to install cable.

SCATTER TRANSMISSION

Forward propagation scatter transmission is a point-to-point method of HF or UHF radio communications. It permits reliable multichannel telephone, teletype, and data transmission out to a range of 400 miles.

Two types of scatter systems that have been used are ionospheric and tropospheric. Because of greater capacity and reliability, only the tropospheric system is now being used.

Forward propagation ionospheric scatter (FPIS), a system using HF range, utilizes SSB or ISB. A transmitted signal is beamed at the ionosphere where it is scattered in a forward direction. A receiving antenna is beamed at the same point in space to receive the signal. Because of its limited bandwidth, relatively high-power requirements, and crowded HF spectrum, this system is not used extensively.

Forward Propagation Tropospheric Scatter (FPTS)

Numerous communication networks now in operation, extending for thousands of miles, utilize "tropo" terminals with hops of 300 miles or more. These relay hops are accomplished by using both transmitting and receiving equipment and antennas at each terminal. At the initial transmitting point, many separate telephone conversations and teletype circuits are combined into a single radio signal. A feedhorn on a tower beams the signal out toward the horizon similar to a huge, precisely aimed searchlight. A minute reflected portion of the signal is picked up by a parabolic receiving antenna well over the horizon. There it is reamplified and sent on its way again, if necessary, for another leap over the horizon toward its destination at the other end of the circuit.

Tropo has many advantages over other methods of long-distance communications. Besides greater economy in areas where construction and maintenance present problems, it is relatively free of atmospheric interferences that affect other transmission methods.

Tropospheric scatter transmission operates in the UHF band, using f-m transmission. The troposphere is the lowest area of the atmosphere, extending from the ground to a height of approximately 6 miles. Above this area are the stratosphere and the ionosphere.

Almost all weather phenomena occur in the tropospheric area. The troposphere itself is made of various layers similar to the entire atmosphere. Within the troposphere, these layers are sharply defined, differing in temperature and moisture content. Because these layers are shifting constantly, the refractive index for any one area of the troposphere changes. Boundaries between layers act as reflecting surfaces. The present theory is that the phenomenon of refraction and reflection within the troposphere makes possible the scatter system of transmission. Part of a radio signal beamed upward through the troposphere goes through a complex series of partial refraction and reflection, causing most of the energy to be scattered in all directions and become partially diffused. Figure 6-9 shows how this refraction/reflection change might take place.

A receiving antenna, beamed at the same point in the troposphere as the transmitting antenna, will pick up enough transmitted energy to make it useful. For any particular transmitter power and a given antenna size, an average received signal depends on beam (scatter) angle, distance between stations, frequency used, and weather conditions at the midpoint of the radio path (fig. 6-10).

To obtain optimum results, high-power transmitters are used, and antennas range in size from 8 feet in diameter for mobile use to 120 feet for fixed installations. Output power, size of antenna, and frequency used depend on the type of circuit desired.

Scatter angle influences the amount of received signal. Better reception is obtained when scatter angle is kept to a minimum. The take-off angle of transmitter and receiver antennas is made as low as permissible by local terrain and general geographical location.

The received signal of scattered energy varies extensively, causing conditions of fast and slow fading. Fast fading, caused by multipath transmission, exists for short intervals. Slow fading usually extends over several hours and is brought about by changes in refractive properties of the troposphere. Seasonal variation in signal strength also is experienced. Received signal level is lower during the worst month of the winter season, and higher during the best month of the summer season. Another factor is that communication paths in tropical

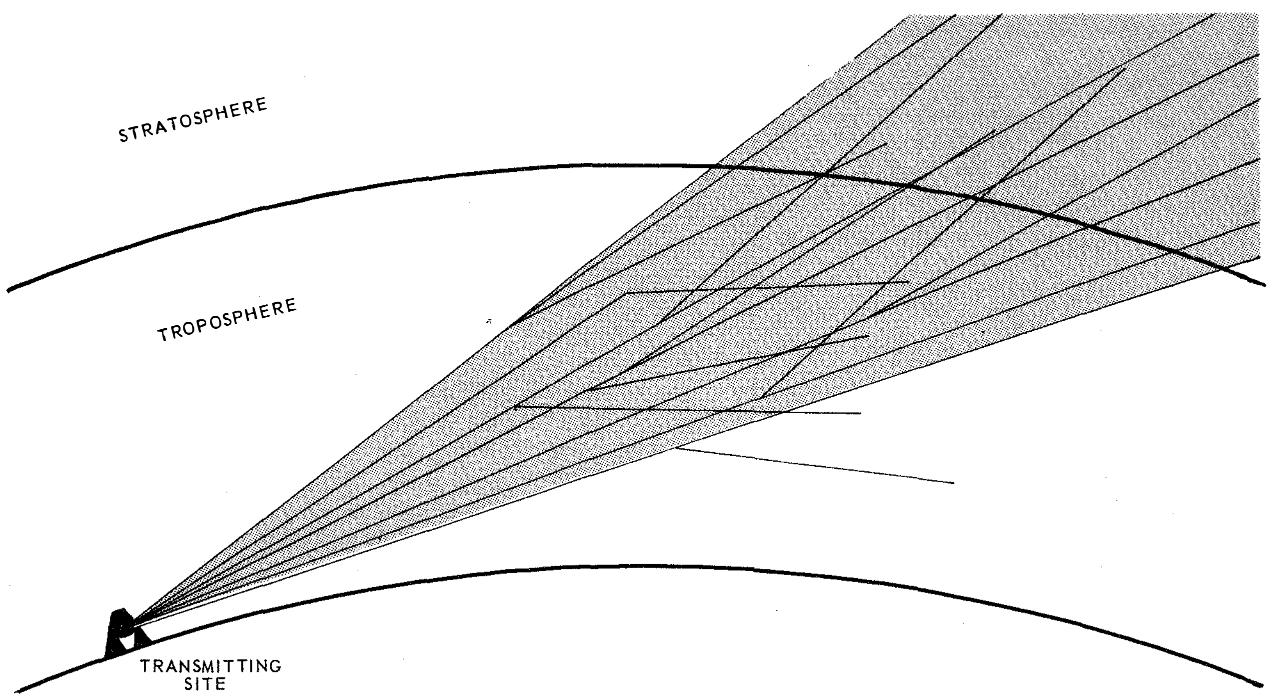

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Figure 6-9.—Scattered radio signal—shaded area is a beamed signal. Lines within the beam show a simplified idea of how the signal is partially refracted and reflected.

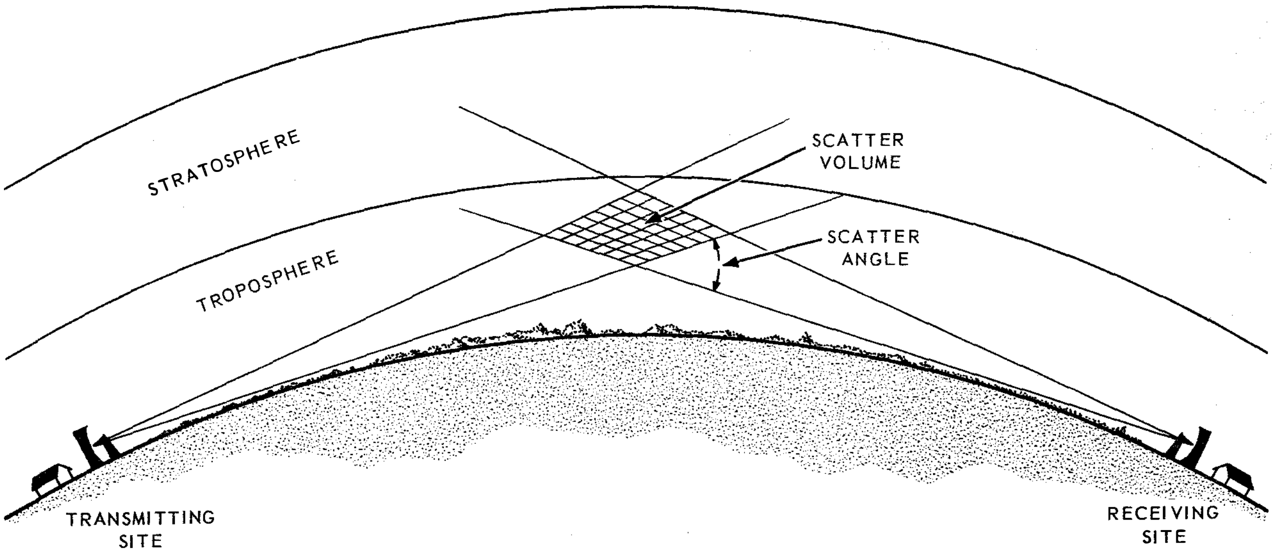

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Figure 6-10.—Scatter propagation.

or temperate zones are somewhat better in yearly average signal level than those in higher latitudes.

To obtain a steady signal, energy combined from a number of fluctuating signals is used in a diversity system. Some or all of the following methods are used to obtain a steady signal over different paths that fade and vary independently.

- Space diversity: Receiving antennas separated by 50 wavelengths or more at the signal frequency. (Usually 10 to 200 feet is sufficient.)

- Frequency diversity: Transmission on different frequencies fades independently, even when transmitted and received through the same antennas.

- Angle diversity: Two feedhorns produce two beams from the same reflector at slightly different angles. This arrangement results in two paths based on illuminating different scatter volumes in the troposphere.

The number of channels that can be transmitted over a given link depends on the degree of distortion the particular circuit can accept. For links that are part of long-haul telephone systems, distortion must be kept to a minimum. Typical tropospheric scatter link capacities are given in the accompanying list.

Distance	No. voice channels
0-100 miles	To 252
100-200 miles	To 132
200-300 miles	To 72
Over 300 miles	12-24 (quality usually limited)

SATELLITE COMMUNICATIONS

The United States has no military communication satellites in operational status at the present time. Those presently used are still in experimental stages. One satellite system is in regular commercial use.

Satellite communications will form a part of long-haul links between switching centers. These links will employ satellites in addition to other forms of existing communication media—HF radio, tropospheric scatter, landline, cable, and line-of-sight microwave. In this initial stage, satellite trunks will be in parallel with trunks provided by more conventional means of communication. They will provide added capacity between various points in the network and, because satellite links will continue in operation under conditions that will render other media inoperable, satellite trunks also will furnish the important reliability factor necessary to military communications.

As techniques of satellite communications evolve and are perfected, satellite communications can be expected to provide the major part of all intercontinental links in the DCS. Their particular advantages in terms of flexibility and survivability, which increase dramatically in proportion to the number of satellites in use, will predictably establish communication satellites as a major factor in the system.

Further application will result from existence of satellites in sufficient number to satisfy long-haul requirements. Once these requirements are achieved, use of satellites will be economically justifiable on shorter links also.

Since 1958 a number of satellites, including the moon, have been used successfully for communications. Project Score was the first satellite designed purely for communication purposes. In 1959 the moon was successfully used for communications between Washington and Hawaii.

Satellites are of two different types, and there are two different ways of orbiting them. Each type has advantages and disadvantages, as well as a distinct application in satellite communications.

Types of Satellites

Satellites used for communications are of two basic types: active or passive.

Active satellites incorporate some device to either amplify, or otherwise change, and rebroadcast the signal they receive. The store-and-forward type of active satellite receives message traffic as it passes over one station, records it, and retransmits traffic as it passes over another station. The real-time type of active satellite receives signals from one station, amplifies the signal, and retransmits it directly to another station. In a much oversimplified parallel, these active types perform the same general function in a satellite communication system as a repeater in a microwave relay link.

Passive satellites do not include electronic equipment for purposes of augmenting or manipulating signals transmitted over the link. They provide a reflective surface against which radio waves are bounced. Again, in simple terms, the function performed by passive satellites is similar to that of the troposphere in scatter propagation.

Satellite Orbits

Satellites are placed in one of two different orbits—random or synchronous. A synchronous orbit is one over the equator at such height and speed that the satellite is synchronized with the rotation of the earth and consequently appears to hang motionless over a point on the earth's surface. Random orbits actually take in all other satellite orbits achieved. They may vary from low-altitude to extremely high-altitude orbits, polar to equatorial and from nearly circular to extremely eccentric.

DCS AUTOMATIC DIGITAL INTEGRATED NETWORK

The DCS automatic digital integrated network (AUTODIN) is a fully automatic digital data switching system (first mentioned in chapter 4). This network provides store-and-forward and circuit-switching message service to data and teletypewriter subscriber terminals. It is capable of handling any type of information in digital form, including voice and graphics. The system consists of high-speed, electronic, solid state switching centers, various types of data and teletypewriter subscriber terminals, and interconnecting transmission media.

Eventually the AUTODIN system will replace all manual and electromechanical relays, such as the Army FGC-30 and Navy 82B1 switching centers.

Administrative and logistic traffic from afloat units will enter the AUTODIN system at Navy communication stations and units, which will be provided direct access to the nearest AUTODIN switching center. Primary routes for Navy command and control traffic will continue to be through Navy dedicated circuits such as HiCom, ASC, and the NavComOpNet.

When fully implemented, AUTODIN will provide instantaneous, error-free, and secure communications around the world to more than 4100 directly connected subscriber terminals. Automatic preemption will give immediate service to command and other top-priority users.

Daily capacity of the 19-switch AUTODIN system will handle 60 million data cards or an equivalent of 5 million average-length messages. Worldwide security will be provided by employing the link encryption concept.

Interconnection of AUTODIN switching centers will be through a network of high-frequency radio channels, submarine cables, microwave and tropospheric channels, and a variety of wire lines. These transmission media will be provided from existing DCS transmission resources, automatic voice network (AUTOVON), and from commercial communication facilities. At least one alternate route will be provided for each trunk. Activation of this alternate path will be controlled from the AUTODIN supervisory position. All d-c digital signals will be converted to suitable analog signals by modulators-demodulators (MODEMS) before they are transmitted over interconnecting trunks.

Backbone of the AUTODIN system is the automatic digital message switching center (ADMSC), which is self-supporting. It includes an automatic digital message switch, technical control facility, power generator and distribution equipment, a timing source, cryptographic and crypto-ancillary equipment, and maintenance facilities. Basic functions of the ADMSC are to accept, store, and retransmit digital messages from one location to another, automatically detect and correct errors, and accomplish alternate routing. For locations requiring real-time service, CONUS switching centers provide automatic circuit switching (direct user-to-user) service.

Each switching center has a high degree of reliability resulting from duplicate major units, which can be activated with a minimum of disrupted service. A standby communication data processor is provided at each center and is automatically tested for on-line use at regular intervals.

Once a message is accepted in the ADMSC, which automatically checks for valid control characters, probability of a message not being switched to its proper terminal is 1 in 10 million messages. (Specification for overseas switching centers specifies 1 in 1 billion.)

Circuits that terminate in ADMSCs can operate at rates of 45.5, 75, 150, 300, 600, 1200, 2400, and 4800 bits per second. These units are equivalent to 60 to 6400 words per minute.

Routing information, message formats, and operating procedures utilized in the ADMSC are in accordance with ACP 121, JANAP 128, and other applicable operating directives and practices.

Traffic classified higher than the security clearance of its intended destination(s) is not delivered by the ADMSC. Any such message is intercepted automatically at the last center, and the originator is informed (via service message) of a nondelivery resulting from a security mismatch.

The ADMSC recognizes the six precedence levels used by NATO and other Allied Nations but processes them as four. Flash and Emergency are processed the same as Routine and Deferred. Messages are processed and transmitted on a first-in/first-out basis, subject to precedence and channel availability. Messages of precedence I, for example, are processed immediately upon receipt of the message address, even to the extent of interrupting transmission of messages of lower precedence. Precedence II messages are capable of preempting precedence III and IV traffic. Normally, however, this function is not used, and becomes effective upon activation by higher authority.

Another special feature of the ADMSC is the provision of incoming and outgoing journals. These message journals store and present (on demand) synoptic information on each message, sufficient to identify it, to record how the message was procured, and to determine where and when it was sent to an outgoing line. Journal information is retained for up to 30 days in inactive storage. Sufficient active storage is maintained for a period determined by operating requirements. Current status of the ADMSC can be checked at any moment by obtaining a printout of exactly how many messages, by precedence and destination, are in the center.

Each overseas ADMSC is capable of recognizing and routing 300 single routing indicators for local tributaries terminated in the center, 200 collective routing indicators, and routing indicators for 300 other switching centers. Service to four types of terminal stations, for example, is provided by CONUS AUTODIN. These four types are—

- Low-speed compound terminals (12 cards or 200 teletype wpm).
- High-speed compound terminal (100 cards or 200 teletype wpm).
- Magnetic tape terminal (2400 baud).
- Computer interfaces (21 to 2400 baud).

Teletypewriter subscribers are served by a controlled teletypewriter terminal. It provides the following functions:

- Automatic acknowledgement of end of message.
- Automatic transmission interruption.
- Automatic resumption of transmission of messages without rerun or intervention.

- Automatic rejection and cancellation of messages.
- Automatic message numbering.
- Automatic verification of received message numbers.

By reducing manual handling of messages to a minimum, AUTODIN is revolutionizing communications. In the future, message delivery times and delays anywhere in the world will be measured in seconds instead of minutes and hours.

DCS AUTOMATIC VOICE NETWORK

The DCS automatic voice network (AUTOVON) offers rapid, direct interconnection of Department of Defense and certain other Government installations. Some overseas areas are now connected into the Continental United States (CONUS) automatic system. As facilities become available, other overseas areas will be connected. The AUTOVON is intended to be a single, worldwide, general-purpose, direct dialing system. Its goal is to complete connections between two prearranged points, anywhere in the world, in about 2 seconds, and to complete regular connections with pushbutton speed. It will be expected eventually to switch every type of information transfer, including voice transmission, teletypewriter, or data.

A number of installations, comparable in function to commercial telephone exchanges, constitute the AUTOVON. An installation in the system is referred to as an AUTOVON switch, or simply a switch. Within individual areas exist local command, control, and administrative voice communication systems. These systems can be connected into the worldwide AUTOVON through manually operated telephone switchboards, or automatic dial exchanges by provision of direct in or out dialing capabilities.

A naval station tèlephone system may be connected into the AUTOVON by its local private branch exchange (PBX), or private automatic branch exchange (PABX). In this instance the PBX or PABX would be considered the AUTOVON subscriber. Some offices and facilities may have direct access to the AUTOVON system, and would be individual AUTOVON subscribers.

NORMAL SERVICE

Normal AUTOVON service provides a capability for subscribers to call other subscribers on a worldwide basis for day-to-day nonpreemptive traffic. Depending on the type of service provided in each locality, this service may be accomplished by either direct dialing or through a local operator. Where users of this type of service require priority calls to be made, they must place the call with their local operator or the AUTOVON dial service assistance (DSA) operator.

Most military installations are provided connection to the general-purpose AUTOVON through their local PBX or PABX. These local systems are two-wire systems. Inasmuch as AUTOVON is a four-wire system, its terminal equipment must be four-wire also. Where such terminal equipment as two-wire local switchboards are to be interconnected, four-wire/two-wire conversion equipment is used. Figure 6-11 shows a local exchange and how it might be connected to the area AUTOVON switch.

Besides general-purpose AUTOVON service provided through local PBX, certain selected subscribers are authorized direct four-wire access to the general-purpose network through pushbutton four-wire telephone sets (fig. 6-12) installed in their offices. These subscribers can be provided with up to four classes of priority. Each level of priority can preempt any lower levels. A four-wire subscriber may employ any level of precedence he desires up to and including the highest level he is authorized. The precedence desired by a four-wired subscriber is selected by pushing one of four buttons on his set.

JOINT UNIFORM TELEPHONE COMMUNICATIONS PRIORITY SYSTEM

Precedence designations in table 6-1 are directed for joint use. These precedence designations indicate the relative order in which a telephone call of one designation should be handled in respect to all others.

SPECIAL NETWORKS

Different types of special networks can be provided within the AUTOVON. They may afford privacy of service, within a specified community of interest, so that only participants are able to communicate on the network without interference from the general-purpose network.

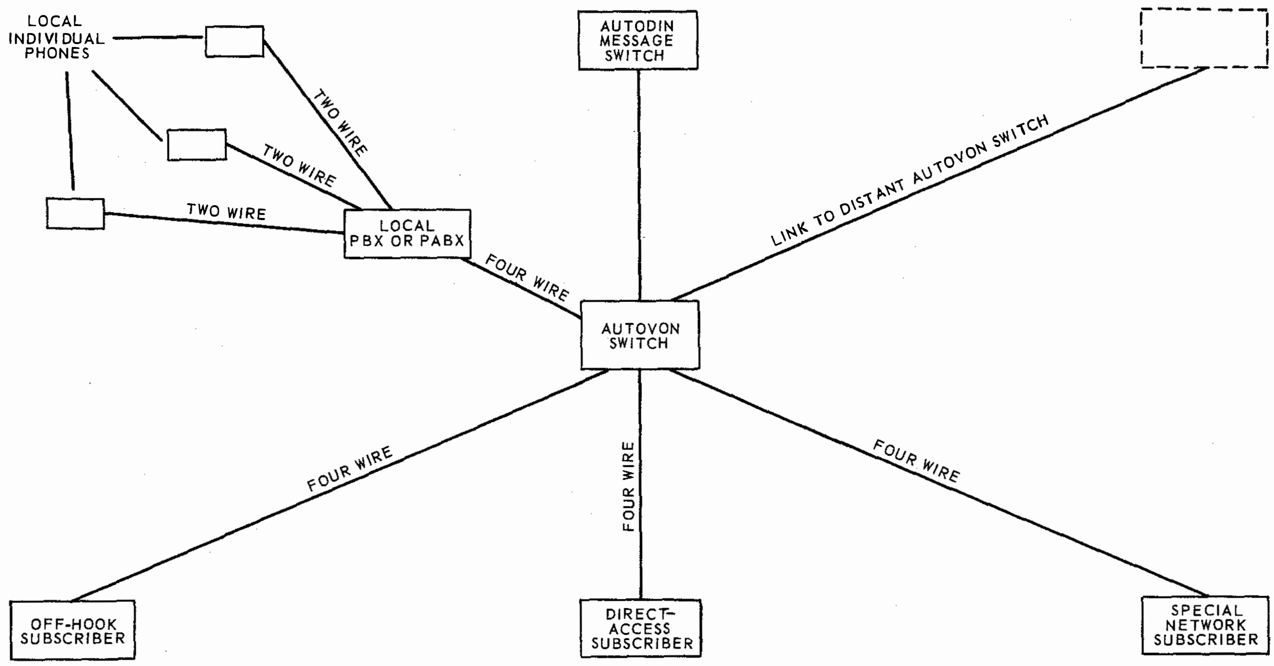

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Figure 6-11.—Area AUTOVON switch and subscribers.

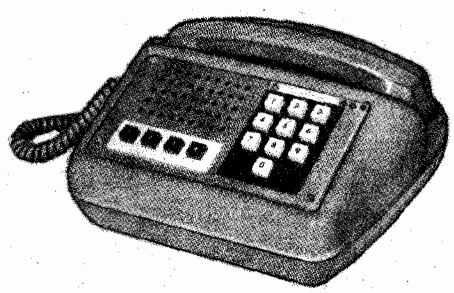

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Figure 6-12.—Type AE-023 four-wire subset.

Off-Hook Service

Certain command and control needs and other operational requirements are met by provision of automatic off-hook (hot-line) preemptive service. When the telephone instrument is lifted off its cradle, it is connected immediately to a predesignated telephone instrument at the distant installation. These instruments cannot be utilized for any other purpose, and only a preset instrument is activated.

Conferences

Conferences can be provided on either a preset or random basis. A preset conference is initiated by the originator to an operator at a preset conference console. An operator keys in the preset codes of a preselected group of subscribers. These codes are translated into a predetermined number of outgoing codes. A call is thereby established to each distant switch indicated. A random conference occurs when an originator desires to call a conference of other subscribers not in a preselected group. This type of conference is accomplished through a PBX operator. If the originator is a four-wire subscriber, a random conference can be made through a dial service assistance (DSA) operator.

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Table 6-1.—Joint Uniform Telephone Communications Precedence System

Precedence designators are for joint use and specify the relative order in which telephone calls should be handled based on the importance (content) of the call.

Numerical Category:	1
Designator:	**FLASH**
Application:	Flash precedence is reserved for alerts, warnings, or other emergency actions having immediate bearing on National, command, or area security. Examples: Presidential use; announcement of an alert; opening of hostilities; land, air, or sea catastrophies; intelligence reports on matters leading to enemy attack; potential or actual nuclear accident or incident; implementation of services unilateral emergency actions procedures, etc.
Numerical Category:	2
Designator:	**IMMEDIATE**
Application:	Immediate precedence is reserved for vital communication (1) having an immediate operational effect on tactical operations; (2) which directly concern safety or rescue operations; or (3) which affect the intelligence community operational role. Examples: Initial vital reports of damage due to enemy action; land, sea, or air reports which must be completed from vehicles in motion such as operational mission aircraft; intelligence reports on vital actions in progress; natural disaster or widespread damage; emergency weather reports having an immediate bearing on mission in progress; emergency use for circuit restoration, use by tactical command posts for passing immediate operational traffic, etc.
Numerical Category:	3
Designator:	**PRIORITY**
Application:	Priority precedence is reserved for calls which require prompt completion for National defense and security, the successful conduct of war, or to safeguard life or property, which do not require higher precedence. Examples: Reports of priority land, sea, or air movement; administrative, intelligence, operational, or logistic activity calls requiring priority action; calls that would have a serious impact on military, administrative, intelligence, operational, or logistic activities if handled as a ROUTINE call. Normally, PRIORITY will be the highest precedence which may be assigned to administrative matters for which speed of handling is of paramount importance.
Numerical Category:	4
Designator:	**ROUTINE**
Application:	Routine precedence is reserved for all other official communications.

Notes:

1. Calls of any precedence may be preempted by the application of the FLASH OVERRIDE capability available to: (1) the President of the U.S., the Secretary of Defense, and the Joint Chiefs of Staff; (2) Commanders of Unified and Specified Commands when declaring either Defense Condition One or Defense Emergency; and (3) CINCNORAD when declaring either Defense Condition One or Air Defense Emergency.
2. Precedence designators FLASH through PRIORITY will be given preemption rights in the order of listing.

CHAPTER 7

COMMUNICATION RECEIVERS

Modern Navy communication receivers use rugged components, which utilize circuits that make them easy to operate and maintain. These communication receivers are capable of receiving several types of signals, and they can be tuned accurately.

RADIO RECEIVER R-390A/URR

Model R-390A/URR (fig. 7-1) is a high-performance, exceptionally stable, general-purpose radio receiver used aboard ship and at shore stations throughout the Navy. It provides reception of CW, MCW, conventional amplitude-modulated, frequency shift RATT and FAX, and single-sideband signals within a frequency range of 0.5 to 32 mc. The receiver is a superheterodyne type with multiple frequency conversion. Double conversion is used when the receiver operates from 8 to 32 mc; triple conversion, from 0.5 to 8 mc.

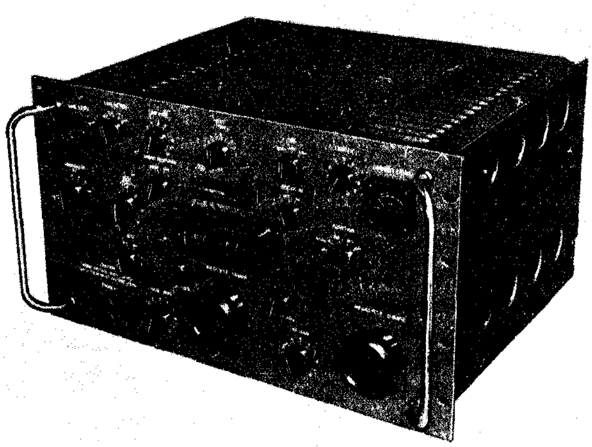

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Figure 7-1.—Radio Receiver R-390A/URR.

Tuning is accomplished by insertion of powdered-iron cores into the r-f and variable i-f coils at a rate controlled by a complex mechanical arrangement of gears, shafts, and cams. The frequency is indicated by a counter-type indicator that is accurate to within 300 cps, an accuracy that permits use of the receiver as an accurate frequency meter.

ANTENNA CIRCUIT

The antenna circuit (fig. 7-2) provides the means for matching antennas of different characteristics to the input of the r-f amplifier.

Antenna relay K101 is actually two relays operated as a single unit. During conditions of standby, calibration, or break-in operation, both sections of K101 are energized. Relay K101A opens the antenna coil primary circuit and grounds both of the wires of a two-wire antenna system. This opening and grounding action of the antenna circuit attenuates the antenna signal input well over 40db. Relay 101B accomplishes the opening and shorting feature for a single-wire antenna system, and the resulting attenuation is also well above 40 db. Resistor R121 drains static charges that may accumulate on a single-wire antenna during mobile operation. Neon lamp I103 fires and shorts R121 when the r-f potential exceeds 80 to 90 volts.

Antennas that have a nominal balance, terminal impedance of 50 to 200 ohms, and terminate in two wires (such as twin lead or dual-conductor

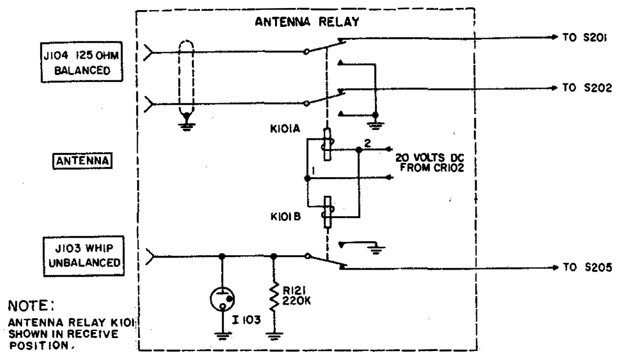

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Figure 7-2.—Antenna relay circuit, simplified schematic diagram.

coaxial cable) are connected to the primary winding of one of six antenna transformers. (See block diagram, fig. 7-3.) The six transformers are employed to cover the frequency range of 0.5 to 32 mc. The transformer in use for a given band is selected by operating the megacycle change switch. Each transformer contains a powdered-iron core, which is movable for purposes of achieving resonance for any desired signal within the range of the receiver. Movement of this tuning core, in conjunction with other tuning cores throughout the equipment, is effected by rotating the kilocycle change control. The signal developed across the secondary of the transformer is applied to the control grid of the r-f amplifier.

The antenna trimmer control (ant. trim.) is part of the antenna transformer circuit. In general, antennas contain a reactive component as well as a resistive component. The antenna trimmer capacitor is used for canceling this reactive component to obtain maximum signal transfer from the antenna to the input of the receiver. The tuning effect of this control is more pronounced with an antenna connected through the unbalanced antenna connector because of the capacitor coupling, which presents a capacitive reactance.

When an unbalanced antenna, such as a whip, is used, the antenna transformer circuits are not used. The signal is coupled through a capacitor directly to the control grid of the first r-f amplifier.

Operational tests and evaluations have shown that many R-390A/URR receivers aboard ship are connected to the coaxial antenna cables in such a manner that performance is impaired substantially. The input marked "Whip Unbalanced" is intended to be used only where a very short wire or cable runs from the antenna to receiver, as in a mobile installation. In the average shipboard installation, there usually is considerable distance between the receiver and antenna. Under these conditions the coaxial cable from the antenna should be connected to the terminal marked "125 Ohm-Balanced," using a UG-970/U adapter connector. The UG-971/U adapter connector may be used as a substitute for the UG-970/U. This connector is built so that it grounds one side of the input terminal, adapting it for use with unbalanced coaxial cables.

R-F CIRCUIT

The r-f amplifier (block diagram, fig. 7-3) increases the amplitude of the signals from the antenna before they are applied to the first mixer stage. This stage also isolates the antenna circuit from the various signals generated by the oscillators in the receiver. The purpose of isolating the circuit is to prevent the radiation of signals by the antenna.

Signals from the antenna circuit are applied through a coupling capacitor to the control grid of the r-f amplifier. The amplified signals appearing at the plate of the r-f amplifier are applied to the tuned tank circuit selected by the megacycle switch. This circuit is arranged to provide a high Q and an increased stability. It also minimizes any detuning that the gain control might cause as a result of tube capacitance variation in the following stage. The r-f gain control adjusts the cathode bias and, consequently, the gain of the r-f amplifier. This control is especially useful for test purposes and during reception of CW and SSB signals. A low setting of this control during CW operation prevents strong signals from producing a pounding effect in the headset or speaker.

Triple conversion is used in the frequency range of 0.5 to 8 mc. Double conversion is used in the frequency range of 8 to 32 mc to

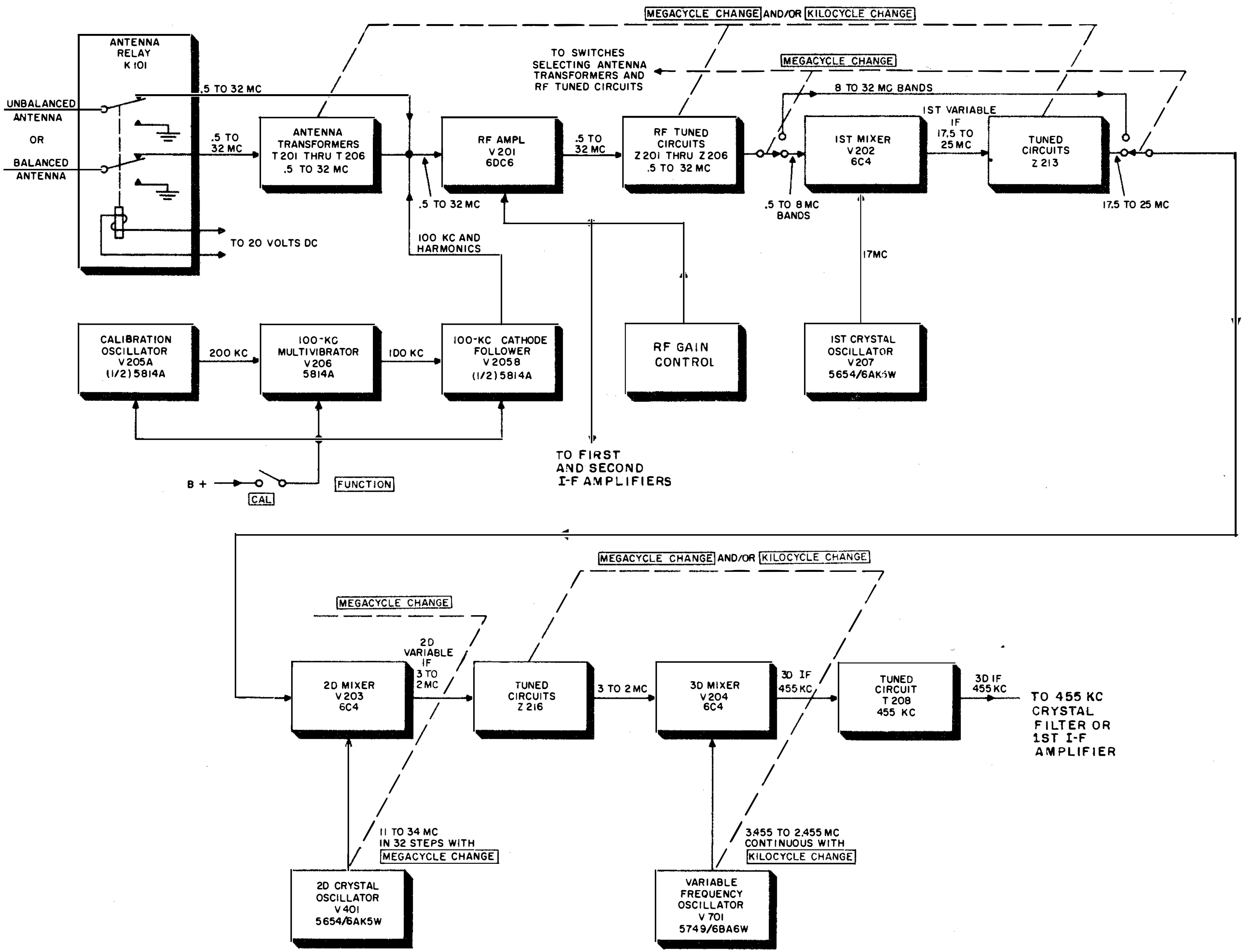

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Figure 7-3.—Section 1 of block diagram of Radio Receiver R-390A/URR.

keep the second variable intermediate frequency between 3 and 2 mc. In the frequency range of 0.5 to 8 mc. therefore, the output from the r-f amplifier is fed through a switch to the grid circuit of the first mixer. In the frequency range of 8 to 32 mc, the output is fed through a switch to the grid of the second mixer.

FIRST MIXER

On frequency ranges from 0.5 to 8 mc, the signals from the output of the r-f amplifier are applied to the control grid of the first mixer. (Refer to block diagram, fig. 7-3.) The 17-mc output of the first crystal oscillator is applied to the cathode, and the two signals are heterodyned in the mixer stage to produce a signal of 17.5 to 25 mc in the plate circuit. The frequency of this signal, which is variable, is the sum of the frequencies of the two input signals.

The plate circuit is tuned over the 17.5- to 25-mc range by changing the positions of the powdered-iron cores in three tuned tank circuits. These tuned circuits (Z213-1, Z213-2, and Z213-3) form a triple-tuned circuit with loose coupling between the coil assemblies. The coils are permeability tuned by the megacycle change control and/or the kilocycle change control.

When the receiver is tuned above 8 mc, the megacycle change control switch shorts the output of tuned circuit Z213-3 to ground. The control switch also opens the plus 150-volt regulated power source to the first crystal oscillator screen grid.

The 17.5- to 25-mc signal from the plate of the mixer is fed through the tank circuits via a coupling capacitor and a parasitic-suppressing resistor to the control grid of the second mixer.

FIRST CRYSTAL OSCILLATOR

The first crystal oscillator (block diagram, fig. 7-3) provides the injection signal to the first mixer stage on the eight lower frequency bands. The oscillator uses a pentode, connected in an electron-coupled Colpitts-type circuit, where a highly selective crystal is substituted for the resonant circuit. The crystal is contained in a crystal oven and is maintained at a temperature between 72° and 78° Centigrade.

The signal is inductively coupled to the secondary winding of the output transformer, and is applied to the cathode of the first mixer.

SECOND MIXER

The second mixer receives 17.5- to 25-mc signals on the control grid from the first mixer, when the receiver is tuned from 0.5 to 8 mc. It receives 8- to 32-mc signals from the r-f amplifier when the receiver is tuned from 8 to 32 mc.

The aforementioned signals, along with the signals from the second crystal oscillator, are heterodyned to produce a difference frequency of 3 to 2 mc.

Unlike the first mixer, the second mixer functions for all bands. Signals are selected from the first mixer or from the r-f stage, and are applied through a capacitor to the control grid. The injection signal from the oscillator is applied to the mixer cathode through the output transformer of the oscillator. The foregoing action serves (1) to isolate the mixer from the oscillator, and (2) to match the low-impedance cathode circuit of the mixer to the comparatively high output impedance of the oscillator plate circuit.

Because the output frequency of the plate circuit is variable over a range of 3 to 2 mc, it is necessary to tune the circuit to resonance. Tuning is achieved by positioning powdered-iron cores in the three output transformers. These cores are positioned by the kilocycle change control.

The signal is coupled through the three tuned circuits by two capacitors. Then it is passed to the grid of the third mixer by a parasitic-suppressing resistor.

SECOND CRYSTAL OSCILLATOR

The second crystal oscillator provides the injection signal to the second mixer on all 32 frequency bands. It uses the same type of tube as the first crystal oscillator. The second crystal oscillator also is an electron-coupled Colpitts-type oscillator circuit that employs crystals as the frequency-determining element.

To permit fewer crystals and to avoid having to use fragile crystals required to cover the higher frequencies, the fundamental frequencies of 15 crystals (or their harmonics) are used. Of these fundamental frequencies, 7 bands operate directly at the fundamental frequency, 22 at the second harmonic, and 3 at the third harmonic of the corresponding crystals.

The output circuit is tuned to 1 of 32 various frequency selections by using 1 of the 15 crystals and 1 of 24 resonant plate circuit selections. The latter usage is accomplished by the setting of the megacycle switch, which connects 1 of the 24 capacitor selections across the plate circuit.

Third Mixer

The output signal (3 to 2 mc) of the second mixer stage is applied to the grid of the third mixer. The variable-frequency oscillator (vfo) signal of 3.455 mc to 2.455 mc is applied from the tuned output circuit and an impedance matching network of the vfo to the cathode of the third mixer through a coupling capacitor.

These two output and vfo signals are heterodyned to give an output of 455 kc in the plate circuit of the third mixer. The output transformer of the third mixer has a broad pass band at 455 kc. This signal is passed through the crystal filter to the first i-f stage.

VARIABLE-FREQUENCY OSCILLATOR

The variable-frequency oscillator generates the signals fed to the cathode circuit of the third mixer. The frequency range is precisely 3.455 mc to 2.455 mc. The vfo oscillator is an electron-coupled Hartley oscillator. The screen grid acts as the plate of an equivalent triode oscillator circuit.

The frequency-determining elements of this circuit are contained in an oven. A powdered-iron core in the coil within this element is moved by the operation of the kilocycle change control. The sealed tuning unit, a precision device, is comparable in accuracy and stability to laboratory frequency standards. It is sealed, and thus is not intended to be repaired in the field.

The plate circuit of the vfo consists of tuned circuit 2702, which includes the primary of the output transformer and a variable capacitor. The secondary coil of this transformer and a capacitor are shunted by a resistor. This resistor broadens the response over the range of 3.455 kc to 2.455 kc. As a result of this broadened response, the output voltage, injected into the cathode of the third mixer, is essentially constant in amplitude with frequency.

CRYSTAL FILTER

The 455-kc output signal from the third mixer is coupled to the i-f subchassis through transformer T208 (fig. 7-4). The secondary winding of this transformer has its center tap grounded, thus placing the ends of the coil 180° out of phase with each other. This coil is coupled into crystal filter Y501.

A quartz crystal, employed as an i-f selectivity filter, contains the properties of a high Q resonant circuit and consists of capacitance, inductance, and resistance. To obtain 0.1- and 1-kc bandwidth, a crystal filter, consisting of tuned circuit Z501 with 455-kc crystal Y501, is used preceding the first i-f amplifier.

Capacitor C520 is also connected to the control grid of the first i-f amplifier. Its purpose is to neutralize the crystal holder capacitance

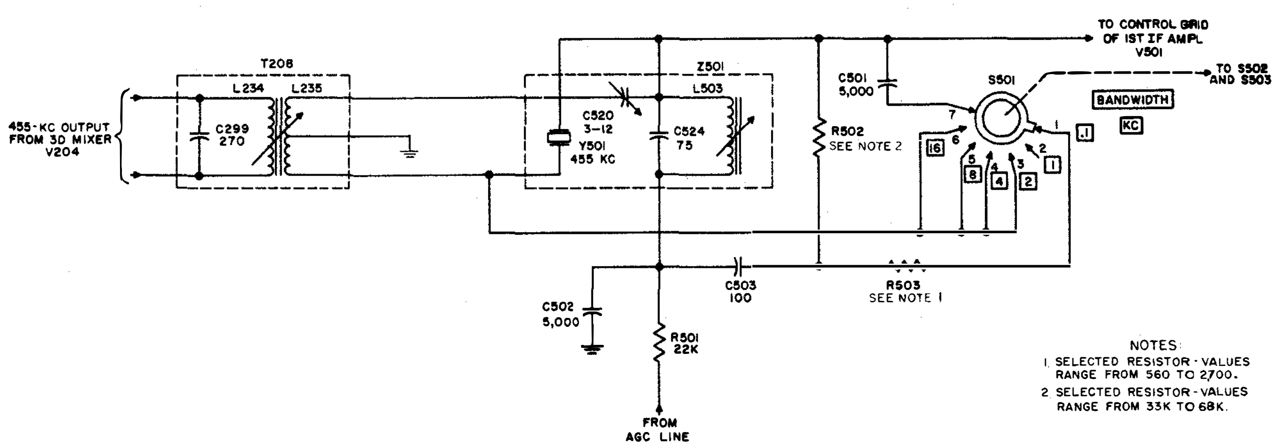

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Figure 7-4.—Crystal filter—simplified schematic diagram.

and stray circuit capacitance. When this capacitor is adjusted properly, extremely narrow and symmetrical bandpass with steep skirts is provided by filter Y501. Coil L503, capacitor C524, and stray capacitances are tuned to 455 kc.

When bandwidth control S501 is in the 0.1-kc or 1-kc position, Y501 functions in the circuit. When the bandwidth control is in the 0.1-kc position, the crystal circuit is loaded by C503, in series with the combination of R502 in parallel with the series combination of C501 and R503. The exact value of R503 is chosen between 560 and 2700 ohms, and the value is selected for a bandwidth of 0.1 kc, and equivalent circuit Q of at least 4500. When the bandwidth control is placed in the 1-kc position, C501 and R503 are removed from the circuit, and the load becomes essentially resistive with R502. This resistive circuit causes the circuit Q to decrease to approximately 450, and bandpass is increased to 1 kc. When this control is turned to the 2-kc, 4-kc, 8-kc, or 16-kc position, the control grid of the first i-f is coupled through capacitor C501 directly to Z501, ahead of crystal Y501. Changing to one of these positions effectively removes the crystal from the circuit.

FIRST I-F AMPLIFIER

The first i-f amplifier stage amplifies the 455-kc i-f signals from the crystal filter. (See fig. 7-5.)

The r-f gain control in the cathode circuit adjusts the bias of the tube. This control is also in the cathode circuits of the first r-f amplifier and the second i-f amplifier.

Four mechanical filters are coupled to the shunt-fed plate circuit of the first i-f amplifier through a coupling capacitor and the bandwidth switch. The bandwidth switch determines which mechanical filter is in the circuit. The bandpass of the i-f amplifiers, and ultimately the entire receiver, is determined by the selection of one of the six switch positions of the bandwidth control. Capacitors in the filter circuits are used to resonate the input and output coils to prevent stray coupling in the unused filters to achieve proper gain and bandpass.

Mechanical I-F Filters

A receiver with perfect bandpass characteristics would be one whose bandpass characteristics were such that the curve would be flat across the top and the skirts would be vertical to a horizontal plane. The selectivity of such a receiver would discriminate against interfering signals not in the bandpass of the receiver. This sort of selectivity is practically impossible to accomplish with conventional tuned circuits. Substitution of mechanical filters in Radio Receiver R-390A/URR approaches this concept.

Figure 7-6 illustrates the typical construction of a mechanical filter. A signal current is passed through the input transducer coil, which causes expansion and contraction (magnetostriction) of the driving wire. Magnetostriction is the dimensional change that certain materials undergo, causing them to lengthen or shorten under the influence of a magnetic field. This mechanical motion is transmitted to the disk resonators through the coupling wires. Each disk resonator is sharply resonant to the intermediate frequency. Several such disks, tuned synchronously, are used to accomplish the required bandpass. The last disk resonator is tied to the driven wire, which induces the output i-f signal into the output transducer coil.

SECOND, THIRD, AND FOURTH I-F AMPLIFIERS

The 455-kc signals from the first i-f stage are fed to the control grid of the second i-f amplifier. As stated previously, the r-f gain control is in the cathode circuit to adjust the bias, thereby adjusting the r-f gain of the receiver. The signals are coupled inductively between all three i-f stages and also between the fourth i-f stage and the detector. Providing attenuation to i-f signals more than 8 kc removed from 445 kc is the most important function of the transformers. This attenuation is made to eliminate spurious responses of the mechanical filters.

DETECTOR AND LIMITER

The detector demodulates the 455-kc i-f signal to recover the intelligence from the modulated signals. The limiter removes noise pulses that exceed the amplitude of the modulation. Before it is fed to the audio channels, the output of the detector passes through the limiter stage.

Detector V506B (fig. 7-7) is connected as a half-wave diode by connecting the control grid and plate together. The secondary winding of

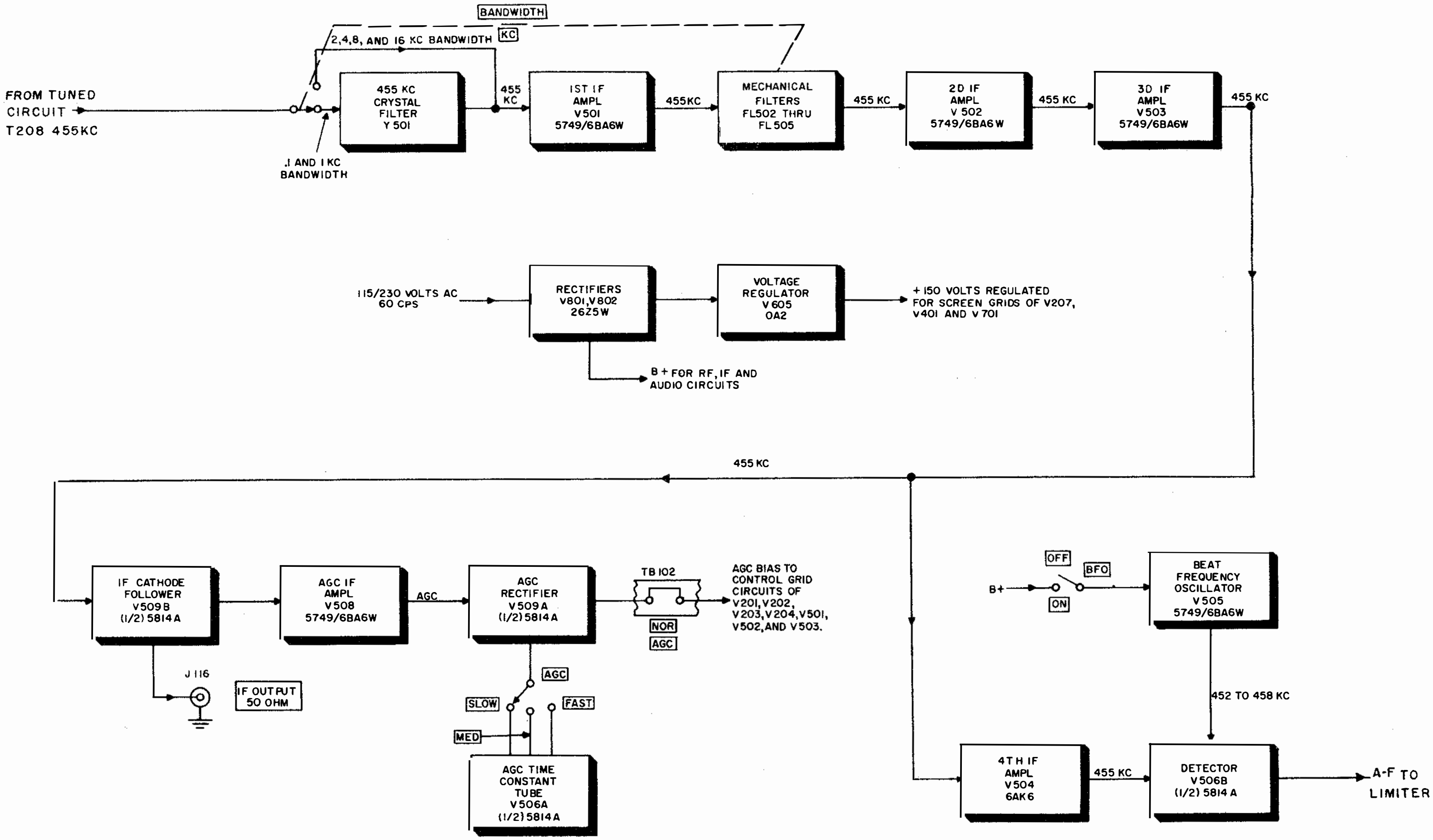

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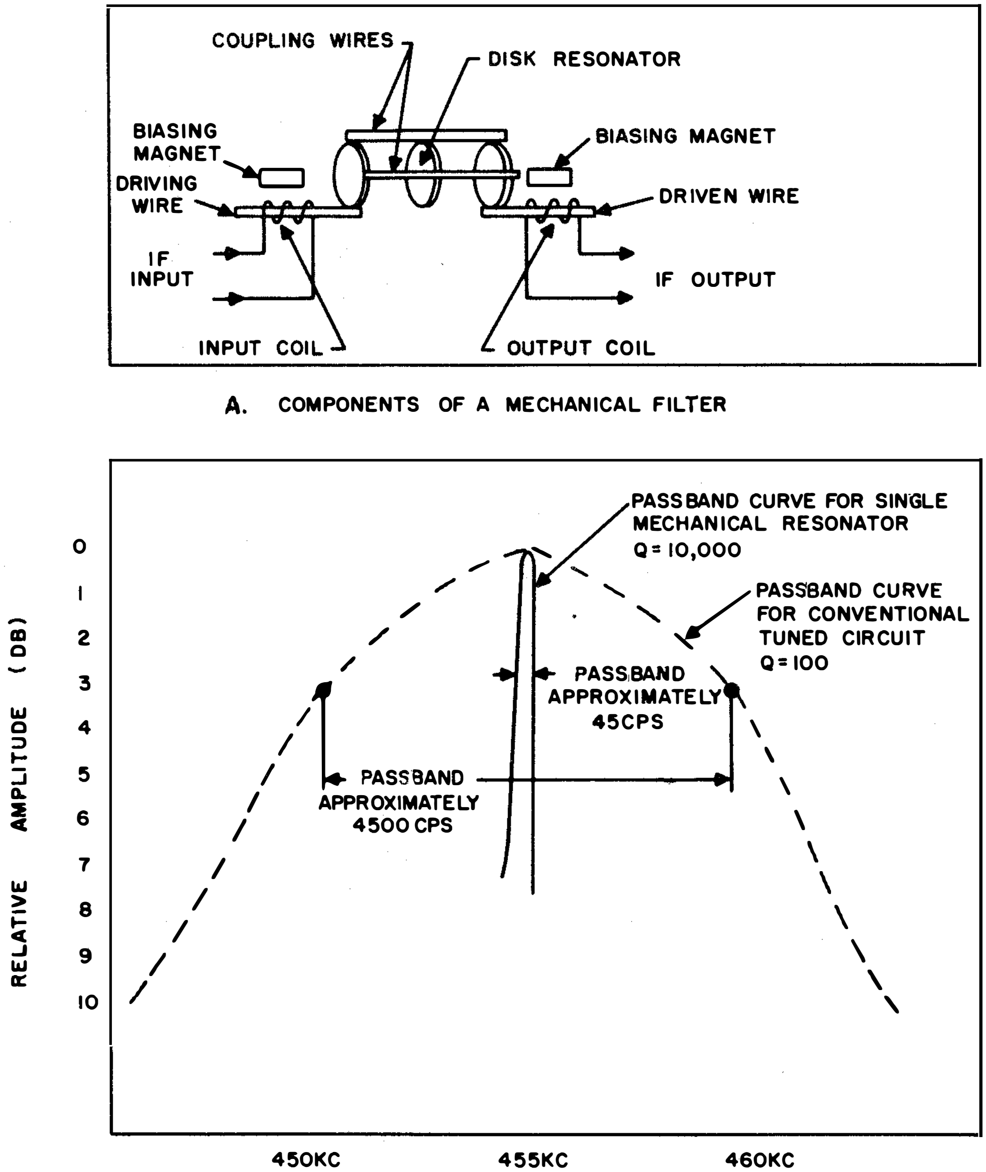
Figure 7-5.—Section 2 of block diagram of Radio Receiver R-290A/URR.



B. TYPICAL PASSBAND CURVES OF CONVENTIONAL TUNED CIRCUIT AND A SINGLE MECHANICAL RESONATOR

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Figure 7-6.—Typical mechanical filters.

T503 feeds the i-f signal to the detector. The diode load consists of resistors R526 and R527. Capacitor C530 and choke coil L502 make up an i-f filter for the purpose of removing i-f signals from the detected audio. A neutralizing capacitor C525 is connected to L512 in T503, and is adjusted to minimize the bfo signal to the 50-ohm i-f output of the receiver. (The 50-ohm i-f output is explained later in this chapter.) The audio signals are taken from the junction of R527 and R526, then are coupled through C531 to limiter tube V507.

Limiter V507 (fig. 7-7) is a series-type diode limited, which couples the audio signals from the detector to the audio channels. When the limiter switch S108 is off, audio signals pass through V507 without any limiting action. When this switch is turned on, the amount of limiting applied is controlled by the limiter control R120.

The B section of V507 is the negative peak limiter; the A section is the positive peak limiter. The limiter effectively removes noise peaks above the level of the modulation. When the limiter control is set to the OFF position, switch S108 grounds cathode resistor R535. Simultaneously, B plus voltage is applied to the diode plates through their plate resistors R532 and R533 and common resistor R534. Audio signals from the detector diode load pass to the plate of V507B and superimpose the audio on the B plus voltage at the plate. This audio signal causes the cathode of V507B to follow the audio signal without any limiting. Because the cathodes of both sections of the tubes are tied together, the cathode of V507A modulates the plate current of this section of the tube. Then the audio signal is coupled through C549 to the grid circuit of the first a-f amplifier.

When the limiter control is turned on, switch S108 removes the ground from the bottom of R535 and short-circuits B plus to ground at the junction of R532 and R533. The entire B plus voltage is dropped across resistor R534. The cathodes of V501 assume a negative threshold, the level of which is determined by the setting of R120. Resistor R119 and capacitor C101 remove the audio component from the threshold voltage, leaving the threshold voltage at the average d-c level. At this level, the threshold voltage is subject to the setting of the limiter control, signal strength, and modulation percentage. Depending on the modulation percentage, the total d-c limiter threshold voltage available is equal to or greater than the peak-to-peak level of the audio signal at the junction of R119 and R526. When the plate voltage (audio peaks) is higher that the threshold voltage, current flows through the diode sections. Negative peaks at the plate (pins 6 and 7) of V507B, that exceed the negative threshold level at the cathode (pin 8), are clipped because V507B does not conduct when the plate is more negative than the cathode. Simultaneously, the audio signal appears on the common cathodes, and is fed to section A of V507. This common connection is at the same negative level, with respect to ground (as determined by the setting of R120). Any positive peaks that are sufficiently positive to cut off the current flow through V507A are clipped. As the limiter control is turned clockwise toward 10, the threshold voltage approaches ground, resulting in more severe clipping. Because the amplitude of the threshold voltage (as well as the audio signal) is a function of the signal strength and modulation percentage, the circuit adjusts automatically to any level of signal input and modulation percentage.

BEAT-FREQUENCY OSCILLATOR

The beat-frequency oscillator (bfo) circuit generates a stable signal that is variable from approximately 452 kc to 458 kc. These signals are 3 kc above and 3 kc below the intermediate frequency. This range of frequencies beats with the 455-kc i-f signal at the detector, producing audio signals variable from 0 to 3000 cycles.

The oscillator circuit is an electron-coupled Hartley-type oscillator. It is similar to the variable-frequency oscillator. The frequency element of this circuit is tunable by means of the bfo pitch control on the front of the receiver. Turning this control gives a frequency of 0 to 3000 cps.

The output is coupled through a capacitor to the plate of the detector. There, it is mixed with the intermediate frequency.

FIRST A-F AMPLIFIER AND A-F CATHODE FOLLOWER

The purpose of the first a-f amplifier and the a-f cathode follower stages is to amplify the audio signals and provide a circuit to distribute the audio signals to the local and line audio channels. These two stages are seen in figure 7-8.

Audio signals from the limiter are fed through an isolation resistor to the control grid of the first a-f amplifier. The audio output of the first a-f amplifier is coupled through a capacitor to the audio response switch. Then it is fed either straight through the switch to the a-f cathode follower (wide position) or through the switch and the 800-cps bandpass filter (sharp position) to the a-f cathode follower.

Amplified audio signals from the audio response switch are fed through a grid resistor to the control grid of the a-f cathode follower.

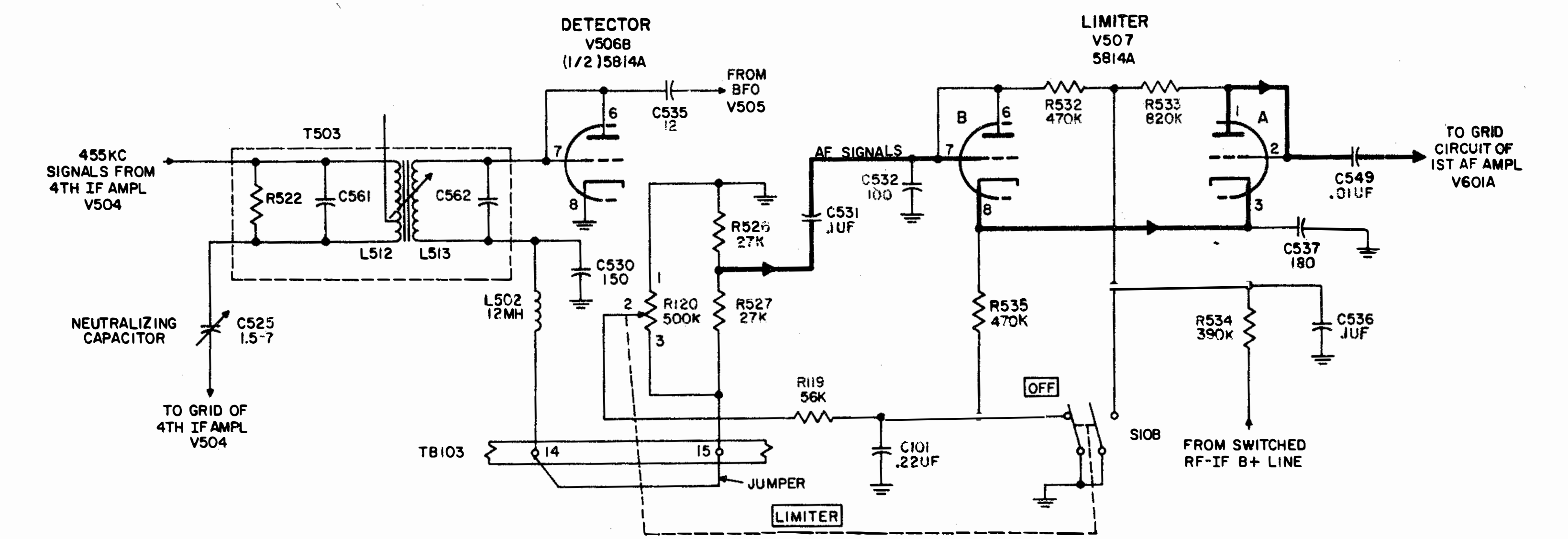

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Figure 7-7.—Detector V506B and limiter V507—simplified schematic diagram.

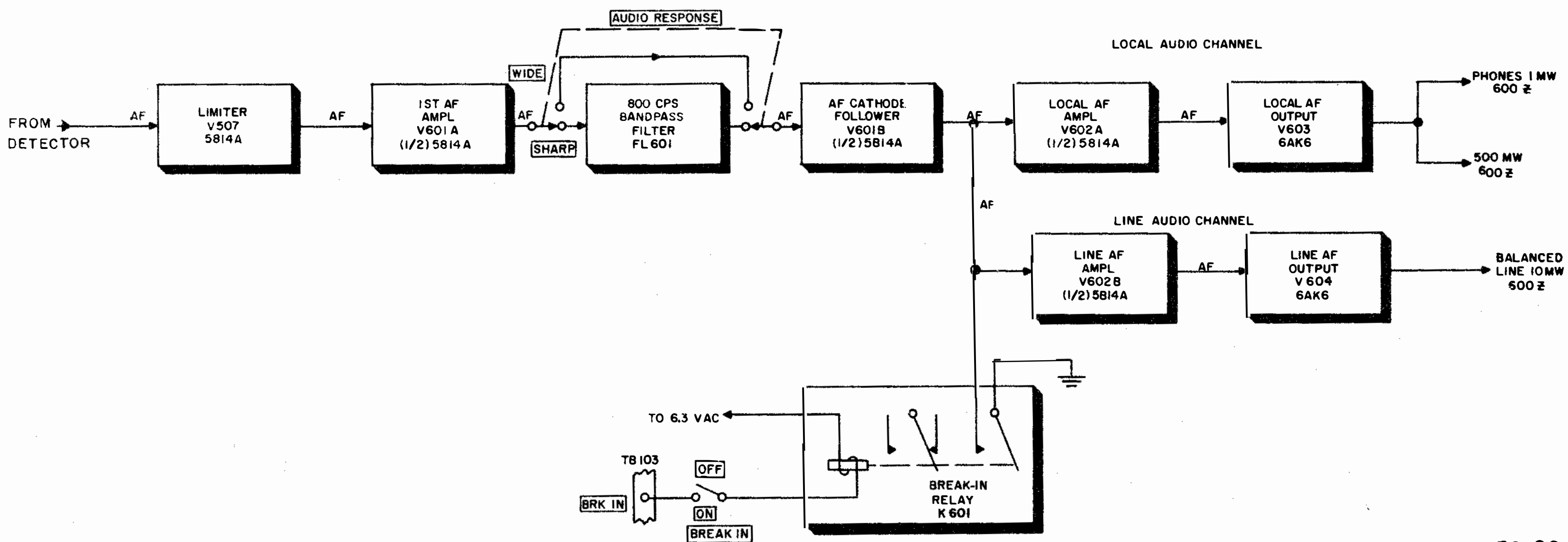

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Figure 7-8—Section 3 of block diagram of Radio Receiver R-390A/URR.

The cathode of this tube is connected to ground through a cathode resistor, in series with the parallel-connected line gain resistor and the local gain resistor. These two controls are on the front panel of the receiver. The line audio signals are taken from the arm of the line gain resistor and are coupled to the control grid of the line a-f amplifier. Local audio signals are fed from the arm of the local gain resistor, through a coupling capacitor, to the control grid of the local a-f amplifier.

Local Audio Channel

Audio signals from the local gain control are fed through a coupling capacitor to the control grid of the local a-f amplifier. The amplified audio output of this stage is coupled to the control grid of the local a-f output amplifier by a capacitor. The primary of the audio output transformer is the plate load for the local a-f output amplifier. The audio signals are induced in the series-connected secondary windings are fed to 600-ohm local audio connectors. The maximum audio output is at least 500 milliwatts (mw). The same audio signal is passed through an attenuator, to a terminal board, and to the phone jack on the front panel of the receiver. The maximum output at these connections is at least 1 mw.

Line Audio Channel

The line audio channel is similar to the local audio channel. It includes a line level meter and a line meter switch for measuring and calibrating the line level meter. When matched into a 600-ohm impedance, the maximum output of this circuit exceeds 10 mw, and is available for teletypewriter operation. The line level meter switch and line level meter are discussed later in more detail.

Audio signals from the line gain control are fed through a coupling capacitor to the control grid of the line a-f amplifier. The signal is amplified and coupled through a capacitor to the control grid of the line a-f output tube. Audio signals developed in the primary of the audio output transformer are induced into the secondary windings. From the secondary windings of the transformer, the signals go through a 600-ohm output impedance network to a terminal board.

SPECIAL CIRCUITS

Circuits to be covered in this section include the—

1. I-f cathode follower, which provides a 50-ohm, 455-kc i-f output signal. It is used with a frequency shift converter in a teletypewriter system.
2. Automatic gain control circuit, which controls the gain of the tubes in the r-f and i-f subchassis in proportion to the average level of the incoming r-f signal.
3. Carrier level meter circuit, which indicates the relative strength of the incoming r-f signal. This circuit also is useful in tuning and calibrating the receiver.
4. Break-in circuit, used for disconnecting and grounding the antenna from the receiver. It also is used for grounding the audio in the receiver when the receiver and a radio transmitter are operated as a radio set.
5. Calibration circuit (100-kc), used for calibrating the receiver at 100-kc intervals over its entire range.

I-F Cathode Follower

Cathode followers, in general, do not amplify. They are used as impedance-matching devices. This stage, being a cathode follower, reflects a very high impedance at its input circuit. It has negligible loading effect on i-f transformer T502, which also feeds the grid of the fourth i-f amplifier. A simplified schematic of i-f cathode follower V509B is diagramed in figure 7-9.

The input circuit of this cathode follower is connected across the secondary winding of T502. The plate circuit is decoupled and bypassed to ground with resistor R539 and capacitor C541. Its plate voltage is obtained from the B plus line.

Two signal output connections are made at the low-impedance cathode of this stage. The first output is developed across the tuned circuit, resonant to 455 kc, which consists of coil L504 and series-connected capacitors C539 and C540. The i-f output connector at the rear panel of the receiver is connected to the junction of C539 and C540 through resistor R552, providing an i-f output impedance to match a 50-ohm load. Resistor R538 develops d-c cathode bias, which maintains the tube operating current at a safe level. A second 455-kc i-f signal is taken directly from the cathode through capacitor

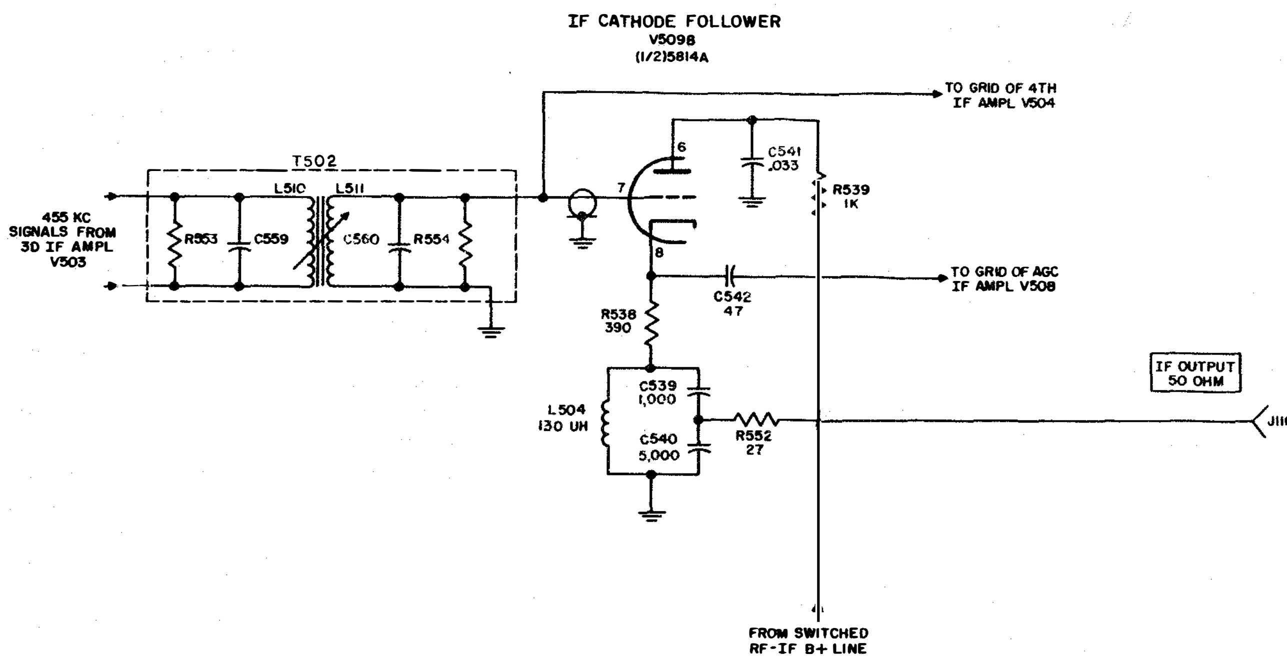

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Figure 7-9.—I-F cathode follower V509B—simplified schematic diagram.

C542 to the grid of the AGC i-f amplifier. The cathode follower stage isolates the AGC i-f amplifier from the fourth i-f amplifier. In this way interaction between the two stages is prevented.

Automatic Gain Control (AGC)

When the function switch on the front panel of the receiver is set on the AGC position, AGC bias is fed to the control grid circuits of the r-f amplifier, the first mixer, the second mixer, and the third mixer in the r-f subchassis. In the i-f subchassis, AGC bias is fed to the first, second, and third i-f amplifiers.

The AGC circuit (fig. 7-10) extends the useful signal strength range of the receiver from a few microvolts to more than 1 volt. The signals appear to have a relatively constant signal strength. The AGC circuit operates only for signals in excess of approximately 5 microvolts, to avoid reducing the gain of extremely weak signals. The AGC switch on the front panel of the receiver allows the operator to select one of three AGC time-constant characteristics. These positions are slow, medium, and fast, and are approximately 5 seconds, 0.3 second, and 0.015 second, respectively. This feature extends the usefulness of the AGC circuit by enabling the operator to choose an AGC time constant that compensates most effectively for fading r-f signals.

AGC I-F AMPLIFIER.—The AGC i-f amplifier stage (fig. 7-10) amplifies the i-f signal from the i-f cathode follower. The signal is coupled through capacitor C542. Resistor R540 is the grid return resistor to ground. The developed AGC bias from the junction of R546 and R547 is connected to the suppressor grid of the fourth i-f amplifier and V508. The purpose is to use them as positive clamps to prevent the AGC line from going more than a few volts positive. The amplified i-f output of V508 is then coupled to the AGC rectifier through capacitor C546.

DELAYED AGC.—The purpose of delaying the application of AGC to the r-f and i-f circuits is to prevent the controlled tubes from having their gain reduced unless the incoming r-f signal is 5 microvolts or stronger. Maximum receiver gain is therefore available for the weakest r-f signals.

The AGC circuit depends on the action of the voltage divider from the B plus line, consisting

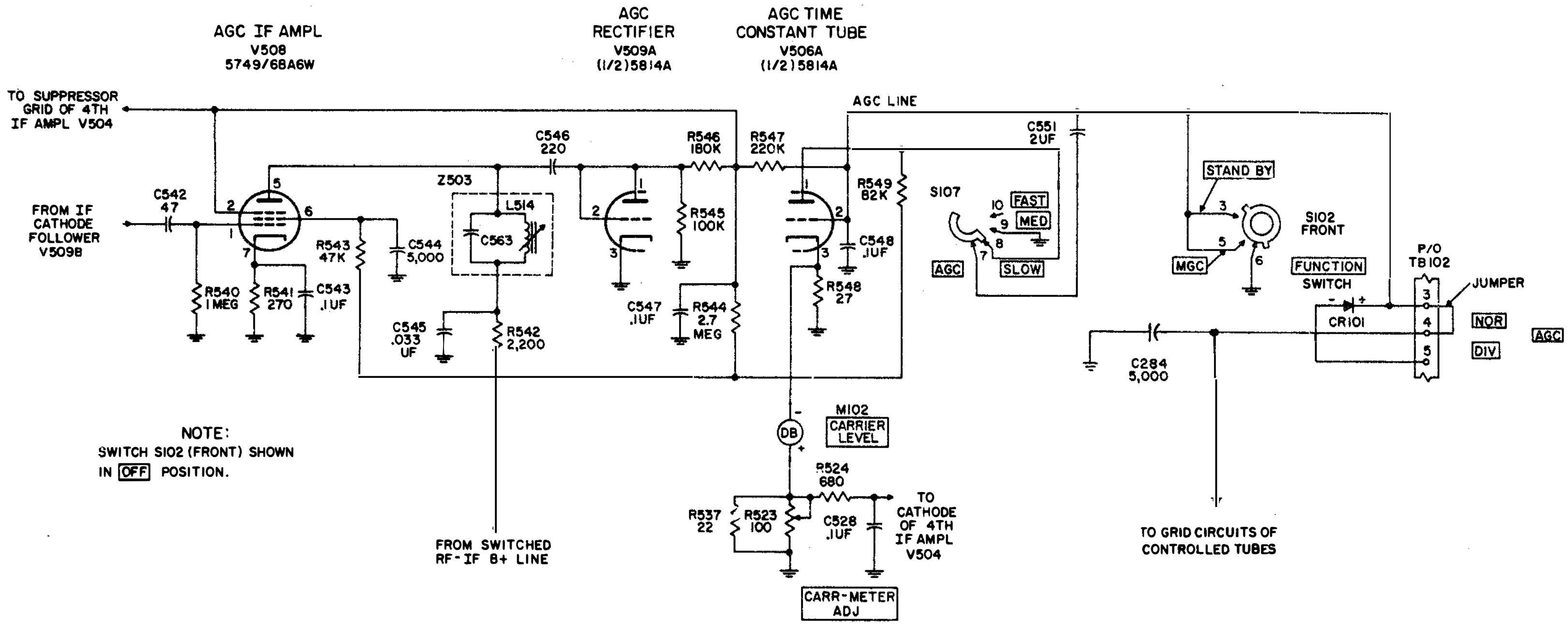

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Figure 7-10.—AGC circuit—simplified schematic diagram.

of R544, R546, and R545. A slightly positive d-c voltage is present at the junction of R546 and R547 and on the suppressor grids of the fourth i-f amplifier and V508. Potential developed at the grid of V506A reduces the positive voltage on the AGC line, and may make it slightly negative, depending on the age and condition of the tube. This positive delay voltage offsets any low level of AGC bias that is developed at the junction of R546 and R547 on account of weak signals.

When the positive peaks of the 455-kc signal are applied to the AGC rectifier, the tube conducts and effectively places a low impedance to ground at C547, putting a negative charge on it. On the next half-cycle, when the 455-kc signal swing is downward, V506A does not conduct, and current flows from C547 through R545 to ground. Thus, the junction of R545 and R546 is made negative with respect to ground. The amplitude of this negative voltage depends on the positive voltage being developed simultaneously at this junction by the B plus voltage divider action. If the developed AGC voltage is larger, a negative voltage appears at both ends of isolation resistor R547 and also on the AGC line. Capacitor C547 bypasses to ground any audio or 455-kc signals appearing at the junction of R546 and R547. Only d-c bias remains at this point.

Depending on the strength of the incoming r-f signals, strong 455-kc signals cause larger currents to flow through R545, and thereby charge C547. Substantial AGC bias is developed and fed, through the AGC line to NOR terminals 3 and 4 of TB102, to the controlled tubes.

When the function switch is in the MGC position, the AGC line and the grids of the controlled stages are grounded. As a result, no AGC bias is allowed to enter the controlled tubes. Under this condition the only control of the receiver r-f and i-f gain is through the r-f gain control.

TIME-CONSTANT SYSTEM.—The time constant of the AGC system is the time required for the AGC line to drop to 37 percent of its full voltage when the signal is removed that produces the AGC voltage. Three levels of AGC time constant are available. The time constants are approximately 0.015 second, 0.3 second, and 5 seconds, respectively.

In the fast position, the ability of the AGC circuits to follow fast-fading r-f signals is maximum. With the AGC switch in this position, the time constant depends upon the resistance-capacitance (RC) combination of R546 and C547, and R547 and C548, as well as each of the AGC decoupling circuits for the individual controlled stages.

In the medium position, the AGC line is influenced by the same RC combinations as in the fast position, plus the additional capacitance of C551 in parallel to C548 through AGC switch S102.

In the slow position, the ability of the AGC line to follow the fading signal is minimum. This rate is often useful for holding the receiver gain constant with on-off keying. It is more desirable than a rapid AGC discharge, which would raise the noise level between characters. In the slow position, the RC combination for the fast position is used. Also used is the effective time constant produced by capacitor C551, connected to the plate of AGC time constant tube V506A. The time constant in this slow position is approximately 16 times that achieved in the medium position.

As the AGC bias at the control grid of V506A goes more negative, the voltage drop across plate resistor R549 decreases, and the plate voltage at pin 1 of V506A rises. At this point, capacitor C551 begins to charge to the level of the AGC voltage, as referenced to the B plus level at the plate of V506A. As this charging advances, the plate voltage of V506A continues to rise, and C551 continues hunting for a new voltage level as a reference for its charging rate. This bootstrap action continues until the grid of tube V506A reaches the level of voltage at the junction R546 and R547. As C551 discharges, its rate of discharge also is retarded. The reason is because the plate of V506A and the switch side of C551 gradually go less positive.

Carrier Level Meter Circuit

The carrier level meter (fig. 7-11) is connected across the AGC time-constant tube, cathode resistor R548, and two cathode resistors of the fourth i-f amplifier tube. These two cathode resistors consist of the carrier meter adjustment potentiometer R523 and R537 in parallel. The remainder of the carrier level meter circuit is so arranged that it forms a bridge circuit with the meter connected to read the bridge unbalance. In the absence of an incoming r-f signal and with the r-f gain control fully counterclockwise, the current through the

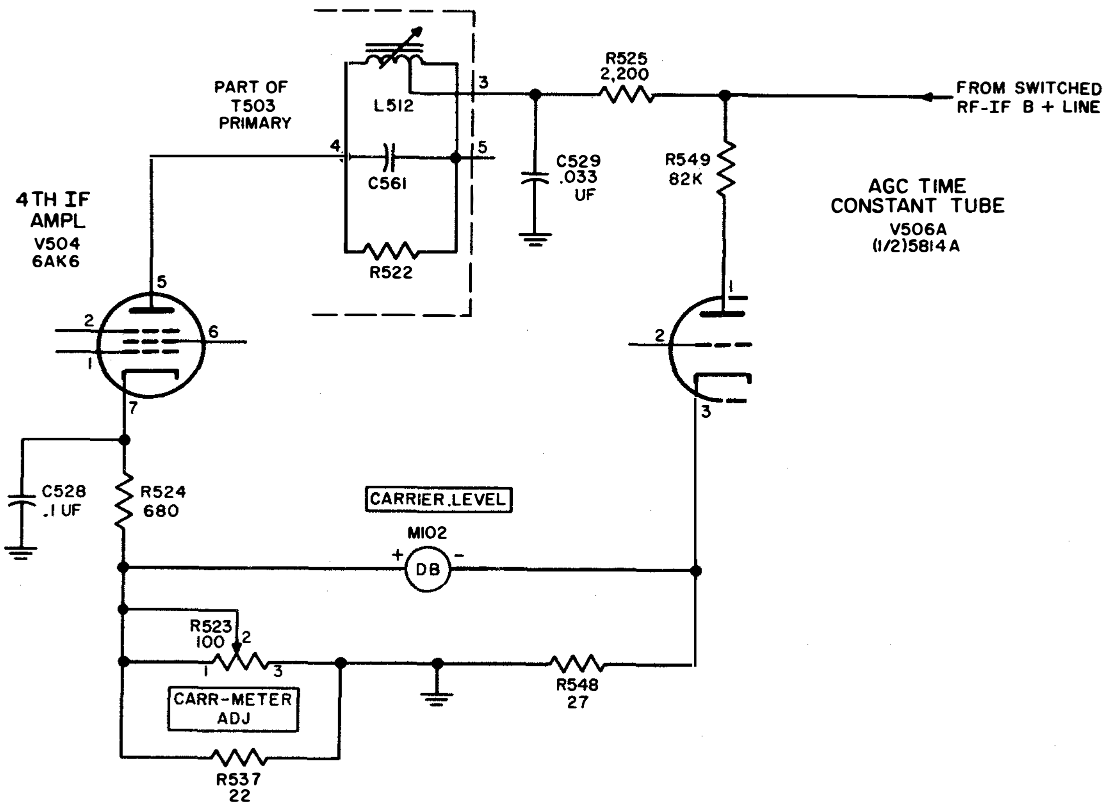

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Figure 7-11.—Carrier level meter circuit—simplified schematic diagram.

fourth i-f amplifier and the AGC time constant tube is adjusted with the carrier meter adjustment control, until the carrier level meter reads zero. At this time the currents through the fourth i-f amplifier and the AGC time constant tube are equal. As the r-f signal is applied to the receiver (r-f gain control fully clockwise), the developed AGC bias is applied to the control grid of the AGC time constant tube, and its plate current and the voltage drop across R548 decrease. Meter M102 then reads some value proportional to the level of the incoming r-f signal. Electron current flows from ground, through R548, through M102, and to the junction of R524 and R523 (which is at a higher potential than pin 3 of the time constant tube). From there the flow is through cathode resistor R524, through the fourth i-f amplifier and its tuned circuit T503, through the decoupling network consisting of R525 and C529, to the B plus line.

When the function switch is in the MGC position, the grid of the time constant tube at pin 2 is grounded, and the carrier level meter reads zero unless the signal input to the grid of the fourth i-f amplifier is large enough to draw grid current. This condition indicates an overload, and the r-f gain control should be turned counterclockwise until the carrier level meter once again reads zero.

Break-In Circuit

When break-in terminal 9 on TB103 (fig. 7-12) at the rear of the receiver is grounded through the ground terminal 16, and break-in switch S103 is in the ON position, current flows through the coil of break-in relay K601 from the 6.3-volt a-c filament circuit to ground.

Terminals 9 and 16 on TB103 normally are not connected. If the break-in feature of the

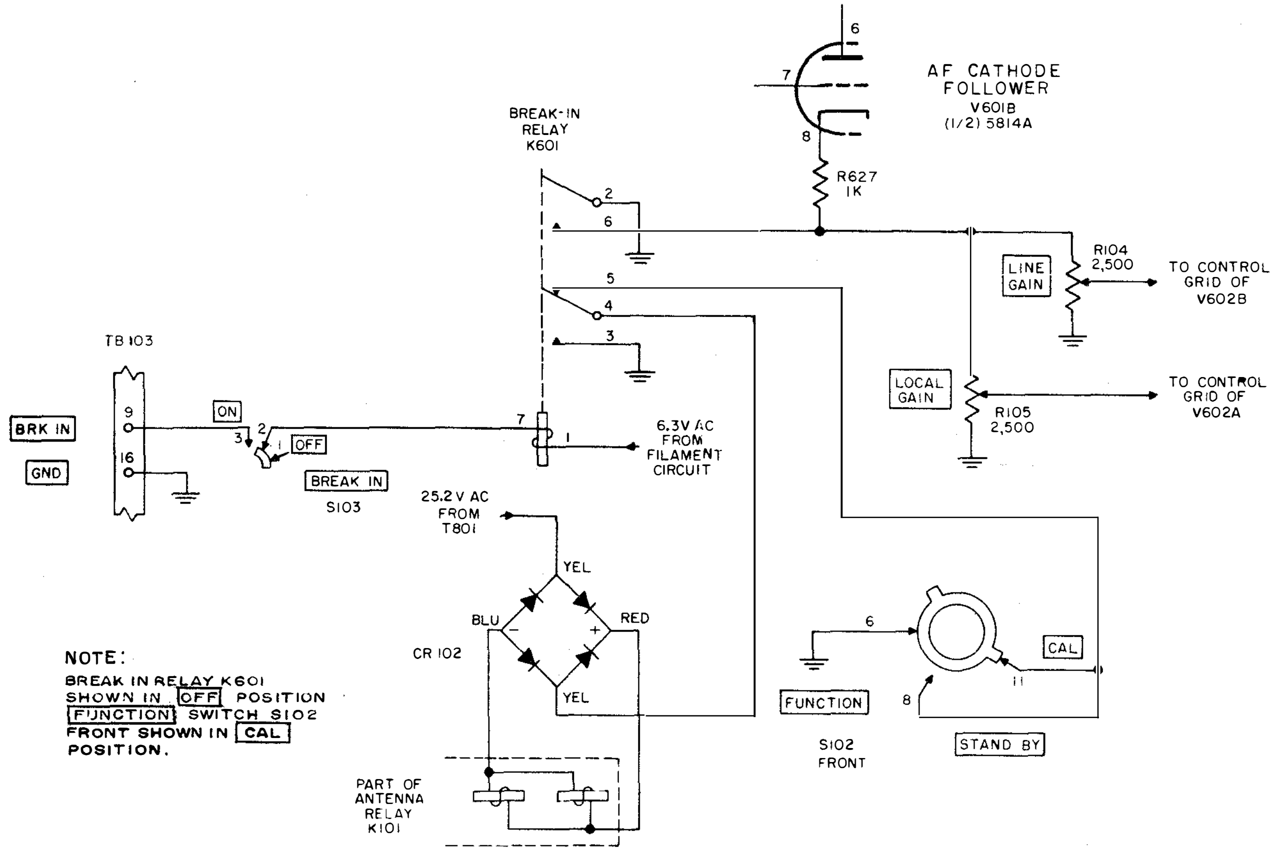

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Figure 7-12.—Break-in circuit—simplified schematic diagram.

receiver is desired, a strap must be placed on the terminal board to connect these terminals.

When the break-in circuit is actuated and break-in relay K601 is operated, terminals 2 and 6 and 3 and 4 make contact. Terminals 2 and 6 ground out the audio signal input to the local and line a-f amplifier stages, silencing the receiver. Terminals 3 and 4 complete a ground circuit to CR102, energizing antenna relay K101. This action disconnects and grounds the antenna signal input. When the break-in relay K601 is de-energized, antenna relay K101 can also be energized by the function switch when the latter is placed in the calibrate or standby position. This ground is applied through the calibrate or standby position of the function switch, through contacts 5 and 4 of K601, to the same connection of CR102.

Calibration Circuit (100-kc)

The calibration circuit (fig. 7-13) consists of the calibration oscillator V205A, the 100-kc multivibrator V206, and the 100-kc cathode follower V205B. A crystal oscillator generates a 200-kc signal, which synchronizes a 100-kc multivibrator. The output from this multivibrator consists of nonsinusoidal waves, producing many 100-kc harmonics. This stage drives a cathode follower, which, in turn, feeds this source of 100-kc markers to the r-f amplifier.

Calibration oscillator V205A is essentially a Pierce crystal oscillator. Resistor R220 is a d-c grid return to ground, and resistor R221 is the plate load resistor. Capacitor C312, at the plate of the calibration oscillator, provides a feedback path to sustain oscillation. The 200-kc crystal Y203 is connected between the control grid and

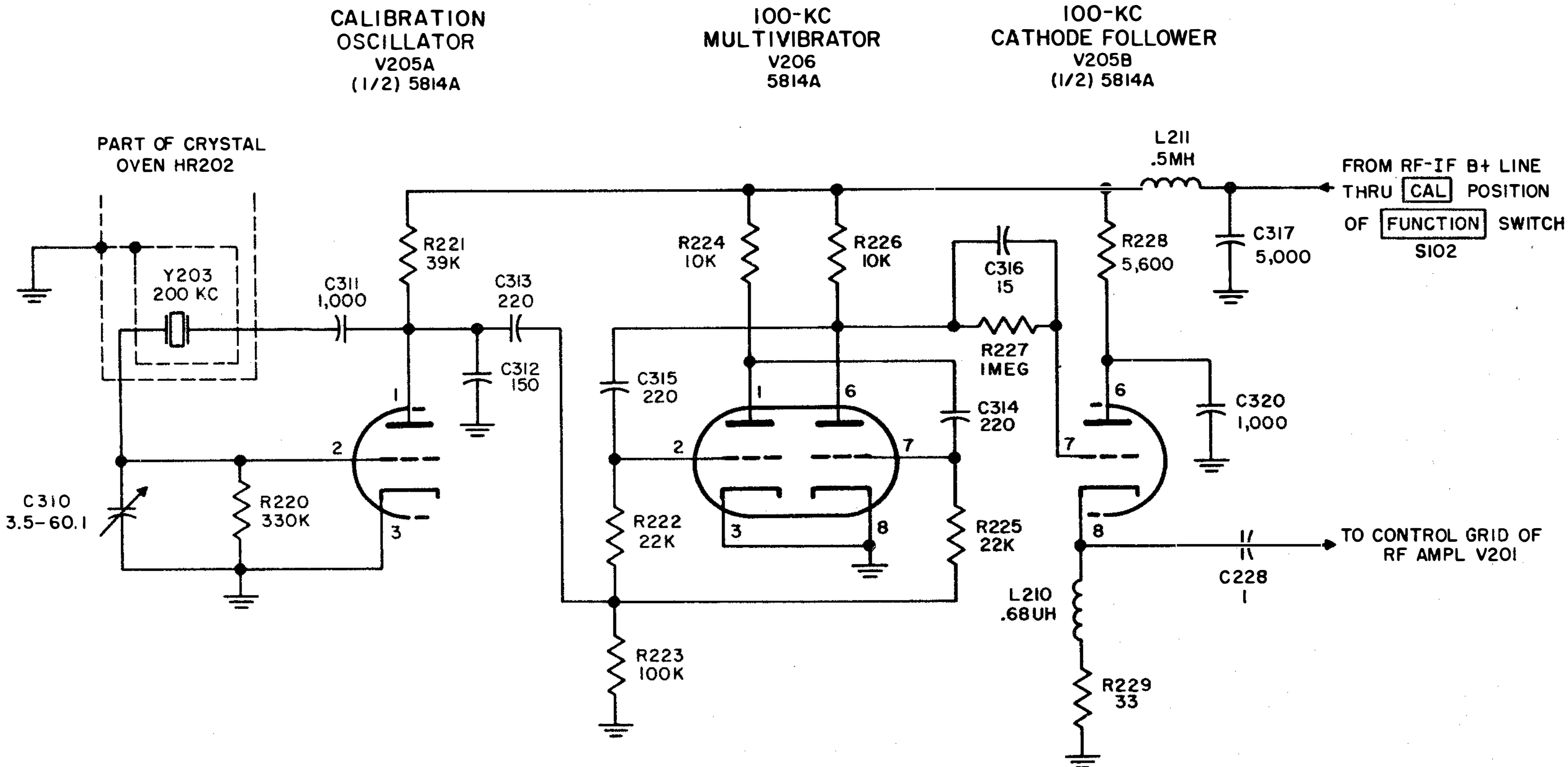

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Figure 7-13.—Calibration circuit (100-kc)—simplified schematic diagram.

the plate through capacitor C311. Crystal Y203 is kept at a constant temperature by the crystal oven. Trimmer capacitor C310 provides a means of making very small frequency adjustments. The calibration circuit harmonics can be checked against a secondary frequency standard or one of the test signals from station WWV. Capacitor C313 couples the 200-kc signal into the grid circuits of 100-kc multivibrator V206 at the junction of grid resistor R225 and R222 and the common grid resistor R223.

Tube V206 is a conventional multivibrator, with the plates of each section coupled back to grid circuits of the other section to sustain oscillation. The frequency of oscillation is governed chiefly by the time constants determined by the values of grid resistors R222 and R225, and coupling capacitors C314 and C315. Resistors R224 and R226 are the plate load resistors for the halves of this twin triode. Capacitor C316 couples 100-kc harmonics to the grid of V205B, placing a high grid circuit impedance across V206. The output of V205B is developed across L210 and R229. Coil L210 resonates with circuit and output cable capacitance above 32 mc, and provides high-frequency compensation to the 100-kc markers at approximately the same amplitude at the control grid of the r-f amplifier. Resistor R229 furnishes the load for the lower frequency harmonics. It also prevents the stage from drawing excessive cathode current. The 100-kc harmonics are fed through coaxial cable and the small 1-uuf coupling capacitor C228 to the control grid of the r-f amplifier. The plate of V205B is kept at r-f ground potential through the decoupling network consisting of R228 and C320. Plate voltage for all three stages is applied through r-f filter choke L211, bypassed by C317, when function switch S102 is in the calibrate position.

POWER SUPPLY SECTION

The power supply section consists of a power transformer, two rectifier tubes, a filter circuit, and a voltage regulator.

Rectifier Circuit

The primary windings of the power transformer may be connected for a 115- or 230-volt a-c power source. The 6.3-volt a-c winding in the secondary supplies power to the break-in relay, oven heater HR202, and all filaments except the beat-frequency oscillator and the variable frequency oscillator. The 25.2-volt a-c winding supplies power to the filaments of the two rectifier tubes, to the variable-frequency oscillator and the beat-frequency oscillator, and to oven heaters HR401 and HR701.

The plates of each rectifier are connected in parallel and, in combination, both tubes function as a full-wave rectifier. Power of 570-volts a-c is developed by the center-tapped high-voltage winding of the power transformer, and is rectified by the two rectifier tubes. The unfiltered d-c voltage from the parallel cathodes of the rectifier tubes is fed to the filter circuit.

Filter Circuit

The B plus distribution follows three separate paths from the power supply filter circuit. The first path is through a choke coil and capacitor filter network to the a-f B plus line. The second path is also through a choke coil and capacitor network. This network supplies B plus to the r-f and i-f sections of the receiver. The third, a regulated B plus path, utilizes a voltage regulator tube, a capacitor, and a resistor voltage divider.

USE OF SINGLE-SIDEBAND CONVERTER

For various modes of operation, use of a single-sideband converter improves the operation of the receiver in a number of ways. Single-sideband converter CV-591A/URR is mentioned here because it usually is installed with the R-300A/URR receiver.

The converter sharpens the overall skirt selectivity of the receiver, rejecting unwanted adjacent signals or interference, with no detrimental effect to the desired signal. The tuning of SSB signals is simplified because the final tuning is done at the converter, not the receiver. A mechanical and electrical bandspread tunes over the i-f bandpass. This effective vernier arrangement easily tunes SSB signals within cycles of correct tone. By means of the bandpass tuning feature or by inverting the oscillator separation, either sideband may be selected.

In addition to single-sideband reception, the bandspread feature of the converter makes it easy to tune CW, MCW, and frequency shift teletype signals as well.

AN/SRR-11, -12, AND -13 RECEIVERS

The AN/SRR-11, -12, and -13 receivers consist of several major assemblies. Each assembly is physically independent of the other. Individual subassemblies are mounted with each assembly, and they plug into an appropriate socket of their major assemblies. When it is necessary to make repairs, and time is an important factor, a defective assembly or subassembly can be replaced quickly with a spare.

The AN/SRR-11, -12, and -13 receivers are designed for Navy shipboard installation. They cover the frequency range from 14 kc to 32 mc. The AN/SRR-11 operates at the low-frequency end of the frequencies covered. The AN/SRR-12 and -13 cover the medium and high frequencies, respectively. Each receiver has its total frequency range divided into five bands, as shown in table 7-1. Continuous tuning within each band is accomplished by the tuning controls located on the front panel of the receiver. The AN/SRR-11 is capable of receiving CW (A_1), MCW (A_2), and frequency shift keyed signals (F_1). In addition to those modes mentioned, the AN/SRR-12 and -13 are equipped with circuits that permit voice (A_3) reception.

The AN/SRR-11 is illustrated in figure 7-14. Radio Receivers AN/SRR-12 and -13, whose external appearances are the same, are represented by a single picture in figure 7-15. Operating controls are mounted on the front panel of the respective receivers.

BLOCK DIAGRAM OF AN/SRR-11

A block diagram of the AN/SRR-11 is shown in figures 7-16 and 7-17. These two illustrations are used to trace the signal path through the receiver.

Table 7-1.—Tuning Bands and Range of Each Band

Band	Low-freq. receiver AN/SRR-11	Medium-freq. receiver AN/SRR-12	High-freq. receiver AN/SRR-13
1	14 to 30 kc	.25 to 0.5 mc	2.0 to 4.0 mc
2	30 to 63 kc	0.5 to 1.0 mc	4.0 to 8.0 mc
3	63 to 133 kc	1.0 to 2.0 mc	8.0 to 16 mc
4	133 to 283 kc	2.0 to 4.0 mc	16 to 24 mc
5	283 to 600 kc	4.0 to 8.0 mc	24 to 32 mc

Signals coupled from the antenna are amplified in two stages of r-f amplification. The first stage, the antenna preamplifier, couples its output to the second stage, the r-f amplifier. The bias, and therefore the gain of the amplifiers, is controlled by an r-f gain control connected in the two stages.

The r-f amplifier couples its output to the mixer. In addition to the signal received from the r-f amplifier, the mixer receives a signal from the local oscillator. The output of the mixer is determined by the band to which the receiver is tuned. On bands 1 and 4, the mixer output frequency is 60 kc. On bands 2, 3, and 5, the output frequency of the mixer is 200 kc. When the output frequency of the mixer is 60 kc (bands 1 and 4), band switch S1 is set so that the signal passes through the filter and the first i-f amplifier.

The first i-f amplifier of the first i-f assembly is a frequency converter for bands 1 and 4. On bands 2, 3, and 5, it is an i-f amplifier. It receives the 60-kc signal from the filter. This signal is mixed with a 140-kc signal generated within the stage to produce a sum frequency of 200-kc output.

On bands 2, 3, and 5 of the mixer output is already 200 kc and needs no further mixing. Therefore the first i-f assembly is bypassed entirely (S1 in position shown).

The output of the first i-f assembly, whether heterodyned or bypassed, is coupled to the second i-f assembly. The latter section consists of filters, three stages of 200-kc i-f amplification, a diode detector, a beat-frequency oscillator and mixer, and a cathode follower.

The signal enters the second i-f assembly through either of two filters. The filter selected depends on the setting of the reception control switch S2A, which is located on the receiver front panel (fig. 7-14). When the switch is set at FSK, A_1 BROAD, or A_1 SHARP (as indicated by the reception control), the signal is fed through the sharp filter. This filter has a bandpass of 3.2 kc centered on the 200-kc intermediate frequency. When S2A is set at A2, the medium filter is selected. The bandpass of the medium filter is 8 kc, centered on the 200-kc intermediate frequency.

The output of the selected filter is amplified in the three i-f amplifiers. The first two stages are controlled by a section of the r-f gain control. The output of the third i-f amplifier is fed to the diode detector, the bfo mixer, and a cathode follower.

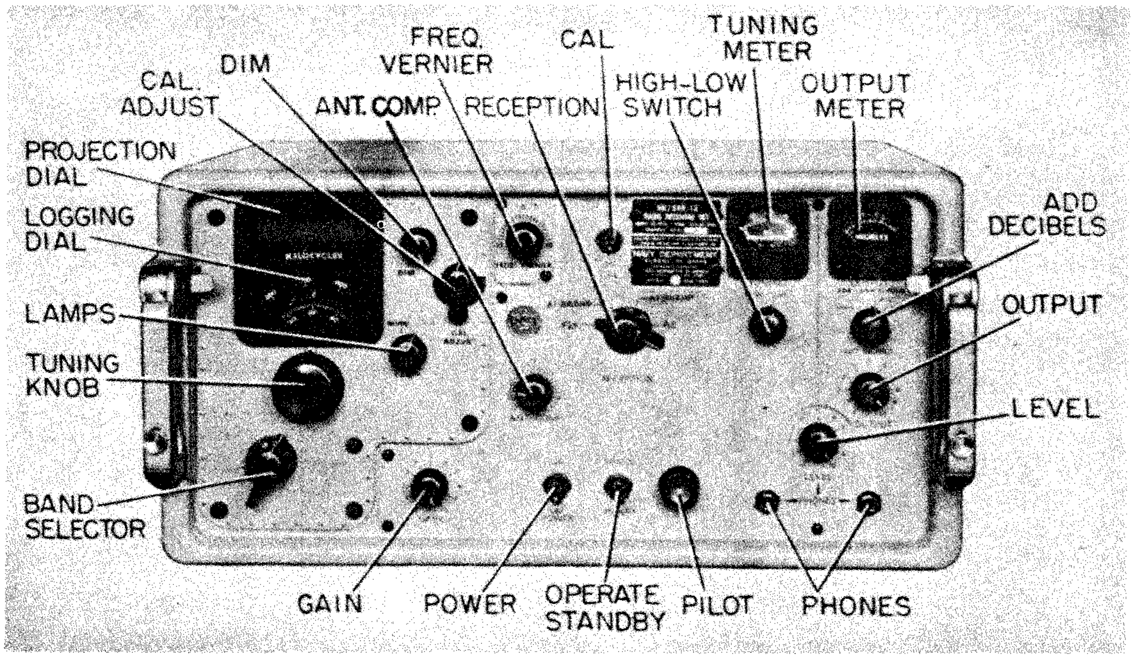

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Figure 7-14.—Radio Receiver AN/SRR-11.

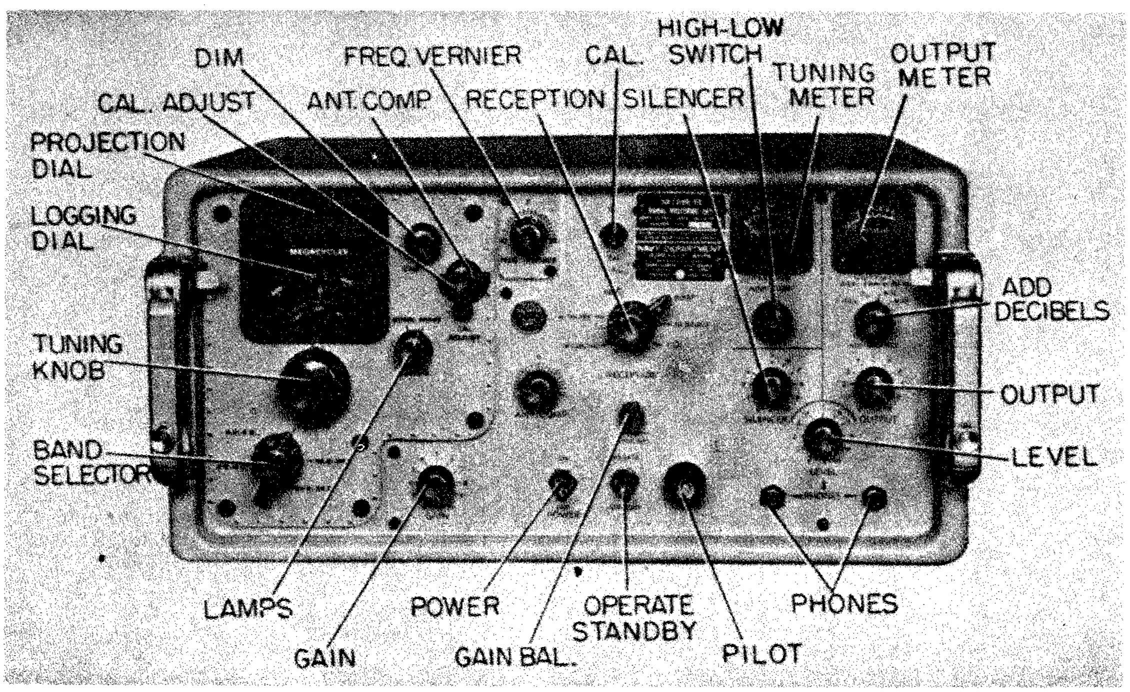

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Figure 7-15.—Radio Receiver AN/SRR-12 and -13.

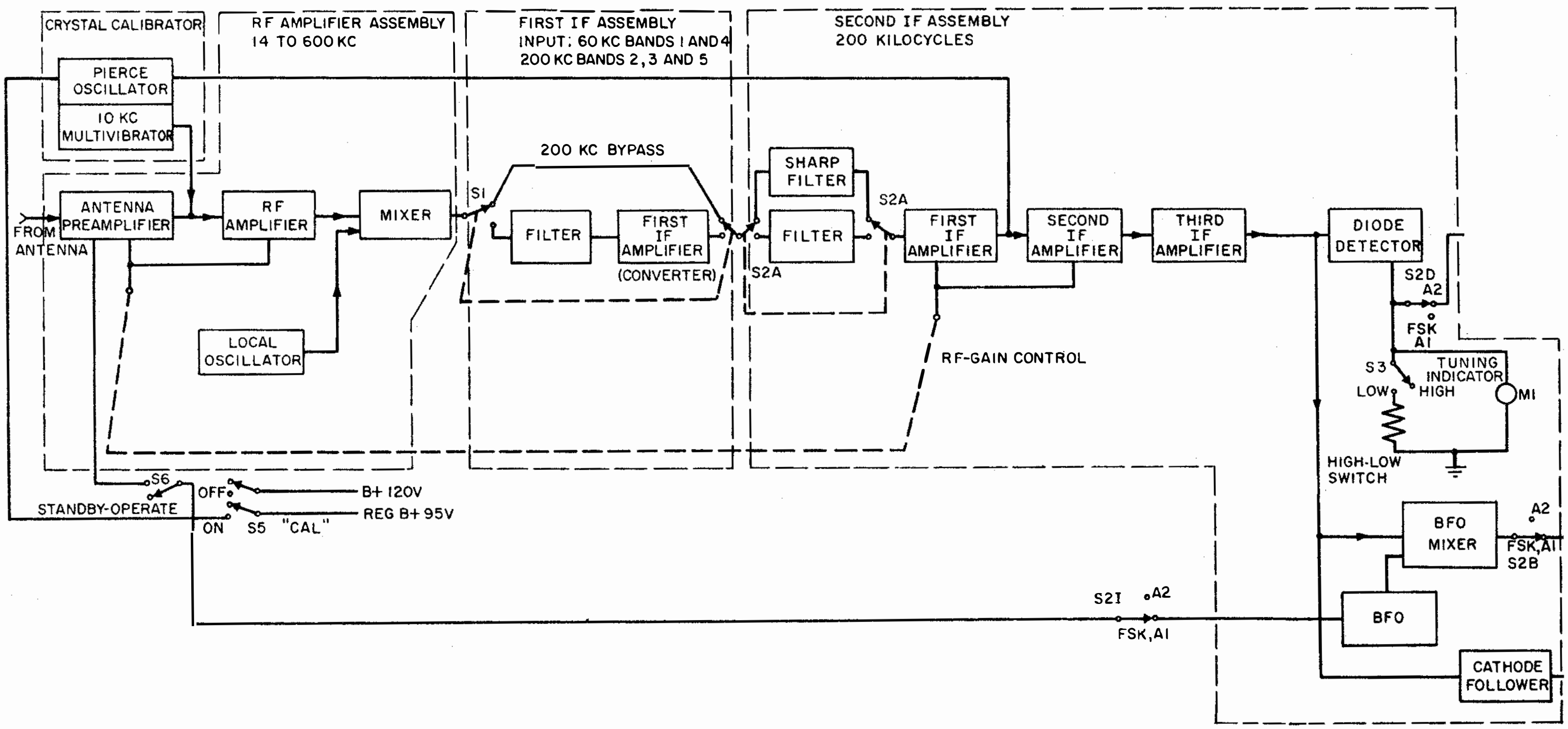

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Figure 7-16.—Section 1 of block diagram of AN/SRR-11.

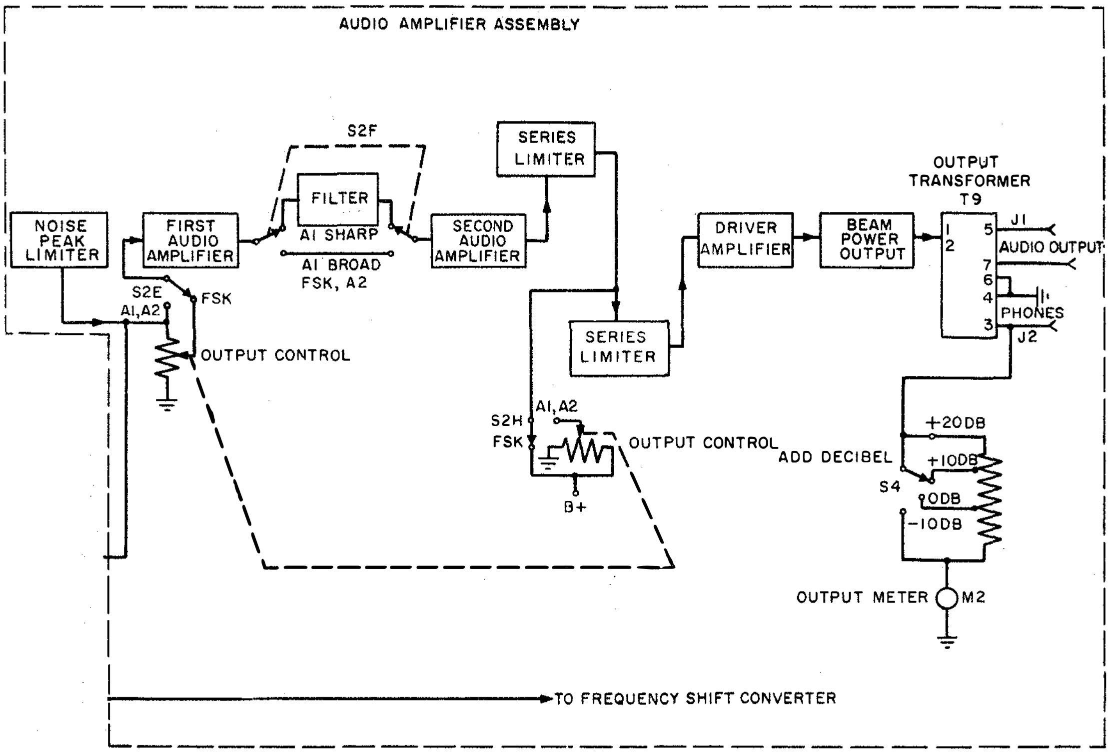

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Figure 7-17.—Section 2 of block diagram of AN/SRR-11.

The diode detector receives the i-f signal during MCW reception, feeding its output through switch S2D to the noise limiter. During normal signals, the output of the noise limiter is developed across the output control. When a noise pulse of greater than normal amplitude arrives, the noise limiter automatically cuts off the audio output for the duration of the noise pulse. During C-W and frequency shift reception, the signal received at the bfo mixer is heterodyned to produce a signal in the audio range. Its output is passed through S2B to the output control.

Tuning meter M1 in the detector circuits shows the diode detector output current and gives a visual indication of tuning.

The cathode follower of the second i-f assembly is provided to supply frequency shift signals to a frequency shift converter.

For CW and MCW reception (positions A_1 and A_2) the input to the first audio amplifier is obtained directly from S2E. In these positions of S2, the output control is inactive. Frequency shift signals are applied to the first audio amplifier from the arm on the output control.

The second audio amplifier receives the output of the first audio amplifier either directly or by way of a narrow bandpass filter. During A_1 reception S2F is placed in the A_1 SHARP position to insert the filter and decrease adjacent channel interference. The A_1 BROAD, A_2, and FSK positions of the switch bypass the filter.

The output of the second audio amplifier is applied to two series limiters. During A_1 and A_2 reception, alternate limiters clip the signal equally on the positive and negative half-cycles. When the reception control is switched to the FSK position, the series limiters are inactive.

The signal is then fed to a driver amplifier, which increases the signal strength required to drive the beam power output amplifier. The latter stage feeds the output transformer T9. The secondary of the transformer supplies a balanced 600-ohm line through its terminals 5 and 7, and applies the signal to the phone jack through an unbalanced winding connected between terminals 3 and 4. The signal developed in the unbalanced line is also applied to the output meter M2, which indicates the signal level in decibels. Multipliers are switched in series with the meter to increase the decibel range that may be covered. Zero db corresponds to power level of 6 mw through a 600-ohm lead.

The power supply used in the AN/SRR-11 is a conventional full-wave supply, and is considered in this discussion.

The crystal calibrator circuit provides accurate frequency checkpoints, which may be used for calibrating the main tuning dial. The checkpoints occur at every 10 kc throughout the tuning range of the AN/SRR-11. A calibration switch S5 is connected so that, in the OFF position, the B voltage is removed from the calibrator. When placed in the ON position, S5 allows the B voltage to be applied to the calibrator and removed from the preamplifier and the bfo. This arrangement presents interference with the crystal calibrator from either externally applied signals or the bfo.

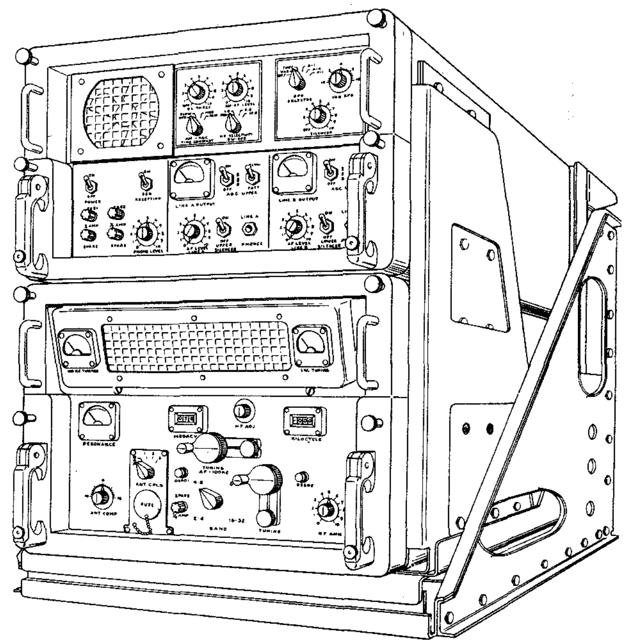

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Figure 7-18.—Radio Receiving Set AN/WRR-2.

MODEL AN/WRR-2 RECEIVER

One of the latest shipboard radio receivers for the MF/HF bands is the AN/WRR-2, shown in figure 7-18. (The same receiver, with rack mounting for shore station use, is called AN/FRR-59.)

The AN/WRR-2 is a triple-conversion superheterodyne receiver. It covers the frequency range 2 to 32 mc. This modern receiver is intended primarily for the reception of single-sideband transmissions with full carrier suppression. It can be used also to receive conventional amplitude-modulated signals of various types, including CW, MCW, voice, facsimile, and frequency shift RATT.

In order to meet strict frequency tolerances, special features provide extremely accurate tuning and a high degree of stability over long periods of operation. Simultaneous use can be made of both upper and lower sideband channels for receiving two different types of intelligence. Both single-sideband and conventional a-m signals cannot be received at the same time, however.

Other features of the receiver also contribute to its high performance. Any error in frequency resulting from drift in the local oscillator is removed before the last conversion by a drift-canceling circuit. Receiver tuning is in 100-kc steps. Through the use of an interpolation oscillator, each 100-kc increment is scanned either continuously or in 1-kc steps. Counter-type tuning dials permit accurate presetting to any desired frequency.

The frequency range of 2 to 32 mc is covered in four bands: band 1 2.0 to 4.0 mc; band 2 4.0 to 8.0 mc; band 3 8.0 to 16.0 mc; and band 4 16.0 to 32.0 mc.

SYSTEM BLOCK DIAGRAM

The basic block diagram of the receiver (fig. 7-19) shows the functional relationship between the two equipment drawers that make up the receiver. The lower drawer (fig. 7-18) is the electronic frequency converter CV-920/WRR-2, generally referred to simply as the converter. The upper drawer is the intermediate frequency—audiofrequency amplifier AM-24771 WRR-2, called the demodulator.

The converter receives a signal in the 2- to 32-mc range and converts it to an 80-kc intermediate frequency. It also generates an 80-kc signal for carrier reinsertion. Both signals

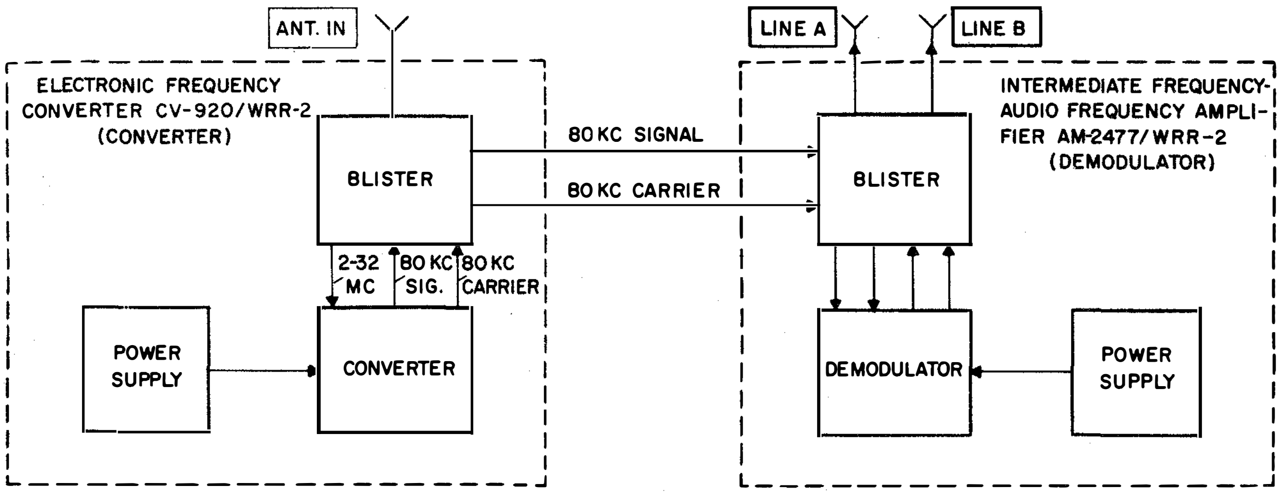

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Figure 7-19.—Radio Receiving Set AN/WRR-2 basic block diagram.

are applied to the demodulator, the basic functions of which are i-f amplification, detection, and a-f amplification.

FUNCTIONAL OPERATION

The functional block diagram in figure 7-20 shows the converter and demodulator as separate major units. The main signal path through the various assemblies is indicated by a heavy line.

Converter

An r-f signal from the antenna is applied to the antenna coupler, which provides three degrees of signal attentuation for optimum performance under strong signal conditions. The output of the antenna coupler goes to the preselector, where it is amplified and fed to a mixer. Here it is combined with a locally generated r-f signal from the high-frequency oscillator to produce the first i-f signal at a frequency between 1625 and 1725 kc. This frequency is selected by the tunable i-f filter and applied to the injection i-f amplifier, which in turn produces the 80-kc signal to be fed to the demodulator. The injection i-f amplifier performs intermediate frequency amplification and two frequency conversions—the first from 1625—1725 kc to 220 kc and the second from 220 kc to 80 kc.

Demodulator

In the demodulator, the 80-kc filter receives the signal and distributes it to the amplitude-modulated detector-amplifier and upper sideband (USB) detector-amplifier. The latter unit supplies the 80-kc signal to the lower sideband (LSB) detector-amplifier.

In the detector-amplifier, the 80-kc signal is amplified and detected. Several stages of audio amplification follow. A beat-frequency oscillator (bfo) is also included for CW reception. Audio limiting, silencing, and automatic gain control circuits are also included but are not shown in figure 7-20.

In the USB detector-amplifier, the 80-kc signal is amplified and applied to a demodulator, where it is mixed with an 80-kc carrier to produce an audio output. A two-stage audio amplifier, a silencing circuit, and an AGC circuit are also included but are not shown in the block diagram.

In the LSB detector-amplifier, the 80-kc signal is amplified and also applied to a demodulator similar to that in the USB detector-amplifier. Included also are a two-stage audio amplifier, silencing circuit, and AGC circuit.

The AN/WRR-2 receiver can be used with all presently installed converter-comparator auxiliary equipment for receiving facsimile and frequency shift teletype signals.

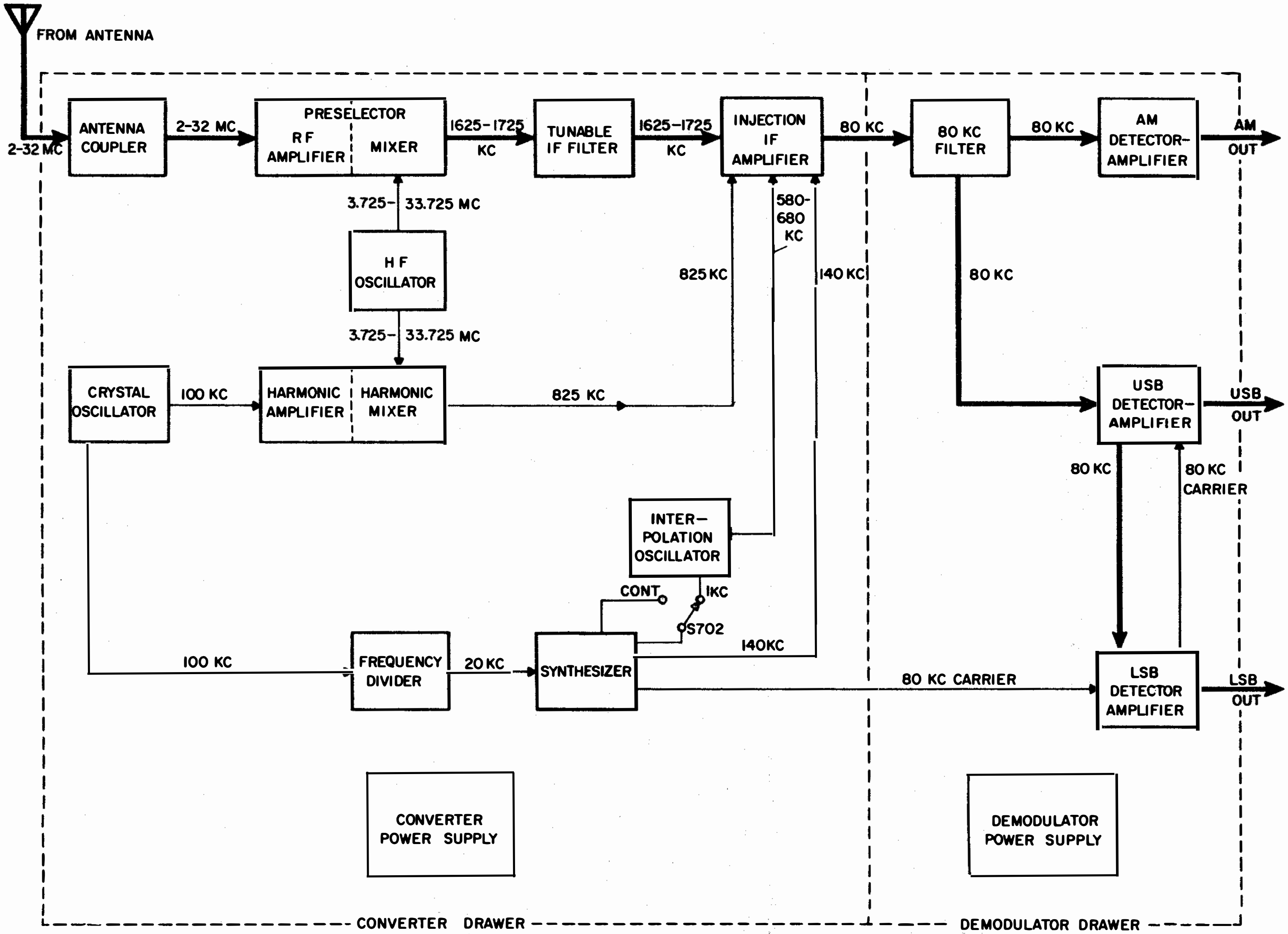

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Figure 7-20.—Functional block diagram of Radio Receiving Set AN/WRR-2.

CHAPTER 8

RADIO TRANSMITTERS

Modern medium-frequency and high-frequency shipboard transmitters must be capable of transmitting over a wide range of frequencies. In addition to CW and radiotelephone modes of operation, these transmitters must be used also for RATT and FAX transmissions. They must be of rugged construction for long service life. Transmitters that meet these requirements have become quite complex and, because of limited space available for radio installations in naval ships, they are of compact construction.

A shipboard transmitter that has the foregoing characteristics is model AN/SRT-15. This transmitter is chosen for presentation in this chapter because it is a modern, sophisticated communication transmitter in wide usage throughout the Navy. Its electronic circuits represent, to a great extent, most of the new features of present-day transmitters.

Information on other transmitters appears in later portions of this training course. The VHF/UHF transmitters are included in chapter 9, and SSB equipment is described in chapter 11. Other MF/HF transmitters are described briefly in Radioman 3 & 2, NavPers 10228.

AN/SRT-15 TRANSMITTER

The AN/SRT-15 (fig. 8-1) is one model of a new series of radio transmitters. This transmitter and other late models are replacing older equipments such as Navy models TAJ, TBL, TBK, and TBM. Transmitters in this series are capable of performing operations that heretofore required several separate transmitters. Space needed in newer transmitters is considerably less than for older models.

Three transmitters constitute the AN/SRT series. They are known as the AN/SRT-14, -15, and -16. The AN/SRT-14 is the basic transmitter, and has a power output of 100 watts. The AN/SRT-15 is the same, with the addition of a 500-watt booster amplifier and its associated power supply, thus providing optional output power of either 100 or 500 watts over the frequency range 2 to 26 mc. Output is limited to 100 watts in the MF band from 0.3 to 2 mc. The AN/SRT-16 consists of two AN/SRT-14 equipments plus the booster amplifier. It furnishes two entirely independent transmitting channels. One channel is limited to a 100-watt output, whereas the other may be transmitted at the 500-watt level or at the 100-watt level. Although carrier levels are referred to as 100 and 500 watts, actual output varies over the frequency range, depending upon the frequency and the mode of operation. All three transmitters cover the frequency range 0.3 to 26 mc, and may be used for CW, radiotelephone, radioteletypewriter, and FAX transmissions. Further discussion in this chapter is limited to model AN/SRT-15.

The main transmitter cabinet holds five pullout drawer-type chassis. From top to bottom these units are (1) radiofrequency amplifier (RFA), (2) low-level radio modulator (LLRM), (3) radiofrequency oscillator (RFO), (4) low-voltage power supply (LVPS), and (5) medium-voltage power supply (MVPS).

The 500-watt booster amplifier is contained in the smaller cabinet to the left of the transmitter. In his cabinet the top unit is the high-level radio modulator (HLRM). The lower unit is the high-voltage power supply (HVPS).

BLOCK DIAGRAM

A functional block diagram of the AN/SRT-15 transmitter is shown in figure 8-2. The relationship existing between major units, as well as the progression of the signal through the set can be seen in the diagram. A description of each major component of the transmitter is given later in this chapter.

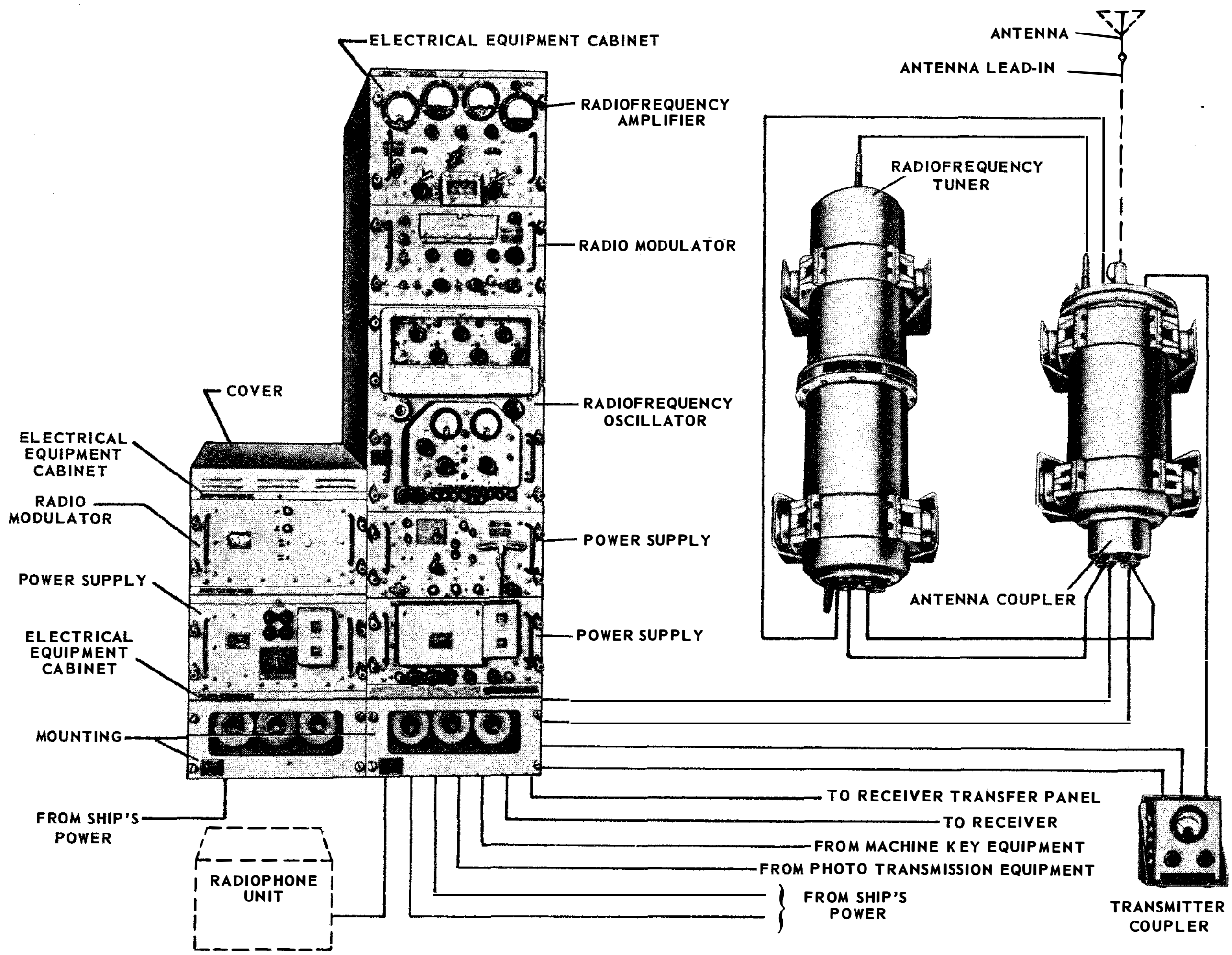

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Figure 8-1.—Radio Transmitting Set AN/SRT-15, relationship of units.

A radiofrequency oscillator is the master frequency source for the transmitting set. It generates its output signals through 14 subunits, employing oscillators, frequency multipliers, and frequency converters. The r-f output ofthe radiofrequency oscillator can be varied in steps of 10 cps from 0.3 to 26 mc. This output is fed to the radiofrequency amplifier, which contains three stages of amplification: a buffer, an intermediate power amplifier, and a power amplifier. These stages are tuned manually to the desired frequency. During 100-watt operation, the radiofrequency amplifier amplifies all frequencies in the 0.3- to 26-mc range. In 500-watt operation, only signals within the range from 2 to 26 mc are amplified in the radiofrequency amplifier. Selection of a frequency between 0.3 and 2 mc during 500-watt operation automatically switches the output to the 100-watt level.

The low-level radio modulator accepts audio and keying signals from the external circuits, and amplifies and shapes them, as required, to modulate the carrier. A 50-watt audio signal is coupled directly to the radiofrequency amplifier during 100-watt operation. During 500-watt operation, the low-level radio modulator supplies a 6-watt audio signal to the high-level radio modulator, which amplifies this input to the 250-watt level and feeds it to the radiofrequency amplifier. Keying signals for frequency shift and CW transmission may be applied to

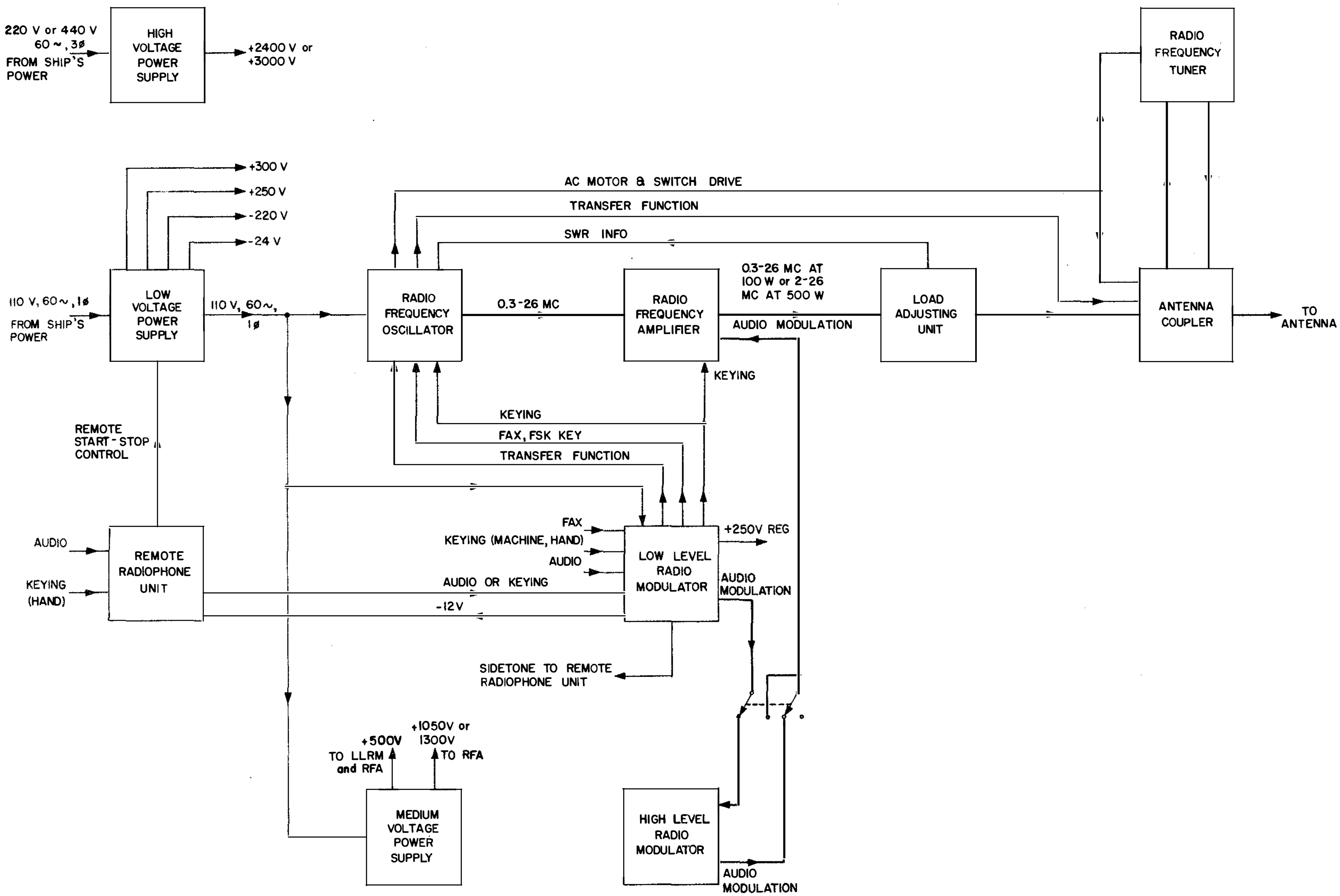

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Figure 8-2.—Functional block diagram of Radio Transmitting Set AN/SRT-15.

the low-level radio modulator from either machine-key or hand-key equipment.

Output of the radiofrequency amplifier is fed to the load adjusting unit. This unit provides a method for improving the impedance match between the output of the radiofrequency amplifier and the antenna. From the load adjusting unit, a signal is applied to the antenna coupler whose prime function is to extend the range of tuning. This extension of tuning range is done by switching inductance or capacitance into the line to lengthen or shorten the apparent electrical length of the antenna. The antenna coupler also contains a switch, making it possible to bypass the tuning components completely, thereby connecting the antennas directly to the load adjusting unit. The radiofrequency tuner serves as a variable length transmission line. Its function is to match sufficiently the impedance of the antenna to the characteristic output impedance of the radiofrequency amplifier so that the standing wave ratio is no greater than 4:1.

The low-voltage power supply receives 110 volts a-c from the ship's supply and distributes this power to other units. It contains rectifier circuits that provide B plus voltage of +300 volts, +250 volts, -24 volts for control circuits and motor lines, and -220 volts for bias.

The medium-voltage power supply receives 110 volts from the low-voltage power source, and supplies +500 volts and +1300 volts, respectively. The +500 volts is applied to the low-level radio modulator and the radiofrequency amplifier. During phone operation, the +1300 volts is reduced to +1050 volts and is applied to the radiofrequency amplifier. The medium-voltage power supply contains a relay, which ensures that the 500-volt source is activated before the 300-volt source in the low-voltage power supply comes on. This action is necessary because, primarily, the 300-volt source is a screen voltage supply and causes damage to the tubes it serves if plate voltage is not applied.

The high-voltage power supply, used only during 500-watt operation, is provided with a separate input of 200-volt, single-phase or 400-volt, three-phase, 60-cycle, a-c from the ship's supply. This circuit has a d-c output of +3000 volts that replaces the 1300-volt output of the medium-voltage power supply during 500-watt operation. During phone operation, this 3000 volts is reduced to +2400 volts.

As previously stated, the types of signals that may be applied to the input circuits are voice, CW, frequency shift telegraph (hand-keyed or machine-keyed), or facsimile. The radiophone unit (not a part of the radio transmitting sets) is located at a remote position. This unit consists of a power start-stop circuit and an audio and keying input circuit. The power start-stop circuit is connected to the control circuit of the low-voltage power supply, and permits turning the transmitter on or off. Audio signals are received locally from either a carbon or dynamic microphone. With a standard Navy remote radiophone unit, the input circuit is restricted to the use of a carbon microphone.

For CW operation, the low-level radio modulator feeds keying signals directly to the radiofrequency amplifier and radiofrequency oscillator at either 100- or 500-watt levels. In frequency shift key operation, the low-level radio modulator reshapes the input keying signals, and feeds them to the radiofrequency oscillator. Facsimile signals are switched through the low-level radio modulator and applied directly to the radiofrequency oscillator.

Over the entire frequency range, the unmodulated carrier level for radiophone communication may vary from 55 to 100 watts at the low level, and from 265 to 400 watts at the higher level. For telegraph and facsimile transmission, however, the same frequency range carrier level may vary from 85 to 150 watts for the lower output level, and from 400 to 600 watts for the higher output level.

In the discussion of the AN/SRT-15 in this chapter, it is simpler to use abbreviations for major components of the sets. These major components and abbreviations are—radiofrequency oscillator (RFO); low-voltage power supply (LVPS); medium-voltage power supply (MVPS); high-voltage power supply (HVPS); low-level radio modulator (LLRM); high-level radio modulator (HLRM); radiofrequency amplifier (RFA); antenna tuning unit (ATU); and load adjusting unit (LAU).

RADIOFREQUENCY OSCILLATOR

One of the oscillators used in the RFO of the AN/SRT-15 has a fixed frequency of 100 kc. It provides a transmitter output frequency ranging from 0.3 to 26 mc. These output frequencies are made possible through heterodyning processes taking place in several subunits throughout the radiofrequency oscillator. This method is relatively new in transmitter circuitry. The mixing circuits are therefore made variable in preference to the circuitry of the oscillator. Because the oscillator output is fixed at one frequency (100 kc), it provides a more stable output to other subunits of the RFO.

In addition to the 100-kc oscillator, the RFO contains two other oscillators and several supporting units, including frequency converters, step generators, and frequency multipliers, which are necessary to produce the required frequencies for the transmitter. The RFO unit, therefore, consists of 14 subunits, which in this discussion are referred to by their common name and unit number, as shown in the RFO block diagram of figure 8-3. (The RFO does not have a unit numbered 13.) An external view of the RFO control panel is seen in the lower part of the illustration.

RFO BLOCK DIAGRAM

The block diagram shows the signal distribution and signal progression through the RFO. In the discussion that follows, it would be wise to make frequent reference to the block diagram, particularly when moving from one subunit to another.

Unit 1

The crystal oscillator (unit 1) produces a 100-kc output, which is fed to a frequency multiplier (unit 2), a frequency converter (unit 5), 10-kc step generator (unit 6), and 100-kc step generator (unit 8). This output synchronizes the step generators and, through frequency multipliers, provides higher frequencies required by other units of the radiofrequency oscillator. Another portion of the 100-kc output is fed to a zero adjust indicating circuit in unit 14 (not shown) to enable an operator to check the output of the interpolation and frequency shift oscillators. Finally, a portion of the 100-kc output of the crystal oscillator is fed to an oscilloscope test receptacle in unit 14 for servicing or checking as required.

Unit 2

In the frequency multiplier (unit 2), the 100-kc output of the crystal oscillator is increased to 1 mc and is fed to another frequency multiplier (unit 4), a frequency converter (unit 5), a 10-kc step generator (unit 6), a frequency multiplier (unit 7), and a 1-mc step generator (unit 10).

Unit 3

The interpolation oscillator (unit 3) generates frequencies in the range of 90 to 100 kc. These frequencies are made variable in steps of 10, 100, and 1000 cycles per second. To obtain maximum stability, the main frequency-controlling elements are housed in an oven at a constant temperature of 158° Fahrenheit. The output frequency is varied by means of decade switches that place inductors and capacitors of the required size in the oscillator main tank circuit. The interpolation oscillator produces an output of 90 to 100 kc, adjustable in steps of 10, 100, and 1000 cps. The major portion of this output is fed to the frequency converter (unit 5). Another portion is fed to an oscilloscope test receptacle located on the front panel of the RFO.

Unit 4

The frequency multiplier comprises a frequency quadrupler and a frequency doubler. Unit 4 receives the 1-mc output of unit 2 and, by means of multipliers and harmonic filters, produces an 8-mc signal. This output is fed to unit 5.

Unit 5

In addition to the 1-mc input from unit 2 and the 8-mc input from unit 4, the frequency converter (unit 5) receives outputs from the interpolation oscillator (unit 3) and either the crystal oscillator or the frequency shift oscillator. The frequency shift oscillator (unit 12) generates an output of 100 kc, frequency-modulated in accordance with signals applied from the low-level radio modulator. For frequency shift keying or facsimile operation, the output of unit 12 is fed to the frequency converter (unit 5) to replace the 100-kc signal normally supplied by the crystal oscillator (unit 1).

The frequency converter consists of a series of conventional mixers, tuned filters, and an amplifier to heterodyne its four input frequencies. Output of unit 5 is adjustable in steps of 10 cps from 9.19 to 9.2 mc for CW and phone, or 9.19 to 9.2 mc ±1000 cps (maximum) for

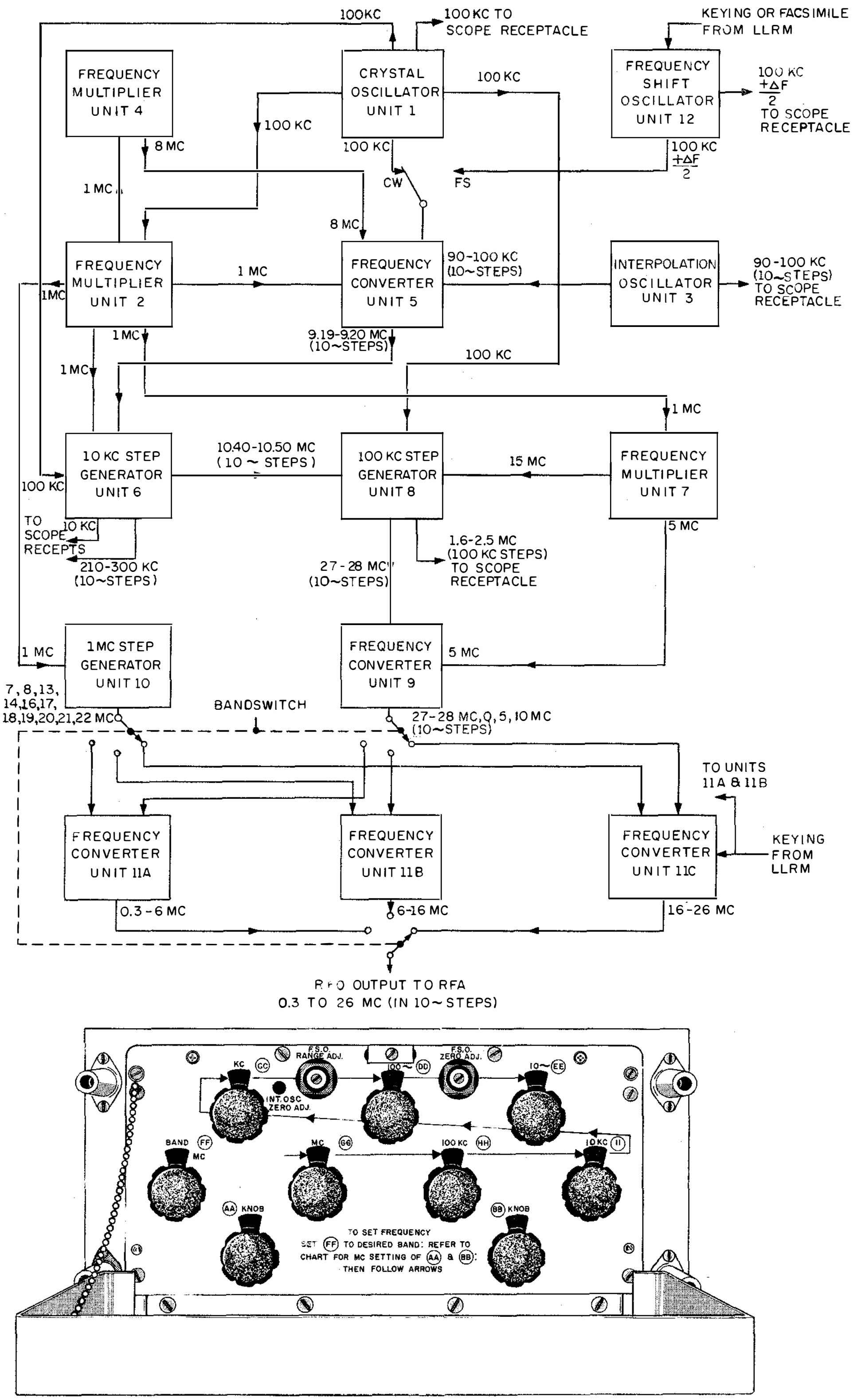

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Figure 8-3.—Functional block diagram of radiofrequency oscillator and external view of control panel.

frequency shift telegraphy, and 9.19 to 9.2 mc +2000 cps (maximum) for fascimile operation.

Unit 6

The output of unit 5 is fed to the 10-kc step generator (unit 6) whose major component is a phase-locked oscillator. Additionally, the 10-kc step generator receives a 100-kc signal from the crystal oscillator and a 1-mc signal from unit 2. The 100-kc input is used to produce a 10-kc signal that is used to stabilize the 10-kc step generator. These frequencies (10 kc and 210 kc in 10-kc steps) are available at oscilloscope test receptacles. A part of the 210- to 300-kc frequency is then mixed with the input from unit 2 and unit 5 to produce a final output from unit 6 of 10.4 to 10.5 mc (in steps of 10 cps), which is fed to the 100-kc step generator (unit 8).

Unit 7

The frequency multiplier (unit 7) receives a 1-mc signal from unit 2 and multiplies it to provide first a 5-mc signal for the frequency converter (unit 9) and, second, a 15-mc signal for the 100-kc step generator (unit 8).

Unit 8

The 100-kc step generator (unit 8) contains a 1.6-mc to 2.5-mc phase-locked oscillator. It functions in a manner similar to that of the step oscillator of unit 6, already discussed. The output from the phase-locked oscillator is mixed with the 15-mc output of unit 7, resulting in frequencies ranging between 16.6 and 17.5 mc. These frequencies then are mixed with the 10.4-mc to 10.5-mc output of unit 6 to yield frequencies in the range of 27 to 28 mc, adjustable in 10-cycle steps. The unit also contains amplifiers and filters, and feeds its output to unit 9.

Unit 9

The frequency converter (unit 9) mixes the 27- to 28-mc input from unit 8 with the 5-mc input from unit 7 to produce frequencies of 27 to 28 mc, 32 to 33 mc, 22 to 23 mc, and 37 to 38 mc. These frequencies correspond to the original, sum, difference, and 5-mc second harmonic sum, respectively. Frequencies are filtered, amplified, and sent (by means of the bandswitch) to unit 11A, 11B, or 11C, depending on the desired final output frequency of the radiofrequency amplifier.

Unit 10

The 1-mc step generator (unit 10) receives a 1-mc signal from unit 2 and passes it through a harmonic generator that produces frequencies of 7, 8, 13, 14, 16, 17, 18, 19, 20, 21, and 22 mc, depending on the selected tuned circuits. These frequencies are amplified by the remainder of unit 10 and are fed to the bandswitch. The bandswitch, located in unit 14, determines to which frequency converter unit (11A, 11B, or 11C) the output signals from unit 9 and 10 are delivered, and from which unit the final output of the RFO will be obtained.

Unit 11

Outputs of units 9 and 10 are fed to one of three final converters (units 11A, 11B, and 11C), only one of which is used at a time. The output frequency desired determines which of the three converters will be selected. The unit chosen is connected by the bandswitch to the outputs of unit 9 and unit 10, and to the radiofrequency oscillator mounting (unit 14). Unit 11A is used for frequencies between 0.3 and 6 mc, unit 11B for the 6- to 16-mc range, and unit 11C for outputs of 16 to 26 mc.

In CW operation, during space (key up condition) and in phone operation, when the press-to-talk button is not depressed, -30 volts is received from the LLRM, and is applied to units 11A, 11B, and 11C. This potential, applied to the input tubes, is sufficient to drive the stages into cutoff. In this condition, the input stages will not allow passage of the input frequencies.

Unit 12

The frequency shift oscillator (unit 12) makes possible frequency shift keying and facsimile operation of the transmitter. This unit includes a 100-kc oscillator, capable of shifting its frequency ±1000 cps from 100 kc at a 240-cps rate during frequency shift teletypewriter operation. During facsimile operation, the oscillator is also capable of shifting up to 2000 cps, as determined by the amplitude of the photo input voltages.

The frequency shift oscillator is employed only when transmitting FSK or FAX signals. During CW and phone operation, the crystal oscillator (unit 1) is used as the master frequency source instead of unit 12. Another portion of the frequency shift oscillator output is fed to an oscilloscope test receptacle.

Unit 14

Unit 14 is the mounting rack into which other units of the radiofrequency oscillator are connected. Unit 14, in turn, plugs into the transmitter group cabinet wiring. The control indicator, which mounts on the unit 14 front panel, contains controls for antenna tuning, an indicator for measuring the standing wave ratio existing on the r-f transmission line, and a meter for measuring percentage of RFT coil length in the circuit.

RADIOFREQUENCY AMPLIFIER

The prime function of the radiofrequency amplifier of the AN/SRT-15 transmitter is to increase power of the r-f output to the required level. The RFA is mounted on a separate chassis from the radiofrequency oscillator just described. The amount of interaction between frequencies of the two units thus is minimized. Another consideration that contributes to the choice of separate chassis for the RFO and RFA (and other major units of the transmitter) can be appreciated when it becomes necessary to service the equipment. For instance, if operational trouble is found in the RFA, this unit alone may be replaced by removing the RFA chassis and substituting one known to be in operating condition.

In addition to amplifying r-f energy, the RFA is equipped with tuned circuits and filters, which are selected in the plate circuits through the use of switches provided for this purpose. A decided improvement is therefore realized over earlier transmitters in the ability of this equipment to select the desired frequency. Also, because each of the six bands utilizes a separate filter, the range of tuning of a particular tank circuit is minimized.

Output circuits of the RFA contain meters and switches, and reactive components for matching the RFA to the chosen antenna. Through the use of the load adjusting unit, r-f tuner, and antenna coupler units of the RFA, the electrical length of the transmission line can be varied to match a fixed antenna. Hence, the standing wave existing along the line can be reduced to the required minimum. These features greatly improve the antenna radiation capabilities.

The radiofrequency amplifier (RFA) accepts from the radiofrequency oscillator a signal in the frequency range from 0.3 to 26 mc. The radiofrequency amplifier consists of three stages: buffer, intermediate power amplifier (IPA), and power amplifier (PA).

Signals from the radiofrequency oscillator are received at a level of approximately 0.1 watt, and amplified to either 100 or 500 watts. The radiofrequency amplifier also contains adequate filters to attenuate undesired harmonics. Output of the RFA is coupled to the load adjusting unit.

The RFA output may be modulated either by audio from the low-level radio modulator or high-level radio modulator, or it may be keyed on and off by keying voltages from the low-level radio modulator. During frequency shift keying and facsimile operation, the r-f signal from the RFO is frequency-modulated in the radiofrequency oscillator.

Tuning of the RFA is accomplished manually by three controls: bandswitch, tune IPA control, and tune PA control. To enable the RFA to tune through the entire range from 0.3 to 26 mc, the total range of frequencies is grouped into six bands. Figure 8-4 shows a block diagram of the RFA with its ganged bandswitches. For simplicity, meters and control circuits are not shown.

The function of the bandswitch is to connect a tank circuit to each of the amplifiers in accordance with the band that contains the frequency chosen for transmission. After the desired band is chosen by the bandswitch, tuning of the buffer and IPA tank circuits is accomplished by the tune IPA control. Tuning of the PA tank circuit is then performed by the tune PA control. Tuning procedures and other common operating adjustments of the AN/SRT-15 transmitter are described in chapter 5 of Radioman 3 & 2.

BUFFER AMPLIFIER

The function of the buffer stage is to isolate the radiofrequency oscillator from the effects of a varying load caused by keying signals received by the RFA from the low-level radio modulator.

The buffer amplifier receives the output of the RFO and amplifies the signal to a sufficient value to drive the intermediate power amplifier.

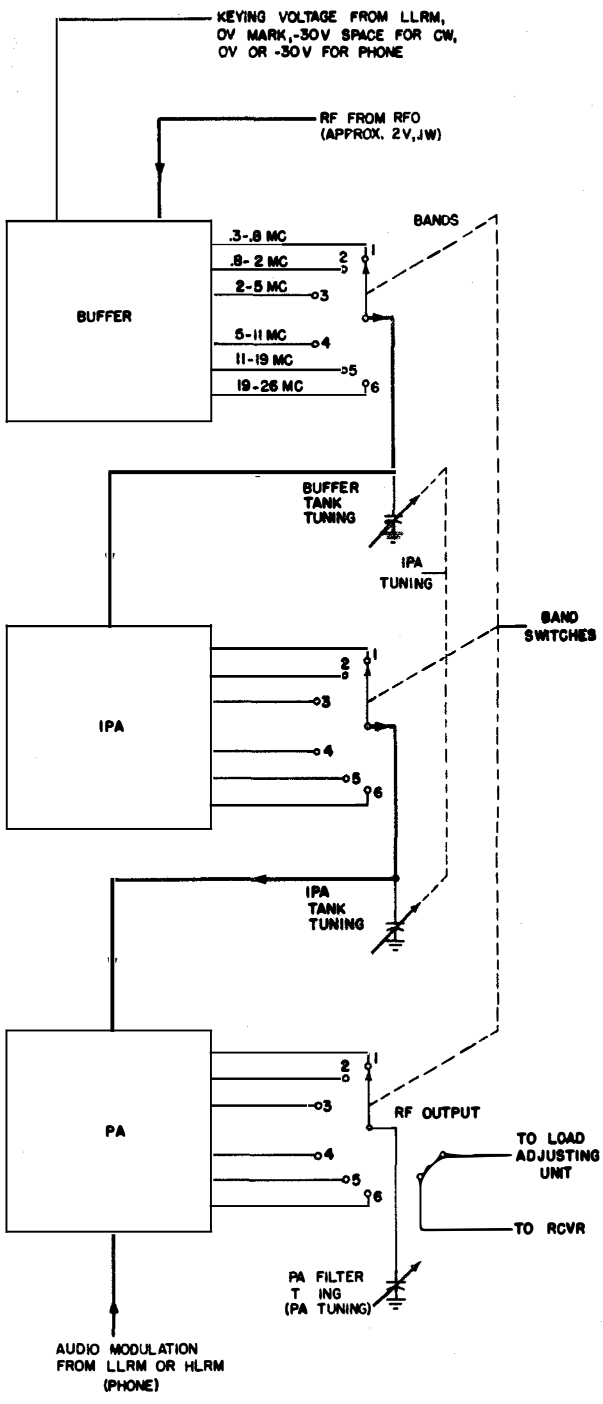

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Figure 8-4.—Radiofrequency amplifier, block diagram.

During frequency shift keying and facsimile operation, the buffer amplifier keys the carrier continuously on the air. In CW operation, during mark (key-closed condition) and in phone operation, when the press-to-talk button is depressed, the buffer allows the carrier to be transmitted. In CW operation, however, during space (key-up condition), and in phone operation, when the press-to-talk button is not depressed, the buffer amplifier will not allow passage of the r-f signal from the RFO, and effectively cuts the carrier off the air.

INTERMEDIATE POWER AMPLIFIER

The intermediate power amplifier amplifies the r-f signal from the buffer. The r-f signal is further tuned in the IPA plate tank circuit. Both the intermediate power amplifier and the buffer amplifier are tuned by the tune IPA control, which is ganged to the IPA tuning capacitor as well as to the buffer tuning capacitor.

POWER AMPLIFIER

The power amplifier stage amplifies the r-f output of the intermediate power amplifier to a power level of 100 watts or 500 watts. The amount depends on the plate and screen voltages selected by means of the control circuits. Once again the r-f signal is tuned in the PA plate circuit and is matched to the antenna transmission line.

During CW transmission, the PA plate voltage is +1300 volts for 100-watt operation and +3000 volts for 500-watt operation. During phone transmission, a 1050-volt potential is supplied to the PA tube plate for 100-watt operation and 2400 volts for operation at the 500-watt level. The plate potential is reduced during phone operation so that, during modulation, maximum plate voltage variations do not exceed the power amplifier tube's peak voltage rating.

OPERATE RELAY AND DISABLE LINE

The 500-watt operate relay K1 (fig. 8-5) controls the ground for the 100-watt line, 500-watt line, and 500-watt AX line.

The grounds for the 500-watt line and 500-watt AX line allow circuit completion for several control circuits. They are responsible for (1) turning on control circuits in the high-voltage power supply, (2) connecting the output of the low-level radio modulator to the input of the

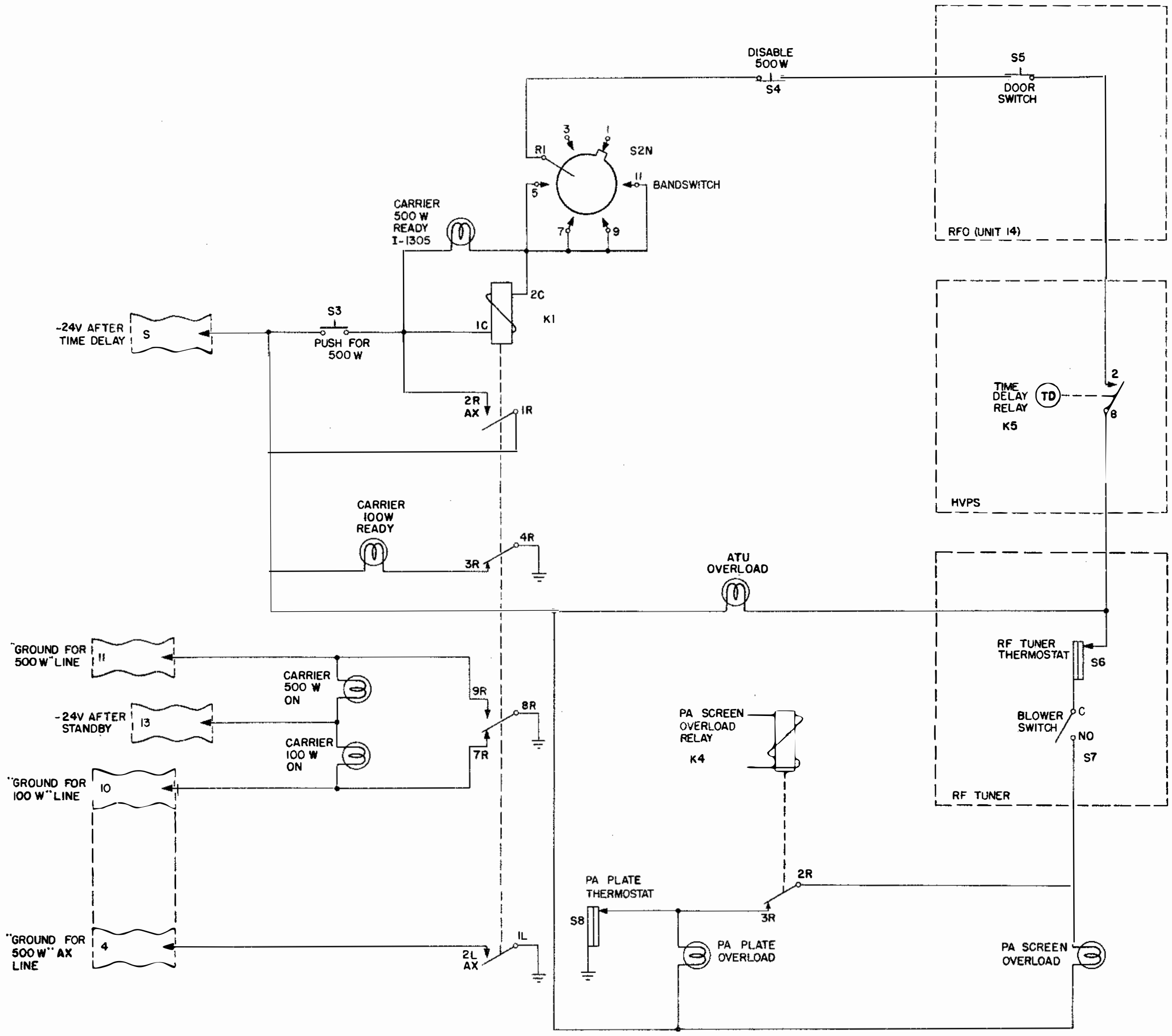

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Figure 8-5.—Simplified schematic of 500-watt operate relay and 500-watt disable line.

high-level radio modulator, (3) switching the input to the PA plate from the low-level radio modulator output to the high-level radio modulator output, and (4) supplying screen grid voltage to the high-level radio modulator during phone operation. Grounds for the 500-watt line and 500-watt AX line are completed when K1 is energized.

The ground for the 100-watt line is completed when K1 is not energized. This line completes the control circuits in the medium-voltage power supply, which then supplies the required PA plate potential for the 100-watt operation.

If K1 is energized, the transmitter group is in 500-watt operation. If the relay is not energized, the transmitter is in 100-watt operation. To place the transmitter in 500-watt operation, the push for 500-watt button S3 is depressed. If the -24 volts after time delay relay K5 has timed out (contacts 2-8 closed), depressing the 500-watt button applies the -24 volts to the winding of K1. The necessary ground for completing this circuit is accomplished through a series of protective devices, constituting the 500-watt disable line. The circuit must be complete before the transmitter switches to the 500-watt level. Protective devices included in the 500-watt disable line are bandswitch S2N, disable 500-watt pushbutton S4, RFO unit 14 door interlock S5, time delay relay K5, thermostat S6, blower switch S7, overload relay K4 (contacts 2R and 3R), and plate thermostat S8. If any one of these controls or protective devices is not closed, the ground is not completed to K1, and the transmitter can operate at the 100-watt level only. When K1 energizes, the -24 volts after time delay connects to the windings of K1 through its contacts 1R and 2R, allowing S3 to be released.

The 500-watt disable line contains a switch, S2N, ganged to the bandswitch control. The switch allows the circuit to be completed in all bands except 1 and 2. It should be recalled that those frequencies up to and including 2 mc may be transmitted at the 100-watt level only.

The disable 500-watt pushbutton S4, ordinarily closed, may be depressed to open the circuit as desired.

A transparent door covers the control knobs of the RFO. The door contains a switch, S5. This door interlock controls the open and closed condition of the 500-watt disable line, and, if open during normal 500-watt operation, the transmitter output is reduced to the 100-watt level.

The heaters of the tubes in the high-voltage power supply (discussed later) are allowed to warm up before power is applied to the plate transformer. Contacts 2 and 8 of the time delay relay K5 are held open until the time delay is over. After this time, contacts 2 and 8 are closed to complete the circuit.

Thermostat S6 usually is closed. When excessive heat is radiated by tuning coils in the r-f tuner (discussed later in this chapter), S6 opens the circuit.

Blower switch S7 is a centrifugal switch operated by the blower motor in the r-f tuner. The circuit is closed through S7 only if the blower is operating.

Contacts 2R and 3R of the PA screen overload relay normally are closed. When K4 is energized, due to excessive PA screen grid current, contacts 2R and 3R are opened, and the ground is removed from the 500-watt disable line.

The normally closed contacts of PA plate thermostat S8 are caused to open when energy radiated by the PA plate dissipation becomes excessive. This action, too, removes the ground from the 500-watt disable line.

Four indicator lamps controlled by the action of K1 indicate the power level of the transmitter and also whether the transmitter is on the air. These indicators are shown in figure 8-5.

As mentioned previously, contacts are provided on the antenna switching relay for connecting a receiver to the antenna when the transmitter is off the air. When it is on the air, the output of the RFA is coupled to the antenna system, and the receiver input is grounded.

During hand-key operation (using the test key S5 in figure 8-6), the circuit for K2 is completed from the -24 volts after time delay, through the winding of K2, into the low-level radio modulator, through contacts 1L and 2L of relay K6, and through the closed contacts of the test key to ground. Energizing the antenna switching relay K2 actually operates the keying relay K6 in the LLRM. This action shifts the ground on K2 from 1L and 2L of K6 to contacts 2L and 3L of K6. Capacitor C1 is provided to continue the ground on K2 during the time of the changeover. Antenna relay K2 therefore becomes energized when the test key is closed, corresponding to a mark, moving its contacts to the transmit position. When the hand-key is up, corresponding to a space, there is no ground for relay K2, and the antenna is switched to the receive position.

In machine CW, frequency shift keying, and facsimile operation, a permanent ground is placed on the keying line (through the keying equipment), keeping K2 energized.

TRANSMITTER COUPLER

The function of the transmitter coupler, generally referred to as the load adjusting unit (LAU), is to improve the impedance match between the 50-ohm output impedance of the radio-frequency amplifier and the impedance presented by the antenna tuning equipment. Improved matching permits the final power amplifier stage of the RFA to operate at maximum plate efficiency, and improves the transfer of power to the antenna. The transmitter coupler (pictured in fig, 8-1, and shown schematically in fig. 8-7) consists of the standing-wave ratio monitor and the impedance transformer circuits.

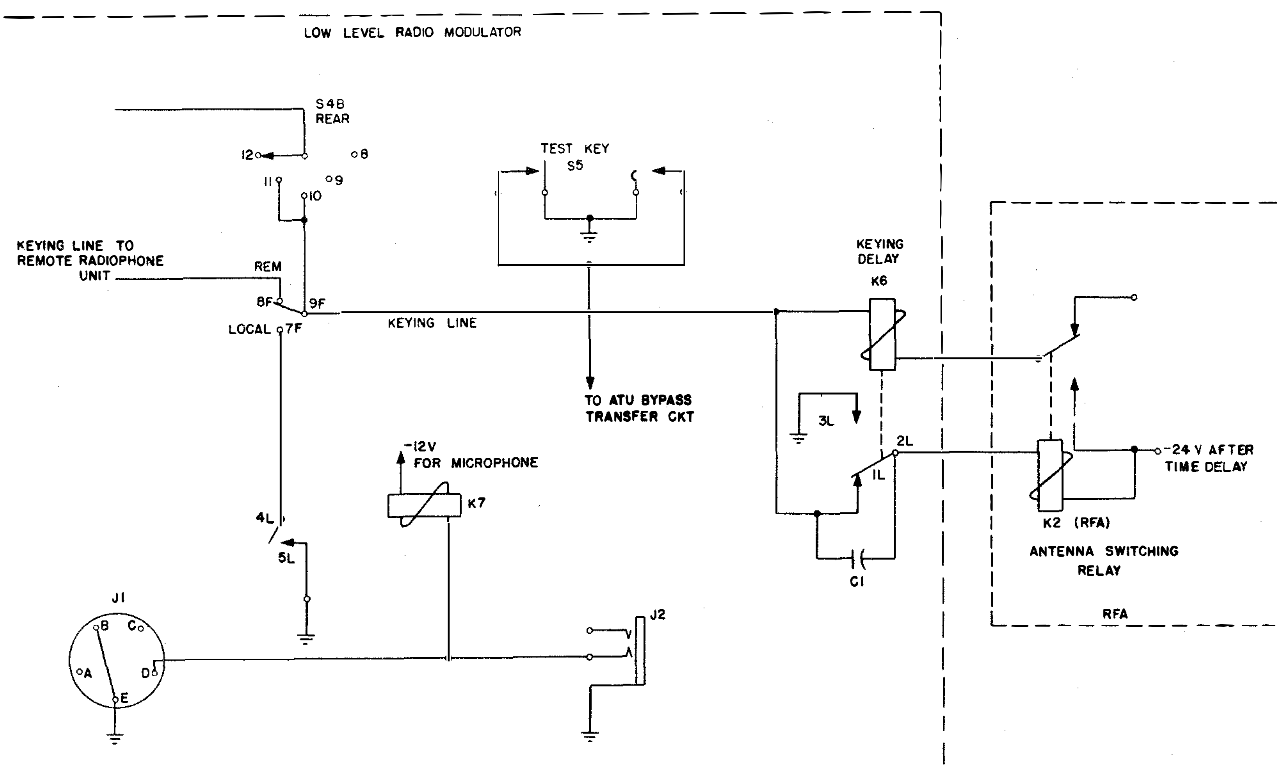

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Figure 8-6.—Antenna switching relay and associated circuits.

STANDING-WAVE RATIO MONITOR

The output of the radiofrequency amplifier is connected to the standing-wave ratio monitor circuit, which functions to detect and monitor the standing-wave ratio present on the r-f transmission line.

The r-f transmission line from the RFA is connected through J1 to the standing-wave ratio monitor circuit and to the impedance transformer circuit. Voltages eV_1 and eV_2, proportional to the r-f line voltage, are obtained directly from voltage divider R1 and d-c blocking capacitors C1 and C2, respectively. Voltage eV_1 is between point C and ground. Voltage eV_2 is between point B and ground. Voltages ei_1 and ei_2 are proportional to the current in the r-f line. They are obtained from the lower and upper halves, respectively, of the secondary winding of transformer T1. The center tap of the secondary is grounded, and ei_1 is 180° out of phase with ei_2. However, eV_1 and eV_2 are in phase with one another and are of equal magnitude. Resistors R2, R3, R4, and R5 are shunted across the transformer and function as damping resistors.

Circuit ABCD, supplied by the T1 secondary and also by a portion of the line voltage via C1 and C2, includes capacitors C3 and C4. These capacitors acquire a charge through the action of crystal diodes CR1 and CR2 and the voltages ei_1 and eV_1 and ei_2 and eV_2.

On one-half cycle, CR1 and CR2 are conducting, and on the other half they are nonconducting. During the time the diodes conduct, ei_1 and ei_2 attempt to establish a charging current clockwise around circuit ABCD so as to charge C3 and C4 with the polarity shown. During this time eV_1 opposes the charge on C3, and eV_2 aids the charge on C4.

As stated before, ei_1 and ei_2 are proportional to the line current; eV_1 and eV_2 are proportional to the line voltage. Now the quantity of charge in C3 is proportional to ei_1 - eV_1 and

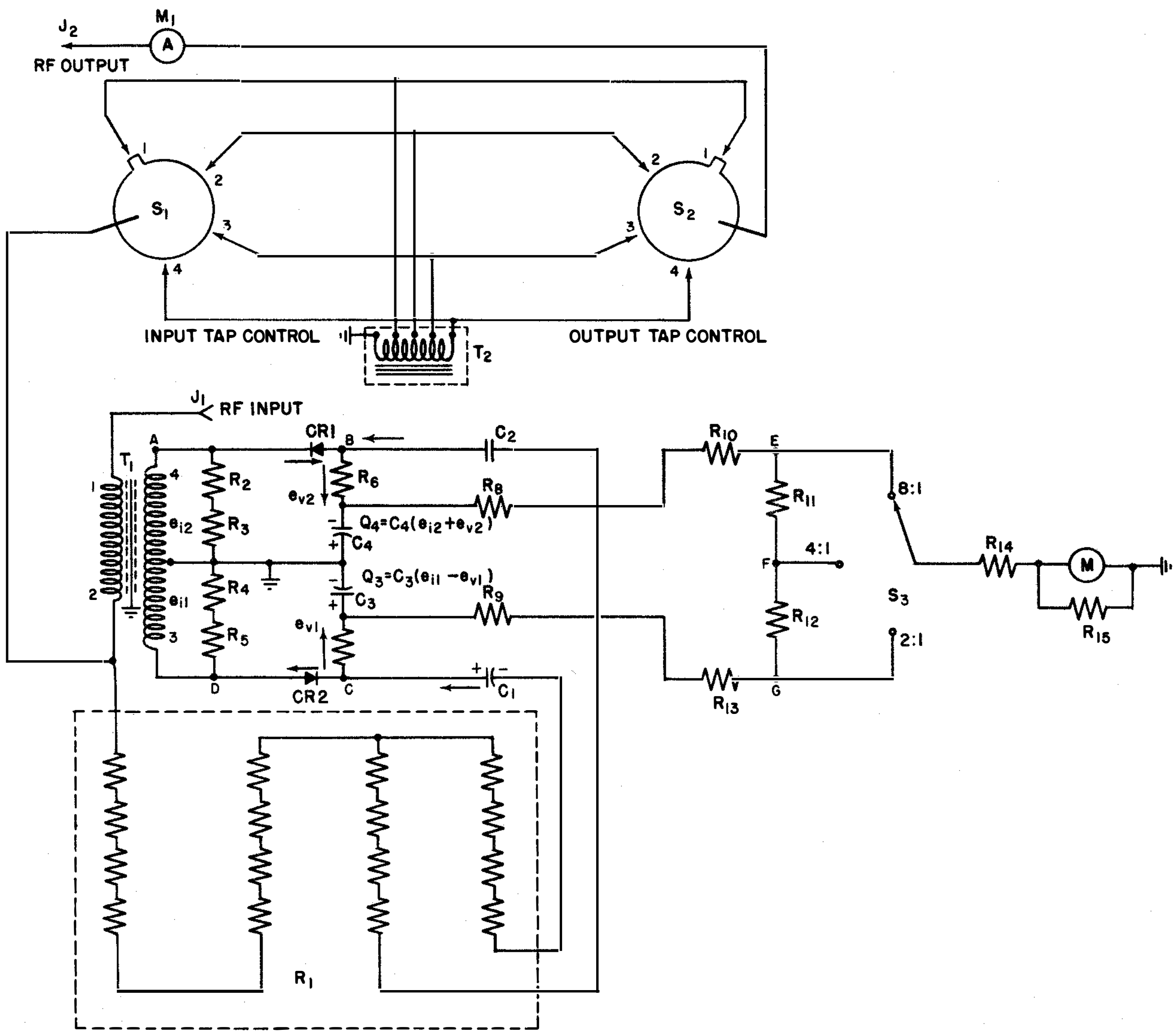

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Figure 8-7.—Transmitter coupler (load adjusting unit), schematic diagram.

the quantity of charge in C4 is proportional to $ei_2 + eV_2$. Thus, the voltage on C3 is proportional to the difference of two quantities, and C4 is proportional to the sum of the same two quantities. These quantities are proportional to line current and line voltage. The ratio of these quantities is proportional to the line impedance. For a matched line with no standing waves, the ratio is proportional to the characteristic impedance of the line. If the line is mismatched, the ratio is upset, and the amount of charge on C3 and C4 is altered.

A voltage divider comprising R8, R9, R10, R11, R12, and R13 is connected across the series combination of C3 and C4. Voltage across this divider is equal to the sum of the voltage across C3 and C4. Meter M is connected effectively between the common junction of C3 and C4 and a point on the voltage divider, depending on the position of switch S3. In this bridge circuit the current through the meter is proportional to the unbalanced condition of the bridge.

The values of R10, R11, R12, and R13 are such that if the standing wave on the r-f line is 8:1, the potential at point E with respect to ground is zero. If the SWR calibrate switch is in the 8:1 position, the SWR balance meter M gives an indication at the center null position. If the standing-wave ratio is less than 8:1, with the switch in this position, the meter reads to the left of the null position. Conversely, if the standing-wave ratio is greater than 8:1, with the switch in this position, the meter indicates a reading to the right of the null position. Voltage at point F with respect to ground is zero when the standing-wave ratio is 4:1. Similarly, a 2:1 ratio gives a zero reading at point G. Resistor R14 in series with the meter is a current-limiting resistor.

IMPEDANCE TRANSFORMER

A method for improving the match between the characteristic impedance output of the RFA and that impedance presented to the RFA by the antenna and antenna tuning equipment is provided by the impedance transformer. Matching is accomplished through the use of a tapped autotransformer T2, introduced into the r-f transmission line. Output of the standing-wave ratio monitor may be connected to one of the taps of T2 shown in figure 8-7. Input connections are made through switch S1, the input tap control. The output of the transformer selected by the position of the tap on the output tap switch S2 is connected through the r-f ammeter M1 to jack J2, which is the output to the antenna coupler.

With the input and output tap controls set at position 4, the full winding of the impedance matching autotransformer is shunted across the line. This position is the normal setting of these controls. If, after all tuning procedures are completed, the standing-wave ratio balance meter indicates a reading higher than 2:1, controls should be reset for optimum impedance match.

Tuning controls of the PA stage are also used in making the adjustment for maximum reading on the r-f ammeter of the load adjusting unit.

ANTENNA TUNING EQUIPMENT

The AN/SRT-15 transmitter is designed to work into a 35-foot whip antenna, Navy type C66047, or into a 60- to 130-foot single wire with a 40-foot down lead. If the impedance presented by the antenna is other than 50 ohms, energy is reflected back along the transmission line, reducing the energy being radiated and causing voltage nodes to exist on the line. The standing-wave ratio measurement indicated by the standing-wave ratio balance meter represents the extent of the mismatch. The ideal matching condition of the antenna load to the RFA output would yield a standing-wave ratio of 1:1. This ratio would occur when the reactive component of the antenna is reduced to zero and the resistive component is equal to 50 ohms. Acceptable tuning of the antenna load by the antenna tuning equipment is achieved if the standing-wave ratio can be reduced to at least 4:1 for any frequency in the transmitter range.

If the antenna length is an exact multiple of quarter-wavelengths corresponding to the frequency in use, the antenna is resonant and presents zero reactance to the transmission line. It should be understood, however, that because the antenna length is constant, the resonant condition will not remain constant for all frequencies. Further, at even multiples of quarter-wavelengths, the resistive component (for end feed) is high; at odd quarter-wavelength multiples, the resistive component presented by the antenna (at the same feed point) is low.

The function of the antenna tuning equipment is to make the antenna length, together with the selected tuning component, appear at the feed point as some odd multiple of a quarter-wavelength for all frequencies within the tuning range from 0.3 to 26 mc. A block diagram of the antenna coupler and r-f tuner is shown in figure 8-8.

ANTENNA COUPLER

Figure 8-9 is a schematic diagram of the antenna coupler. Loading switch S1 permits additional components to be placed into the transmission line to increase its effective length when the length of the main tuning coil is insufficient to achieve the required tuning. This need is particularly apparent at low frequencies when antenna length should be increased. At frequencies where the effective length of an antenna is an even multiple (instead of the desired odd multiple) of a quarter-wavelength, a capacitor may be switched in the line. Without this action, a poor match would exist between the antenna and the RFA because the antenna

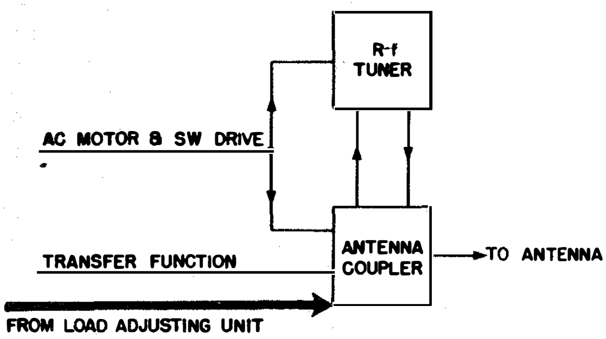

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Figure 8-8.—Block diagram of r-f tuner and antenna coupler.

impedance would be further separated from the characteristic impedance of the line.

The output of the r-f tuner (discussed later) is connected permanently to the loading switch of the antenna coupler. If one of the loading components is needed in the tuning process, the required component is switched into the transmission line through the two-section loading switch S1. If loading components are not required, the transmission line is connected directly through the switch shown in the illustration. Loading switch S1 has six positions: one for direct connection and five (ABCDE) for different combinations of loading components. Components selected may be located easily after proper rotation of the switch. Antenna coupler loading switch S2 supplies operating voltage to

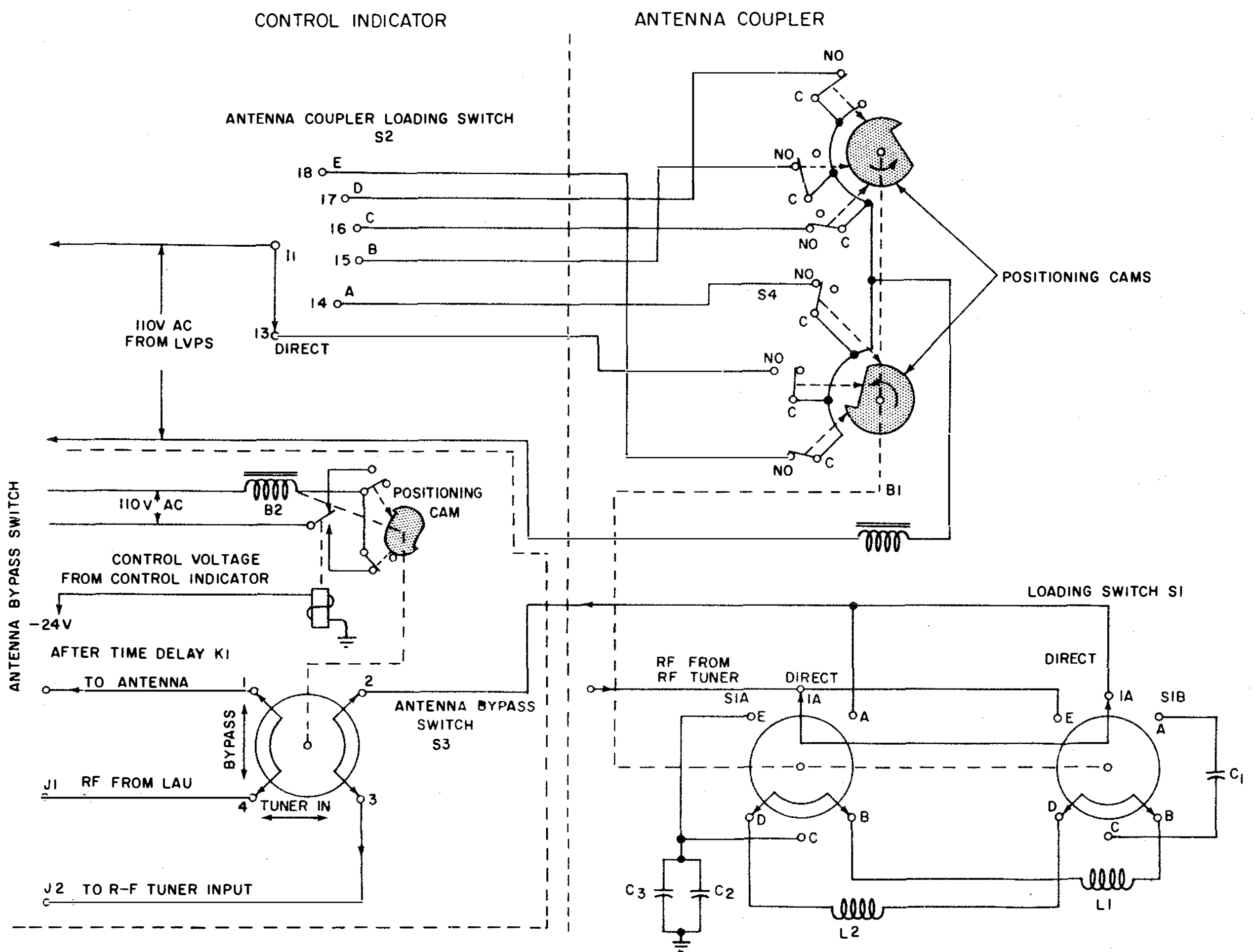

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Figure 8-9.—Simplified circuit of antenna coupler.

an actuator, B1, in the antenna coupler. The actuator then functions to position the loading switch, as required, to select the proper loading component. Table 8-1 lists the components selected by the different positions of the antenna coupler loading control.

Assume that antenna coupler loading switch S-2 (fig. 8-9) is placed manually in position A. This action establishes a circuit from one side of the 110-volt a-c line through 11-14 of S2, through contacts NO and C of microswitch S4, to one side of the actuator winding B1. The other side of the actuator winding is connected directly to the other side of the 110-volt a-c line. The closed contacts NO and C of S4 allow the actuator to rotate until the roller arm of S4 falls into the notch of the positioning cam. This action opens the contacts of S4, breaking the a-c supply to the actuator. The magnetic actuator is ganged to S1 in such a way that the switch is caused to rotate to the A position.

At certain frequencies, the actual antenna impedance is such that no tuning is needed to meet the standing-wave ratio reading of 2:1 required at the r-f output of the radiofrequency amplifier. At other times, it is necessary to use one or more of the tuning components described in the discussion of the loading switch in the preceding paragraphs. To meet these conditions, antenna bypass switch S3 (fig. 8-9) is introduced into the transmission line.

Table 8-1.—Components Selected in Each Position of Loading Switch S1

Positions of antenna coupler loading switch S2	Loading components selected by S1
Direct	None.
A	C1 in series.
B	L2 in series.
C	C1 in series, C2 and C3 shunted across the line.
D	L1 in series.
E	C3 and C2 shunted across the line.

The antenna bypass switch is controlled by the antenna transfer switch on the control indicator (located on the front of RFO unit). The switch is a double-pole, double-throw toggle switch with three positions. These positions are designated TUNER IN, BYPASS, and REMOTE. The REMOTE position is not shown in the illustration. Switch S3 is positioned by a magnetic actuator, B2. One side of the a-c line is connected permanently to one side of the actuator. Relay K1, when energized, completes the line voltage circuit, allowing the actuator to energize. This action, in turn, rotates the positioning cam. In this manner, the antenna bypass switch is caused to position itself in accordance with the position chosen by the antenna transfer switch.

With the antenna bypass switch in the BYPASS position (as shown), relay K1 is not energized, and the r-f output from the load-adjusting unit is connected directly to the antenna through J1 and contacts 4 and 1 of S3. When it is desired to have the tuning elements in the line, the antenna transfer switch is placed in the TUNER IN position. Switch S3 therefore is rotated so that r-f energy now passes through contacts 4 and 3 of S3, then out through connector J2 to the r-f tuner input. Output of the r-f tuner is connected permanently to loading switch S1, discussed in preceding paragraphs. The loading switch selects the desired tuning component. Output of S1 is connected to contact 2 of bypass switch S3, through contact 1, and to the antenna.

When S3 is switched from TUNER IN to BYPASS, or vice versa, the transmission line is interrupted momentarily, removing the antenna load. When the antenna load is removed, even for a short time, it becomes necessary to cut off the radiofrequency energy at the IPA (as previously mentioned) to prevent surges in the transmitter output caused by this removal of antenna load. Grounding cam A (fig. 8-10) is fixed to the shaft of bypass switch S3, and controls the open or closed condition of microswitch S2. Configuration of the cam is such that it removes the ground from the R9 and R10 junction in the IPA control grid circuit during the time that switching takes place. Absence of this ground causes the IPA to cut off, and this action, in turn, cuts off the output of the transmitter.

RADIOFREQUENCY TUNER

The antenna coupler applies its output to transformer switch S1 (fig. 8-11) in the r-f

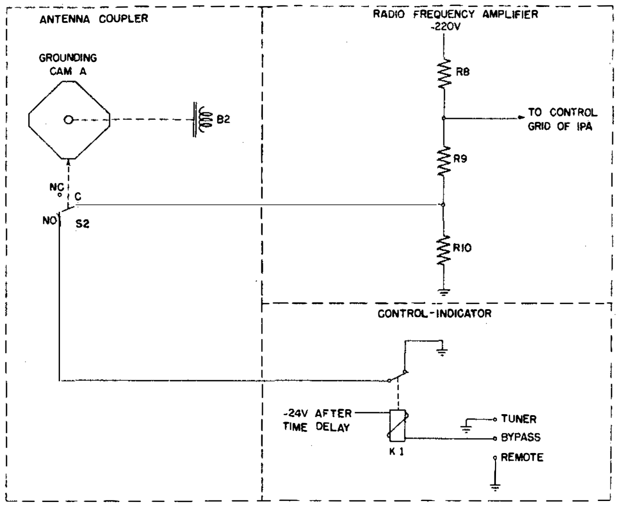

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Figure 8-10.—Antenna coupler grounding cam circuit, simplified schematic.

tuner. This switch, when connected so that circuits are completed through the 1 and 2 contacts and the 3 and 4 contacts, places the 9:1 impedance transformer in the transmission line. The purpose of the transformer is to step up the signal to the required level. In the other position of the switch (as shown), the impedance transformer is bypassed by the connection made between contacts 2 and 4 to the main tuning coil of the r-f tuner.

Magnetic actuator B1, responsible for positioning switch S1, operates under the influence of transformer switch S2, through contacts NO and C of S3, to one side of the winding of actuator B1. The other side of the actuator is connected directly to the other side of the line. Actuator B1 rotates until the roller actuator of S3 falls into the notch of the positioning cam. At this time, the NO and C contacts of S3 open, breaking the line voltage circuit. Transformer switch S1 is now in the position that eliminates the impedance transformer from the circuit. Placing S2 in position 14 again energizes the circuit through S4. Actuator B1 then causes the positioning cam to rotate until the actuator for S4 falls into the notch of the cam. This position corresponds to the position of switch S1, which places the impedance transformer in the circuit.

The transmission line is coupled to the main coil (fig. 8-12) of the r-f tuner by a single loop coupler coil, L1, mounted on the shorting ring. The length and configuration of the single loop coil are such that optimum coupling exists above 1 mc if a standard Navy 35-foot whip antenna is used. The resistive component of the antenna impedance is so low at a frequency of 1 mc or lower that the impedance transformer is necessary to bring the radiated signal to the minimum allowable limit.

The main tuning coil of the r-f tuner is equipped with an adjustable sliding short. This tuning coil is the main tuning component in the r-f tuner.

If the impedance transformer (fig. 8-11) is not required in the antenna tuning process, the r-f tuner input to its loading components is connected to main tuning coil L2. This tuning coil (fig. 8-12) is a section of a helical center conductor transmission line and is adjustable, as stated earlier, by a sliding short. The short is adjusted so that the effective length of the main coil, together with the effective antenna length, is an odd multiple of a quarter-wavelength at the particular frequency in use. This arrangement is the point of resonance or zero reactance.

The position of the sliding short is adjusted remotely by drive motor B1. Speed and direction of the motor are controlled by the UP, DOWN, and SLOW pushbuttons.

LOW-LEVEL RADIO MODULATOR

The low-level radio modulator (LLRM) provides the required level of keying voltage to the RFA when the transmitter is operated at low power (100 watts). When the transmitter is operated at the higher power level (500 watts), the low-level radio modulator serves the high-level radio modulator with the necessary input signal amplitude. The high-level radio modulator then provides the required level of output voltage to the RFA. Among circuits contained in the low-level radio modulator are an audio amplifier chain, a squelch circuit, automatic gain control circuit, keying multivibrator, and circuits that control the key-up and key-down condition of the transmitter.

The term "low-level" in the unit name implies that this particular modulator is used as the modulating source for the RFA during 100-watt operation. It should not be associated with control grid and cathode modulation, nor modulation at a point of low r-f potential, which is also referred to occasionally as low-level

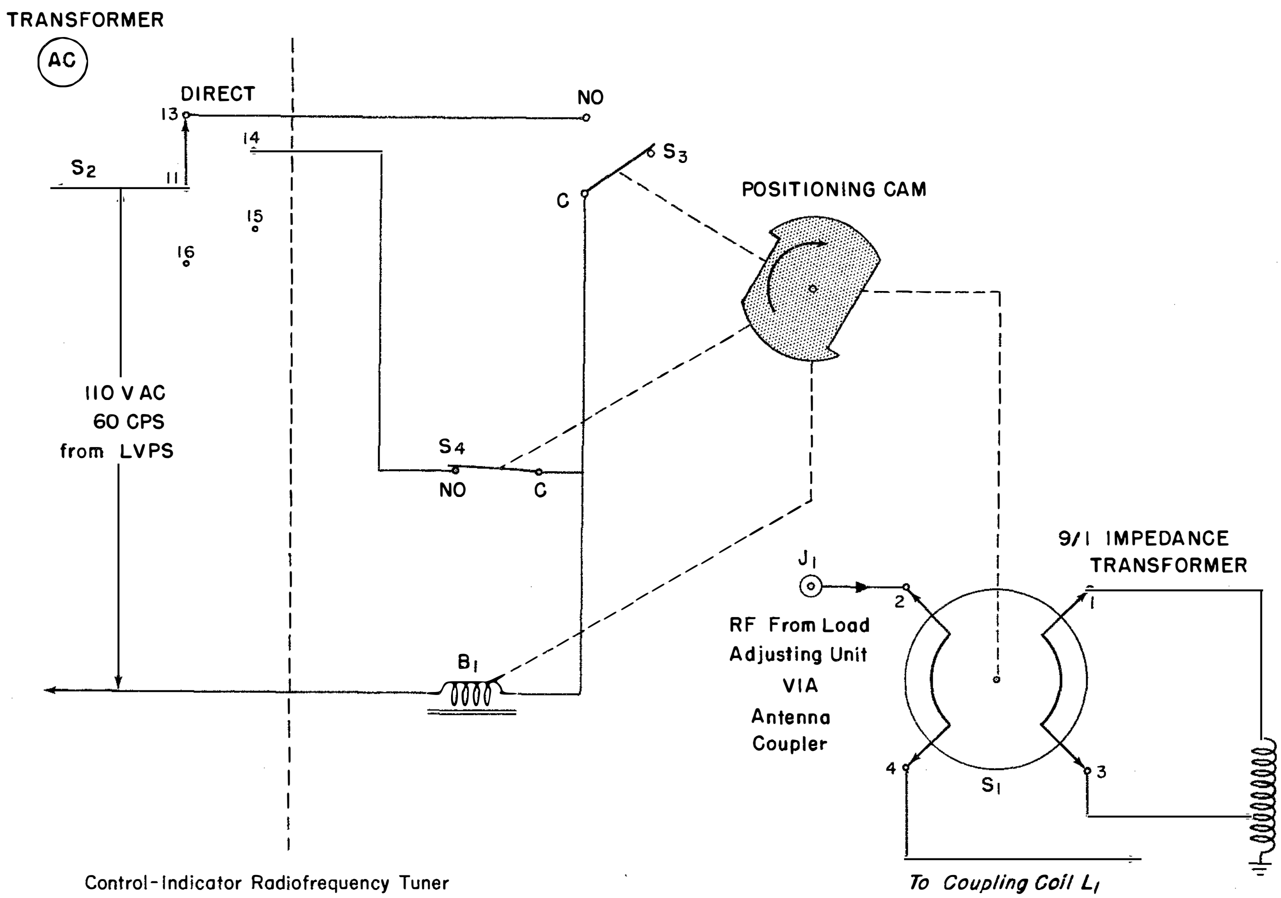

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Figure 8-11.—Impedance transformer (r-f tuner), simplified schematic.

modulation. Likewise, the term "high-level" in the title of the high-level radio modulator, implies that this unit is utilized during 500-watt operation; it does not refer to the method of modulation.

A block diagram of the LLRM is seen in figure 8-12. The LLRM accepts voice, telegraphy (hand- or machine-keyed), or facsimile signals at its input. A service selector switch is provided for manual selection of mode of operation. The unit contains audio amplifying and modulating circuits for modulation of the carrier at the 100-watt level. During 500-watt operation, as previously stated, the low-level radio modulator feeds a high-level radio modulator, which boosts the audio signal to the required level. A squelch circuit prevents transmission of noise when no signal is present. Either a carbon or dynamic microphone may be used to apply voice signals to the input.

The electronic keying circuit of the LLRM furnishes keying voltage to control the RFA and units 11A, 11B, and 11C of the RFO during amplitude modulation (voice and CW). It controls only the radiofrequency oscillator during frequency shift keying. Facsimile signals also are connected through the low-level radio modulator to the frequency shift circuits in the radiofrequency oscillator.

The front panel of the low-level radio modulator has controls for selecting mode of transmission, receptacles for a local carbon or dynamic microphone, gain controls, and a squelch circuit control. A test key is provided for carrier frequency control.

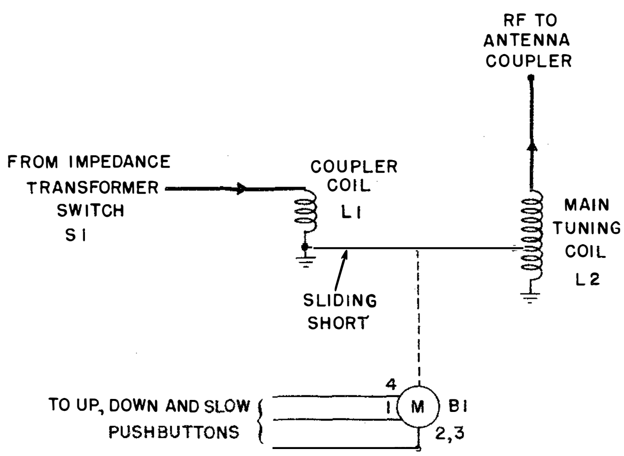

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Figure 8-12.—Main tuning coil (r-f tuner), simplified schematic.

HIGH-LEVEL RADIO MODULATOR

The high-level radio modulator (HLRM) is used only when the transmitter is operated at the highest output power. It contains a push-pull power amplifier, which boosts to the required level the audio signal received from the LLRM. The high-level radio modulator also has circuits that control the amount of the plate potential applied to the power amplifier of the RFA. This potential is lower during phone operation to prevent overdriving of the power amplifier during modulation.

When in phone operation at the 500-watt level, an audio signal of 250 watts is required to amplitude-modulate the plate of the RFA power amplifier. Feeding a 6-watt signal from the LLRM to the HLRM (fig. 8-14), it is amplified to the required level. During hand-key, machine-key, FSK, and FAX operation, the plate voltage for the RFA power amplifier is routed through the HLRM.

PUSH-PULL AMPLIFIER

During 500-watt operation, an audio modulating signal from the low-level radio modulator is fed to the control grids of push-pull amplifiers V1 and V2 in the HLRM (fig. 8-14). Signals are equal in amplitude but 180° out of phase, making possible push-pull amplification. Amplified signals are applied across output modulation transformer T1. Plate voltage is delivered to the center tap of the transformer primary. The ground for 500-watt phone line is supplied from the radiofrequency amplifier (previously discussed) to relay K1. If the 500-watt operate relay (fig. 8-5) is energized, and the -24V after standby line is activated, K1 energizes. This action supplies the screen grids of V1 and V2 with a +360-volt potential. The potential is applied through contacts 2L and #1 of the now energized K1.

Dropping resistor R1 for the +350-volt screen indicator I1 indicates the HLRM screen supply is present. In phone operation the -24 volts after standby line is energized by the press-to-talk button so that it controls the operation of K2 and application of screen voltage to the HLRM.

In phone operation, +2400 volts from the HVPS is applied to the plate of the power amplifier in the RFA through T1 in the HLRM. The 250-watt audio signal, which also appears across this transformer, is applied to the PA plate. Protection against excessively high voltage across the secondary of T1 is provided by spark gap E1. In other than phone operation at the 500-watt level, +3000 volts is applied directly to the PA plate through shorting contacts 4 and 5 of relay K2 in the HLRM. This shorting action takes place in the deenergized condition of the relay. Relay K2 becomes energized through contacts 3R and 4R of energized relay K1. The latter relay energizes when the press-to-talk button is depressed, activating the -24-volt after standby line. When K2 energizes and removes the short across the secondary of T1, the transformer is placed in series with the high voltage supplied from the HVPS.

When the transmitter is operated at the 100-watt level, the ground for 500-watt AX line is open, as shown in figure 8-5, and K3 is not energized. The LLRM connected to J1 therefore passes its output through contacts 4 and 5 of K3 and to J2, which connects to the power amplifier plate in the RFA. In 500-watt operation, the ground for 500-watt AX line is completed, and K3 is energized after the time delay. This action applies the output of the HLRM to the power amplifier through contacts 6 and 3 of energized relay K3.

BIAS VOLTAGE SUPPLY

In order to generate a bias voltage to operate the audioamplifiers at the desired class

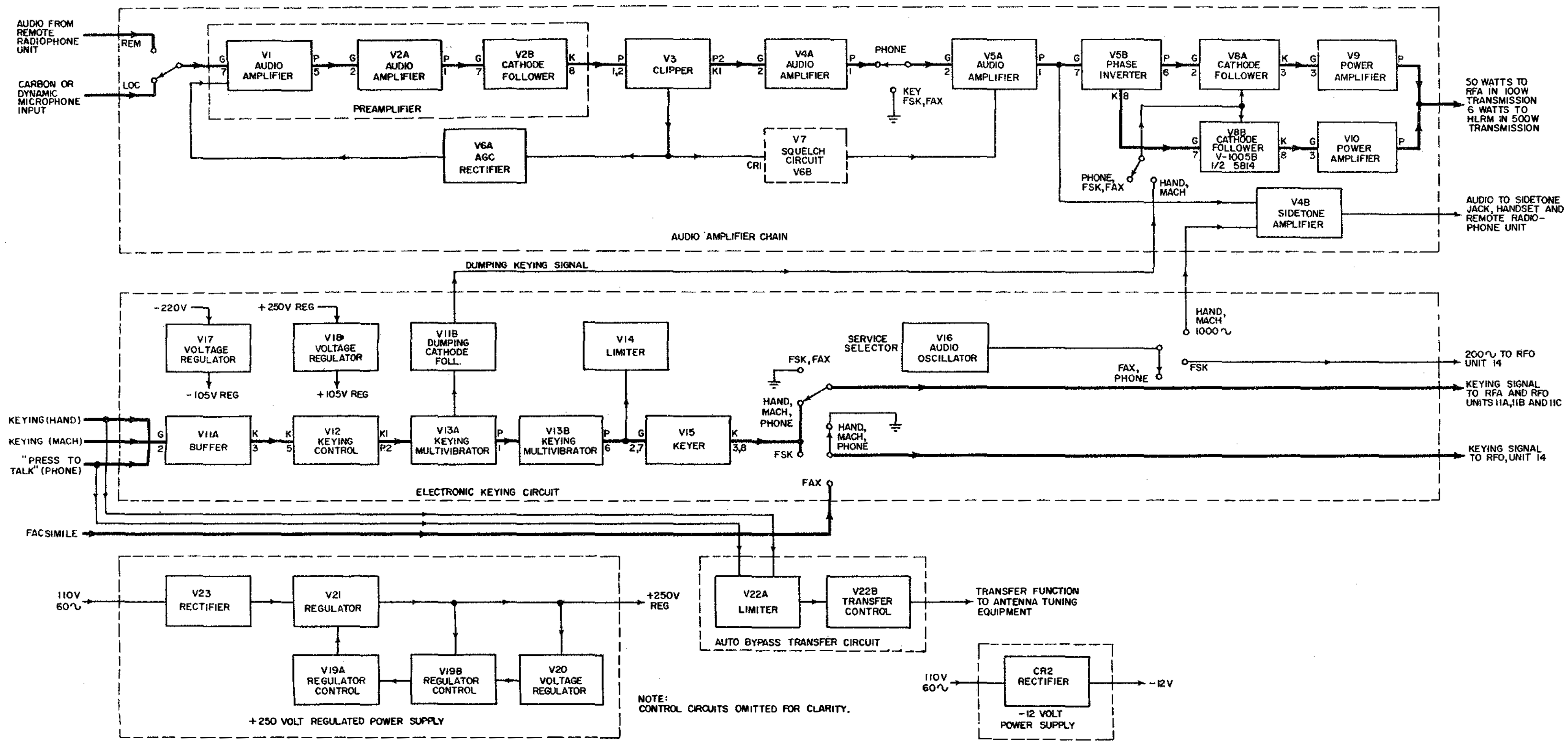

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Figure 8-13.—Low-level radio modulator, block diagram.

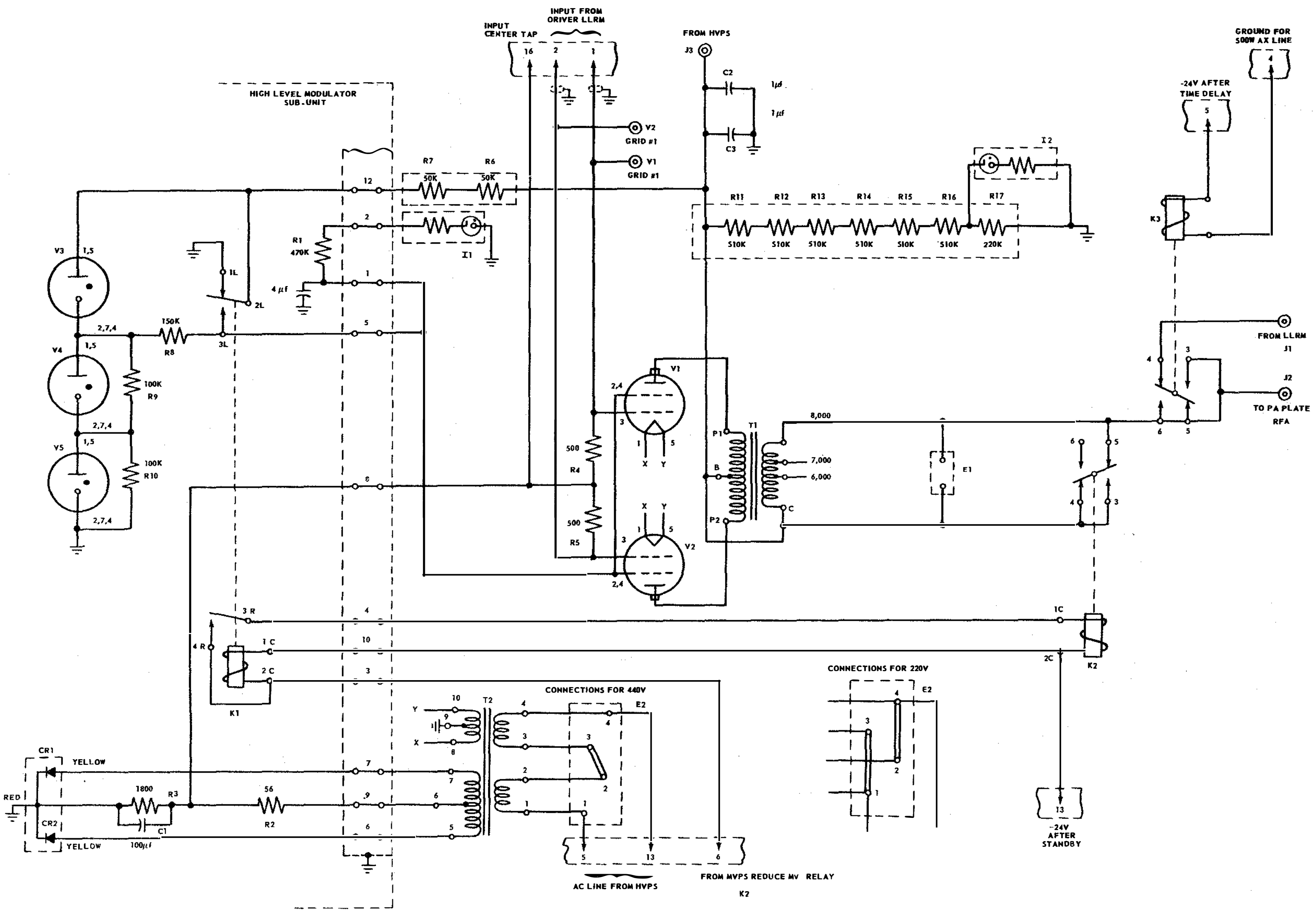

Figure 8-14.—High-level radio modulator, simplified schematic.

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AB2 point on its characteristic curve, a bias source is included in the HLRM. This supply is obtained from terminals 5 and 7 of T2, using metallic rectifiers CR1 and CR2 connected as a negative full-wave rectifier. The rectifier output voltage is taken from terminal 6 of T2 through the single section R-C filter comprised of R2 and C1. The bias source is applied to the center tap of the 6-watt secondary of the driver output transformer. The bias source is also applied to the junction of the audioamplifier grids in the HLRM through resistors R4 and R5 respectively. These resistors limit the amount of grid current drawn, thereby limiting the amount of distortion.

Transformer T2, through secondary terminals 8 and 10, also supplies filament voltage for amplifier tubes V1 and V2. Transformer T2 has two primary windings that may be connected in series for 440-volt, single-phase, 60-cycle input, or in parallel for 220-volt input by means of the links on E2.

REGULATED 360-VOLT D-C SUPPLY

The screen grids of the HLRM receive a regulated +360 volts. This supply is obtained from the voltage divider action of R6, R7, and voltage regulator tubes V3, V4, and V5. These regulator tubes are shorted to ground through contacts 1L and 2L of deenergized K1 during 100-watt operation. During 500-watt operation, relay K1 energizes, removing the ground and applying +360 volts to the screen grid of V1 and V2. Resistors R8, R9, and R10 act as a voltage divider in parallel with the regulators to protect the tubes until they fire and take control.

POWER SUPPLIES

Power supplies used with the AN/SRT-15 transmitter are designated low-, medium-, and high-voltage supplies. Three supplies are necessary because the transmitter at the higher output levels requires higher operating potentials. Several control circuits are contained in the power supplies, which also control the on-off condition of the transmitter. These power supplies are examined separately in the following paragraphs.

LOW-VOLTAGE POWER SUPPLY

The low-voltage power supply (LVPS) shown in figure 8-15 receives 110-volt, 60-cycle, single-phase power from the ship's supply and delivers this voltage to the MVPS, RFO, LLRM, RFA, and antenna coupler. The LVPS also supplies the following d-c voltages: +250 volts to the RFO, +300 volts to RFA and LLRM, -220 volts to RFA and LLRM, and -24 volts for motor and control circuit functions.

Input Circuit of LVPS

The input circuit receives its voltage through receptacle J1 (fig. 8-15). When emergency switch S1 is closed, power is applied through the respective fuses to the start-stop circuit and main power transformer. Power is also applied through fuses and the cabinet heater switch S3 to space heaters in the cabinet (not shown). To assure frequency stability, the heaters maintain the cabinet at a constant temperature.

Power Application

With the emergency switch closed and the start button on main power switch S2 depressed, master control relay K4 is connected across the line. With K4 energized, contacts L3 and T3 close so that when the start button is released, R1 and C1 are added in series with the relay winding. Addition of these components provides a series impedance with the winding, which allows adequate holding current to keep the relay energized when power is on. Main power indicator lamp L2 is also connected across the line through contacts L3 and T3 of K4.

Contacts L1 and T1 and L2 and T2 of energized relay K4 apply 110-volts a-c to main power transformer T1 and a-c line output terminal. From this terminal, a-c is applied to the RFO, LLRM, MVPS, RFA, and antenna coupler. In addition to this action, a-c is applied to contacts 4L and 4R of relay K3. If K3 is energized, a-c potential is advanced to the cabinet blowers (not shown).

When a remote radiophone unit is used, contacts L4 and T4 of energized relay K4 connect a line to the power indicator in this unit.

Removing Power

To turn off the transmitter, depress the stop button of main power switch S2, which places a short across K4. This action causes K4 to deenergize. Depressing the stop button

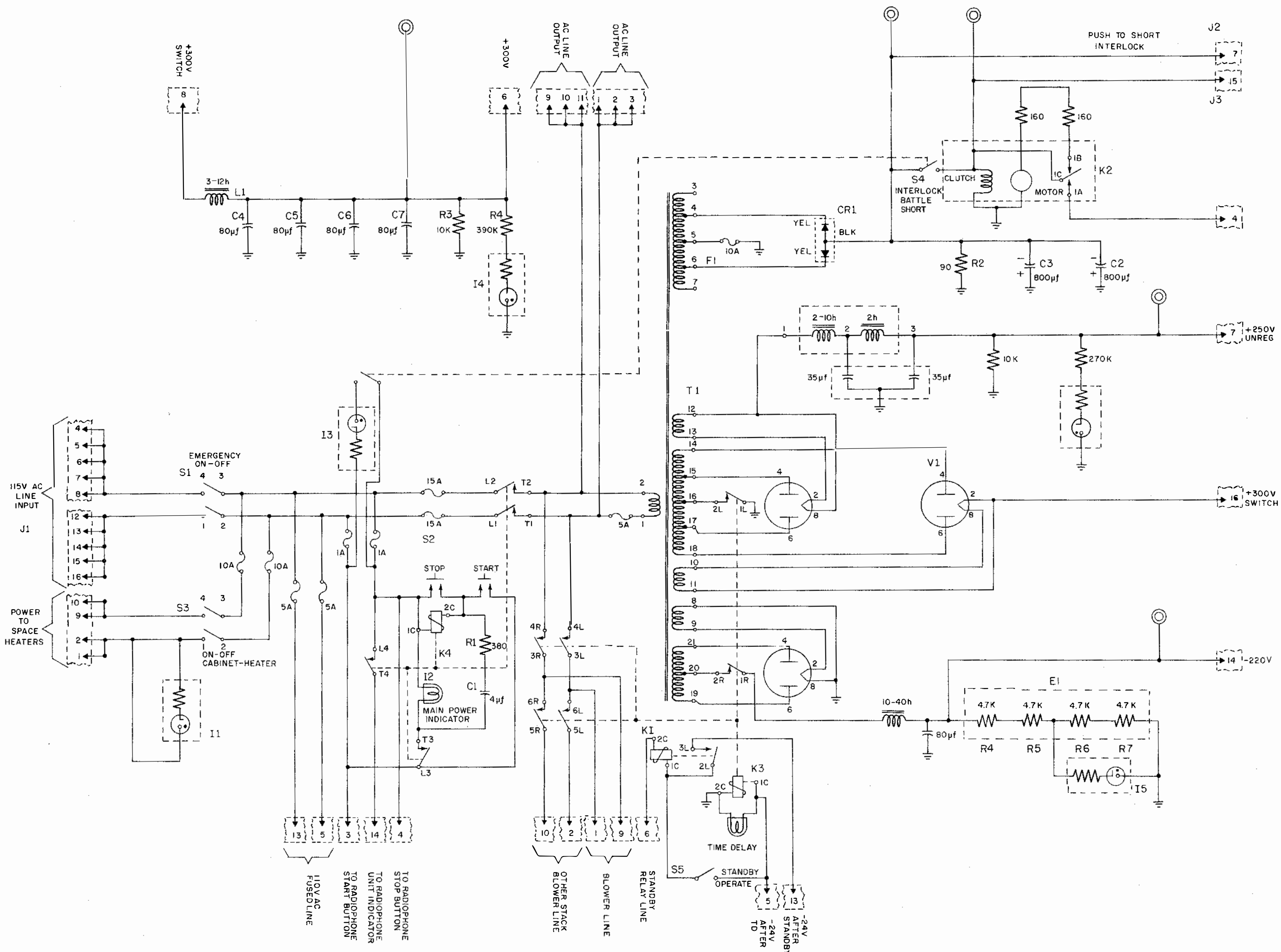

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Figure 8-15.—Low voltage power supply.

on LVPS does not place a short across the line because of the presence of R1 and C1. With K4 deenergized, power is removed from T1 and from all the circuits previously energized by this relay, as explained already.

Minus 24-Volt D-C Supply

The -24-volt d-c supply is taken from the secondary terminals 4 and 6 of T1. This circuit contains a full-wave metallic rectifier CR1 and the filter comprising C2, C3, and R2. The center tap is grounded through fuse F1.

Output of the filtered -24-volt supply is fed to time delay relay K2 through interlocks. Interlocks are contained in the LVPS, MVPS, RFA, LLRM, and RFO. In the AN/SRT-15, interlocks also are contained in the HVPS and HLRM. If all interlocks are closed, they form a short, which exists between J2 and J3 parallel with the interlock battle short, to energize the time delay relay.

The chassis of the major units of the AN/SRT-15 may be pulled out on a slide and rail arrangement without disconnecting cabinet wiring. Drawer interlocks, contained in the slide path, become deenergized when the drawer is withdrawn. An interlock battle short switch bypasses the drawer interlocks when it is in the ON position, but it should be used only in emergencies. Before any major chassis is removed from the cabinet, the battle short switch should be placed in its OFF position. Failure to do so means that the normal action of the drawer interlock is bypassed, and the equipment can be energized with the chassis in the OUT position.

The filtered -24 volts from the -24-volt supply of the LVPS is delivered through the interlocks to the motor and clutch of time delay relay K2. Approximately 30 seconds later, K2 operates its contacts, and this action supplies the voltage described as -24 volts after time delay.

Plate voltage for the +300 volt supply is obtained from terminals 14 and 18 of T1. The center tap (terminal 16) is grounded through contacts 2L and 1L of K3, which is energized when the 30-second time delay times out. This delay allows for the rectifier filaments to reach operating temperature before V1 is required to conduct. The rectified output is fed to a single choke input filter (upper left of schematic) through contacts 5R and 6R of relay K4 located in the medium-voltage power supply. Because the 300-volt supply is mainly a screen voltage supply and the 500-volt supply is basically a plate voltage source in the LLRM and RFA, the action of K4 ensures that plate voltage is present when screen voltage is applied. This provision prevents damage to the screens of the respective tubes they supply. The filter consists of L1, C4, C5, C6, C7, and R3. Resistor R3 is a bleeder resistor, and R4 acts as a dropping resistor for the +300-volt indicator I4. The +300-volt output is rated at 200 ma and is fed to the RFA and LLRM.

Plus 250-Volt Unregulated D-C Supply

The +250-volt unregulated d-c supply (also contained in the LVPS) receives its plate input voltage from terminals 15 and 17 of T1.

Grounding of the center tap is controlled by relay K3, which is energized after time delay.

Minus 220-Volt D-C Supply

The -200-volt d-c supply (fig. 8-15) receives its plate voltage from terminals 19 and 21 of T1. This circuit center tap also is controlled by relay K3, which is energized after time delay. Output voltage is negative because the cathode is grounded, and the rectified voltage is taken from the center tap, terminal 20. Lamp I5 serves as the -220-volt indicator and, when lighted, denotes the presence of this voltage. Terminal board E1 is used as a mounting for voltage divider resistors R4, R5, R6, and R7.

MEDIUM-VOLTAGE POWER SUPPLY

The medium-voltage power supply (MVPS) (fig. 8-16) receives its input voltage from the LVPS, and delivers +500 volts d-c to the LLRM and RFA. Additionally, +1050 or +1300 volts d-c go to the RFA. The MVPS also contains a switching relay to provide assurance that +500 volts is available before +300 volts is applied.

Input Circuit of MVPS

The a-c input to the MVPS is delivered to filament transformer T1. One secondary of T1 supplies filament voltage to the +500-volt rectifiers V1 and V2. The other winding supplies power to the filament of V3 and V4. At the same time, a-c power is delivered to the contacts of relay K1, which must be energized before power

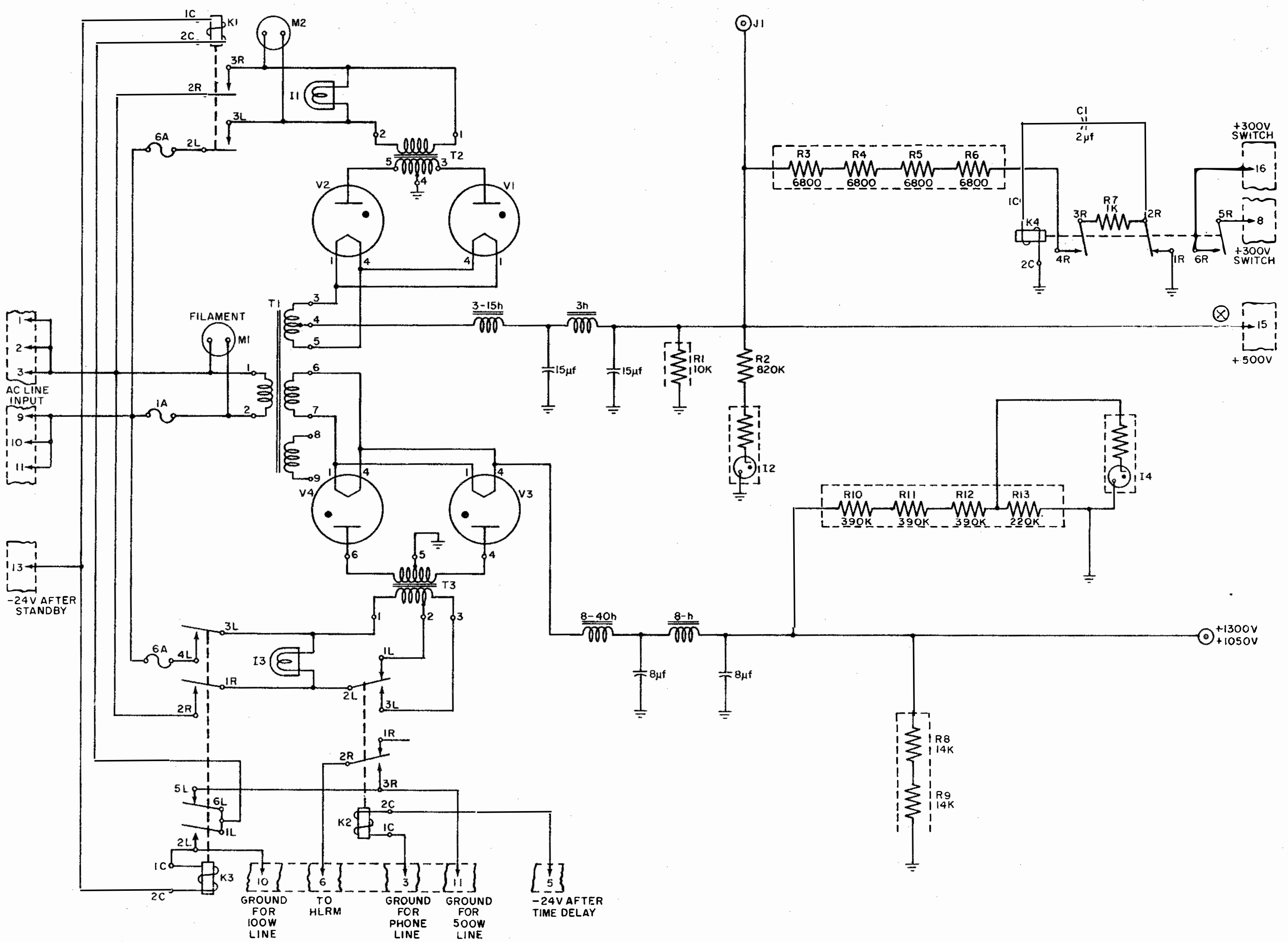

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Figure 8-16.—Medium-voltage power supply.

is applied to the +500-volt plate voltage transformer T2. Relay K1 is energized from the -24-volt after standby line, and it receives ground through the contacts of relay K3.

If the transmitter is operating at 100-watt level, and the standby-operate switch S5 in the LVPS is in OPERATE position, the -24-volt after standby line becomes energized after time delay is complete. The ground for 500-watt line is open, so that the grounding circuit for K3 is completed through the ground for 100-watt line (fig. 8-5). Therefore, K3 and K1 energize through contacts 1L and 2L of K3 to the ground for 100-watt line. Energized K1 supplies plate voltage for the +500-volt d-c supply through its contacts 2R, 3R, 2L, 3L, and plate transformer T2.

It should be noted that relay K1 can become energized in 500-watt operation through contacts 5L and 6L of K3 and the ground placed on the ground for 500-watt line. In 500-watt operation, the 500-volt d-c supply becomes primarily a screen voltage source. Thus the transfer of ground is accomplished, providing assurance that the screen voltage is not supplied before the high-voltage plate supply, which is also under control of the ground for 500-watt line.

If standby-operate switch S3 in the LVPS is in STANDBY position on either 100-watt or 500-watt operation, the +500-volt d-c supply is not energized because the -24 volts after standby line (fig. 8-15) is open and K1 cannot become energized. This action, in turn, prevents application of a-c power to the plate transformer.

When lighted, indicator lamp L1 denotes the presence of the a-c plate input. The rectified output of V1 and V2 of the MVPS is filtered by a double choke input filter. Resistor R1 acts as the bleeder resistor, and R2 is a dropping resistor for the 500-volt output indicator I2. The output is 500 volts, rated at 364 ma, which is supplied to the LLRM and RFA. Jack J1 provides a test point for measuring the +500-volt supply.

Two elapsed time indicators (TOTAL HOURS FIL M1 and TOTAL HOURS PLATE M2) indicate the total time that filament and plate power are on. The filament transformer receives power as soon as the start button in the LVPS is pushed, regardless of the position of the standby-operate switch in the LVPS. Plate transformer T2 receives power only in the operate condition. Hence, the reading of M2 indicates the total time that plate power is on.

Plus 500-Volt D-C Supply

When the +500-volt d-c supply comes on, its output is applied across resistors R3, R4, R5, and R6 in series with switch relay K4. The relay is shunted by capacitor C1 through its normally closed contacts 2R and 1R, which slows operation of the relay. When K4 operates, C1 is removed from the circuit and resistor R7 is placed across C1 through contacts 3R and 4R, providing a discharge path for the capacitor. When K4 is energized, contacts 5R and 6R close, completing the path to the filter circuit in the LVPS.

Plus 1050-Volt to Plus 1300-Volt Supply

The +1050-volt to +1300-volt supply is used only during 100-watt operation. The +1300 volts is supplied to the RFA for all modes of operation except phone, then it is reduced to +1050 volts. When relay K3 becomes energized, 110-volts a-c is applied to its contacts 2R and 1R and 4L and 3L. If the transmitter is in other than phone operation, the ground for phone line is open, and relay K2 cannot become energized. The a-c power, therefore, is applied to the plate transformer through contacts 2L and 1L of K2.

Secondary voltage developed between terminals 4 and 6 of the transformer is approximately 3160 volts rms. When rectified and filtered, it produces the +1300 volts supplying the RFA. When the transmitter is in phone operation, the ground for phone line is completed through contacts 11F and 1F of S4E in the LLRM, and relay K2 of the MVPS energizes from the -24-volt after time delay line. When the relay energizes, the turns ratio is reduced so that the secondary voltage becomes 2480 volts rms. Consequently, the rectified output voltage is reduced to +1050 volts. The smaller voltage is used during phone operation because the power amplifier plate voltage is amplitude modulated by the audio output of either the LLRM or HLRM. If the voltage were not reduced, the peaks of the amplitude modulated plate voltage of the power amplifier would exceed its peak voltage rating.

Because relay K2 energizes only during phone operation, the ground for 500-watt line is completed through contacts 2R and 3R of K2 when the latter is energized. Thus, an additional method of controlling the output of the HLRM during phone operation is obtained.

When K3 energizes, it also supplies 110-volts a-c to the 1300-volt primary indicator I3. The indicator is not controlled by relay K2, and therefore indicates power applied to the plate transformer T3 for either the +1050-volt or +1300-volt output.

The rectified output is taken from the parallel filaments of V3 and V4 and is filtered by a double-choke input filter. Resistors R8 and R9 are bleeder resistors. Resistors R10, R11, R12, and R13 form a voltage divider to which is connected the 1300-volt indicator I4. The output is rated at +1050 volts at 150 ma, and +1300 volts at 180 ma, and is applied to the RFA.

HIGH-VOLTAGE POWER SUPPLY

The high-voltage power supply (fig. 8-17) is used only for 500-watt transmission. It receives either 220-volt or 440-volt a-c, 60-cycle, three-phase input. The HVPS furnishes a d-c output of +3000 volts or +2400 volts, which is supplied to the HLRM.

Input to HVPS

Power to the HVPS is controlled by booster emergency switch S1. The three-phase line supplies voltages to both plate transformer T2 and filament transformer T1. This filament transformer is connected across one phase of the input. Fuses in this power supply for 440-volt input are rated at 3.5 amp. For 220-volt input, a rating of 6.25 amp is required. Power is connected to filament transformer T1 through terminal board E1. When input voltage is 440 volts, a link is placed between terminals 2 and 3 of E1, placing the two windings in series across the line. When 220-volt input is applied, the links are placed between terminals 1 and 3 and between 2 and 4, which action places the two transformer primaries in parallel. In either instance, voltage across each of the two primaries is 220 volts.

The motor of time delay relay K4 is connected across terminals 3 and 4, whose potential is always 220 volts. With S1 closed, voltage applied to the motor causes the time delay relay to time out in about 30 seconds, thereby closing its two sets of contacts. Contacts 5 and 7 place time delay indicator I1 and dropping resistor R1 across the 220 volts.

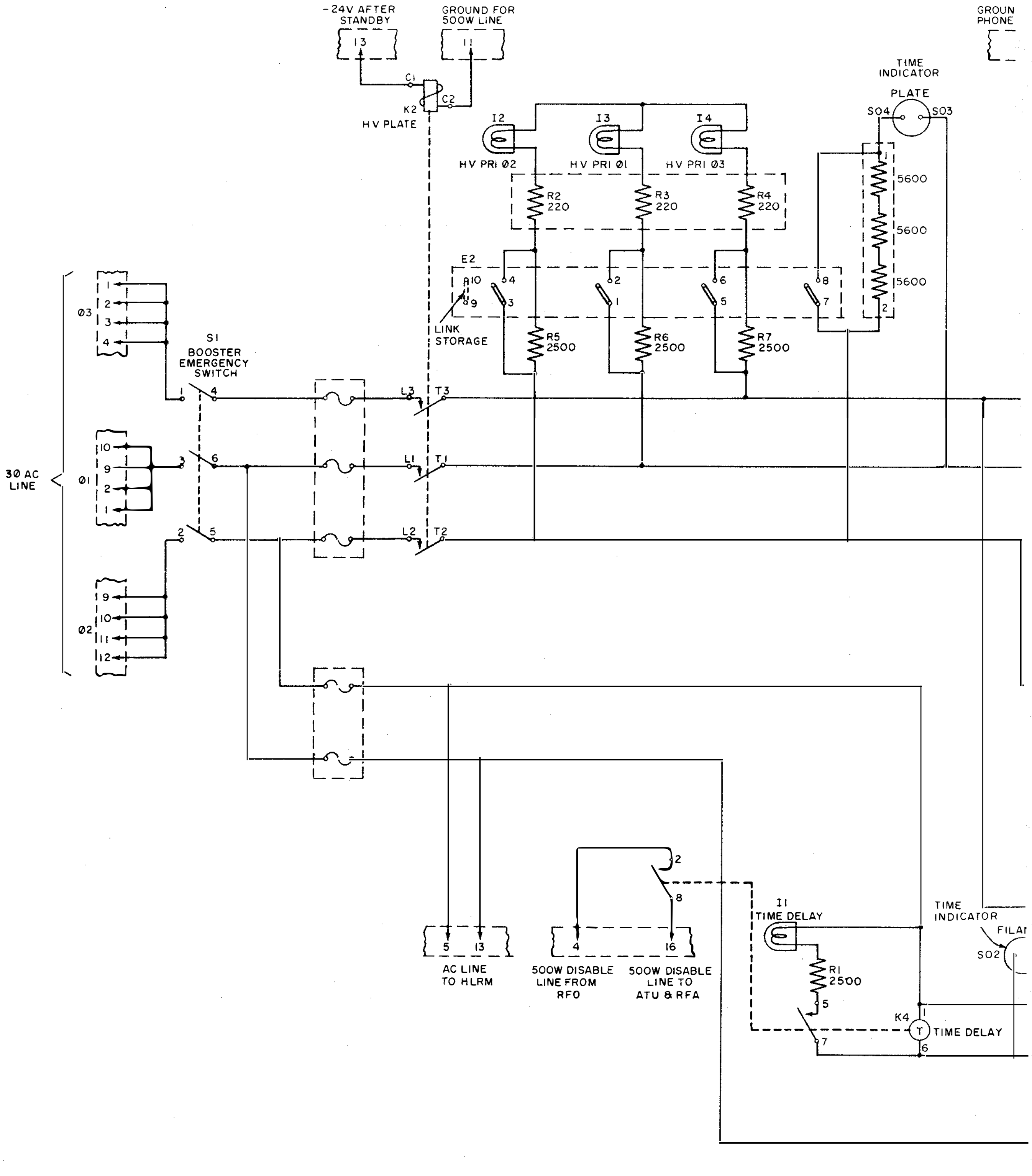
All components of the 500-watt disable line must be activated properly before the transmitter can be placed in 500-watt operation. Contacts 2 and 8 of time delay relay K4 are situated in the 500-watt disable line. Reference to figure 8-5 shows that relay K1 (also in the 500-watt disable line) controls the ground for 500-watt line. When K4 times out, the ground for 500-watt line is completed, and if standby-operate switch S5 in the LVPS is in the operate position, the -24-volt after standby line is energized. Thus, high-voltage plate relay K2 is placed in operation. Plate voltage to the HVPS is controlled in this manner so that filaments of rectifier tubes V1 through V6 may reach proper operating temperature before high voltage is applied.

When contacts L1 and T1, L2 and T2, and L3 and T3 of K2 close, three-phase power is connected to T2 and to primary indicator lamps I2, I3, and I4. These indicator lamps are wye-connected across the phases, and indicate the presence of voltage at the primary of the plate transformer. Resistors R2, R3, and R4 and R5, R6, and R7 are dropping resistors for the indicators. With 220-volt input, R5, R6, and R7 are shorted out by connecting links between terminals 1 and 2, 3 and 4, and 5 and 6 on E2.

HVPS Output

Relay K1 is energized during 500-watt phone operation, and it reduces the output of the supply from +3000 volts to +2400 volts by decreasing the turns ratio of plate transformer T2. The secondary of T2 is delta-connected. Each winding develops 2260 volts rms when the transmitter is in CW operation and 1835 volts during phone transmission. Six half-wave rectifiers, V1 through V6, are connected as a three-phase, full-wave rectifier. When power is applied, two of the rectifier tubes will be conducting at any given time.

Consider the action at one instant in the rectifier operation. Assume that point HV1 is positive momentarily, and that point HV2 is negative at the same time. Two rectifiers V6 and V2 are conducting in such a manner that the electrons flow from HV2 (negative) through V2, to ground, through the external circuit and filter choke L1 and back through V6 to HV1. At another instant the polarity reverses so that HV1 is negative and HV2 is positive. In this condition, rectifier V2 conducts, passing a current to ground through the load and back through V5. In this manner, two current peaks are produced for each cycle input. The other two phases also produce two current peaks per cycle, but at different times, because of the 120° phase angle


-24V AFTER STANDBY
GROUND FOR 500W LINE
GROUN PHONE
TIME INDICATOR
PLATE
SO4
SO3
K2
HV PLATE
I2
I3
I4
HV PRI Ø2
HV PRI Ø1
HV PRI Ø3
R2 220
R3 220
R4 220
5600
5600
5600
E2
LINK STORAGE
R5 2500
R6 2500
R7 2500
Ø3
S1 BOOSTER EMERGENCY SWITCH
3Ø AC LINE
Ø1
Ø2
L3
T3
L1
T1
L2
T2
I1 TIME DELAY
R1 2500
K4
TIME DELAY
TIME INDICATOR
FILA
SO2
AC LINE TO HLRM
500W DISABLE LINE FROM RFO
500W DISABLE LINE TO ATU & RFA

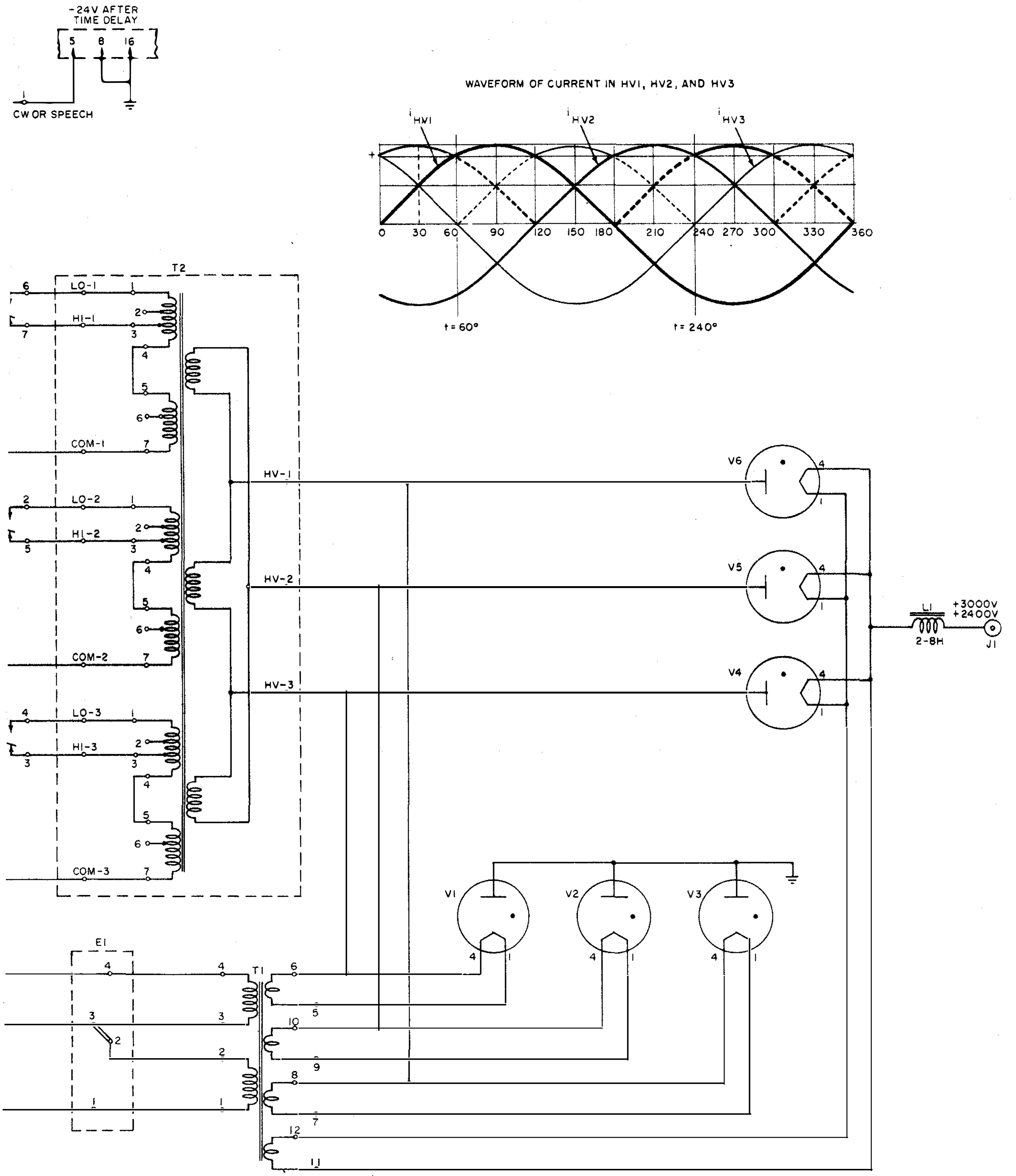


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Figure 8-17.—High-voltage power supply.

between each phase voltage. Six current peaks pass through the load for each input cycle, providing a ripple frequency of 360 cps.

The filter capacitors, bleeder resistor, and 3000-volt indicator, which form an additional portion of the filter circuit with choke L1, are connected from J1 in the HVPS to J3 in the HLRM (fig. 8-14). This connection is made because of space limitation in the HVPS. Because of the high ripple frequency, filter capacitors C2 and C3 can be smaller than would be required for a single-phase, full-wave filter circuit. Resistors R11 through R17 act as a bleeder and a voltage divider from which the 3000-volt indicator I2 receives its operating voltage.

Four filament secondaries of T1 (fig. 8-17) supply the high-voltage rectifier tubes. Three of these windings are rated at 5 amp, and the other (connected between terminals 11 and 12) is rated at 15 amp. The 15-amp winding supplies rectifiers V4, V5, and V6. Each of the rectifiers V1, V2, and V3 employs a separate 5-volt filament winding.

The +3000-volt output of the HVPS is supplied to the HLRM in 500-watt operation during CW, frequency shift, and facsimile operation. During phone transmission at the 500-watt level, the +2400-volt output is supplied to the HLRM.

RADIOPHONE UNIT

To operate the transmitter from a remote location requires a radiophone unit, commonly called RPU. The RPU is not a part of the AN/SRT-15 transmitter set. Radiophone units are installed in such spaces as CIC and the bridge to permit operation of the transmitter from those locations. The RPUs used with the AN/SRT-15 transmitter contain a start-stop switch for turning the transmitter on or off; jacks for connecting a handset or chestset, microphone, headphones, or telegraph key; a volume control for the headphones; and indicator lamps for transmitter-on and carrier-on indications.

A representative Navy radiophone unit is illustrated in Radioman 3 & 2.

CHAPTER 9

VHF/UHF COMMUNICATION EQUIPMENTS

The increase in congestion of the communication channels below 30 mc and the special advantages of shorter wavelengths in the very-high and ultrahigh-frequency bands have led to increasing use of these parts of the r-f spectrum.

The upper limit for radio signals that can be returned effectively to the surface of the earth by the ionosphere is about 30 mc. Therefore, 30 mc was chosen as the low-frequency limit of the VHF band. This 30-mc dividing line is not an abrupt one, because there is no abrupt change in the ability of the ionosphere to return the r-f waves to earth as the frequency is increased. Ionospheric changes take place over a region of the frequency spectrum with its center at about 30 mc. The band of frequencies affected by ionospheric changes may occasionally move higher or lower by considerable amounts.

The 300-mc dividing line between the VHF and UHF bands and the 3000-mc upper limit of the UHF band likewise are more or less arbitrary and are agreed upon for convenience. Again, these dividing lines are not abrupt. The limits should be thought of as transition regions, centering on those frequencies.

It must be understood that the behavior of radio waves at VHF/UHF frequencies is different from lower frequencies, and the differences are extremely important. For this reason, this chapter begins with information on the fundamental differences of radio waves in this frequency range and the reasons for the differences.

Communication equipments below 225 mc in the VHF range are not used extensively aboard ship any more, because most tactical voice circuits now operate in the UHF band. Limited installations of VHF equipment are retained principally for communication with allied forces who have not yet converted to UHF equipments.

Transmitters and receivers installed in Navy ships cover only parts of the VHF and UHF bands. The VHF equipments, described later in this chapter, cover the range of frequencies from 115 to 156 mc. Shipboard UHF transmitters and receivers are designed for 225- to 400-mc operation. Although this frequency range includes the upper portion of the VHF band, the equipments commonly are called and referred to in this chapter as UHF equipments.

The distributed properties of inductance, capacitance, and resistance associated with any conductor are discussed first, because their effects must be understood before the action of radio circuits at these frequencies can be comprehended. In particular, the effect of the distributed properties of inductance, capacitance, and resistance in the connecting leads in radio circuits are presented. These effects are the principal reason for the physical differences between equipment operating in this frequency range and the more familiar circuits used at lower frequencies.

It also is necessary to understand the changes that occur in the behavior of lumped-property components, such as inductors, capacitors, and resistors, when they are operated in the UHF/UHF region. The differences in design of components meant for operation in these frequency bands are compared with the more familiar lower frequency components.

The remainder of the chapter describes shipboard transmitters and receivers in current use throughout the fleet.

SPECIAL ADVANTAGES OF SHORTER WAVELENGTHS

At 30 mc and above, the ionosphere does not return radio waves to the surface of the earth very effectively, except under rather unusual conditions. Effective range of radio communication in these frequency bands is thus limited to points not far beyond the optical horizon, as seen from the transmitting antenna. At first this limitation was considered serious, because most of the emphasis was on long-distance communication, far beyond the horizon. It soon was realized however, that the shorter wavelengths could be used for covering relatively local areas. This capability freed some additional lower frequencies for long-distance communication.

Because propagation of these shorter radio waves does not normally reach points on the surface of the earth beyond the horizon, stations can operate on the same assigned frequency without interference, if they are separated far enough geographically. This separation provides reliable short-range communication and is widely used in naval operations at sea, for convoy communications, and for communications between ships and aircraft.

A second effect of the decrease in wavelength as the frequency is increased is related to the phenomenon of radio-wave reflection. All electromagnetic waves, such as radio, light, and heat, can be reflected, but how well they are reflected depends on a number of different factors.

One factor is the relationship between the length of the wave and the physical size of the reflecting object. Another factor directly related to wavelength is the physical size of the equipment used to generate the r-f energy, and the antenna needed to radiate it effectively. Both of these factors can be made smaller in direct proportion as the wavelength is made shorter. For example, a half-wave antenna for a station operating in the broadcast band requires a tower hundreds of feet high, but at 500 mc an aluminum rod 30 cm (11.8 inches) long is sufficient. Obviously, equipment for the shorter wavelengths can be made smaller and more compact because of this relationship between physical size and wavelength.

DISTRIBUTED PROPERTIES

Distributed properties may be defined as the inductance, capacitance, and resistance uniformly spread along each unit length of any circuit element, plus the inductance and capacitance existing from each conductor to ground and to other objects. For example, a 1/4-inch rod of copper, 4 inches long, placed in free space where no outside influence could act upon it, would be found to possess small but definite values of inductance, capacitance, and resistance. If the conductor were cut in two, each part would possess exactly half the values previously found. In other words, the distributed properties are uniform as long as the conductor itself remains uniform in cross-sectional size, shape, and conductivity, and where no external influences exist. If the conductor is not uniform, the distributed properties still exist, but their distribution is not uniform.

When a conductor is placed in an actual circuit, it possesses these self-contained distributed properites, and may or may not possess additional distributed properties caused by its proximity to ground and to other conductors in the circuit. Distributed properties exist in all conductors and conducting surfaces, even in the leads and other parts of the lumped-property circuit elements (capacitors, coils, resistors), which are manufactured to provide definite amounts of the properties. When used in practical circuits at VHF/UHF frequencies, however, the distributed properties of inductance, capacitance, and resistance in a given conductor actually are not fixed amounts or constants, but slowly change in value as the frequency changes.

At frequencies below 30 mc it is practicable to ignore distributed, or stray, circuit properties, except in circuits such as resonant sections of transmission lines or antennas. Above 30 mc, the effects of distributed properties upon practical circuits can no longer be neglected, because of the relationship between the physical size of the circuit components and the wavelengths. At 3 mc, for instance, one wavelength is 100 meters long, in comparison with which a 6-inch length of wire is very short. When the wavelengths become relatively short, as the frequency increases, it becomes physically impossible to scale down the parts of the electronic circuit and keep them small in relationship to wavelength. Even where such a size reduction is possible, the power-handling ability of the circuit is reduced in proportion. As a result, much of the usefulness of the device is lost.

When the operating frequency increases, the various losses that lower circuit efficiency increase, and make it desirable to use circuit arrangements and elements that have lower built-in losses. So far it has been found impossible to construct lumped-property elements that are pure and do not contain small distributed values of the other two properties. As the working frequency increases, the effects of the unwanted distributed properties cause increased losses, with the result that the efficiency drops.

In circuits having distributed properties, losses are lower than in the same circuits constructed of lumped-property elements, because it is possible to use conductors of proper size and shape to minimize r-f resistance and because the dielectric is usually air. The result is that better circuit stability and efficiency are achieved by using the distributed properties.

DISTRIBUTED INDUCTANCE

The term "distributed inductance" refers to the self-inductance distributed along the length of any sort of conductor, whether it is or is not meant to act as an inductor. Inductance is the property of a conductor that tends to oppose any change of electron flow through the conductor. Inductance reveals itself only when current is varying in the conductor; a back emf (electromotive force) is induced in a direction that tends to oppose the change in current flow. It is apparent that even a very short section of straight wire possesses self-inductance. The conductor does not have to be wire, however; it can be any conductor, any shape or size.

Usually, the actual amount of self-inductance is small, but its effect becomes important at frequencies above 30 mc. The effect may be desirable or unwanted, but it cannot be ignored. A complex equation is needed to find the actual value of self-inductance, but the important point here is that the value depends directly on the number of lines of flux surrounding the conductor. Self-inductance is highest at the center of any conductor carrying alternating current, and tapers off toward the outside surface. This phenomenon is the cause of skin effect, explained later.

Undesirable Effects

The property of distributed inductance can cause serious r-f losses if leads and connecting linkages are not kept as short as possible. Figure 9-1 demonstrates how this loss takes place. The plate tank circuit (part A) is designed to operate at a frequency of 4 mc. The inductor is connected to the tube plate by a 4-inch length of No. 20 wire having a self-inductance of approximately 0.1 microhenry (uh). Ignoring loading and other factors, calculation shows that the resistive impedance offered by the tank circuit at resonance is 4710 ohms, whereas the inductive reactance ($X_L = 2\pi fL$) of the connecting wire is approximately 2 ohms, and is

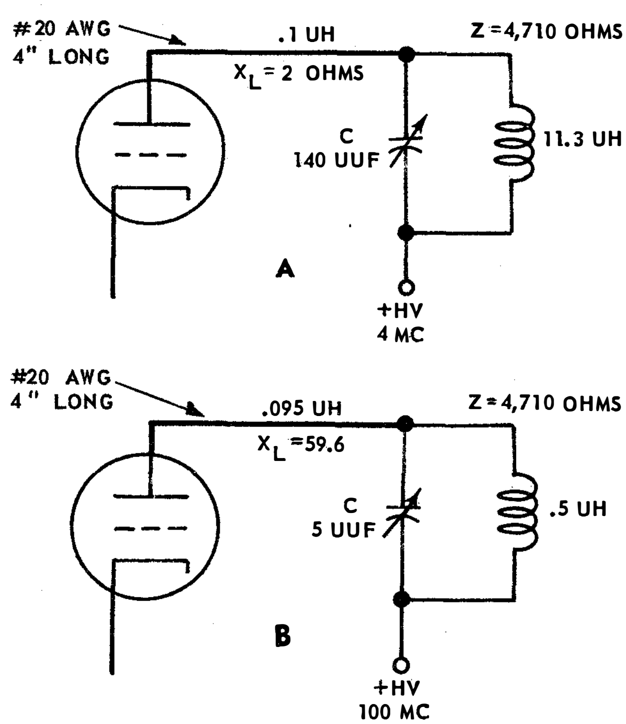

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Figure 9-1.—Effect of distributed inductance at higher frequencies.

so small in proportion to 4710 ohms that it can be neglected at this low frequency.

When the operating frequency is raised to 100 mc (part B, fig. 9-1), the inductance of the tank coil must be reduced to resonate at the higher frequency. At 100 mc, the self-inductance has decreased slightly and, if the tube-plate lead remains 4 inches long, its inductive reactance is 59.6 ohms. The resistive impedance of the tank circuit still is 4710 ohms at resonance and, therefore, a voltage-divider effect occurs, which prevents the entire r-f signal output of the tube from being impressed across the tank circuit and results in a loss of gain. Moveover, in addition, the introduction of an inductive component causes a phase lag that is undesirable in certain applications. At higher frequencies, the effect becomes even more pronounced, introducing larger losses.

Desirable Effects

In certain circuits, a condition of series or parallel resonance is desired, and the property of distributed inductance, distributed capacitance, or a combination of both, may be used to achieve this. For example, to provide a bypass for signal voltages from the low-impedance end of an i-f tank circuit back to the cathode of the tube, a series-resonant circuit offers the lowest impedance path. When the i-f frequency is above 30 mc, it is possible to get the effect of series resonance by cutting the leads of the capacitor to lengths offering the necessary series inductance. This effect is shown in parts A and B of figure 9-2. Note that the capacitance is lumped, but the inductance is the distributed inductance of the capacitor leads. However, the signal voltage sees a certain value of each property, regardless of whether the properties are lumped, distributed, or any combination thereof.

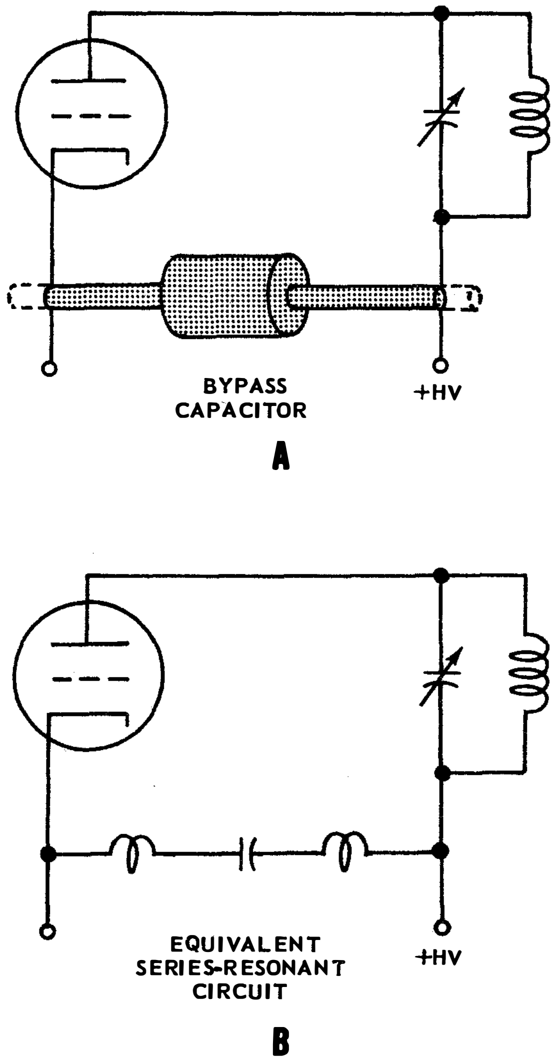

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Figure 9-2.—Series resonance; lumped capacitance and distributed inductance.

Inductive Coupling

When a conductor carrying alternating current runs sufficiently close to another conductor, its magnetic field induces an electromotive force in the second conductor, causing a current to flow. This combination is the effect of mutual inductance.

The study of mutual inductance and coupling at lower frequencies usually is restricted to coils and transformers, but above 30 mc the effect of coupling between two conductors—even two straight pieces of wire—becomes important. The amount of coupling or mutual reactance between two inductors increases as the frequency is increased if the physical relationship remains the same.

Some effects of coupling between distributed inductances are undesirable. For instance, if the grid and plate leads of a single-tube amplifier stage are permitted to run close to each other, signal energy from the plate circuit may be coupled back to the grid, causing either regeneration or degeneration. Distributed capacitance also is present, but only the inductive coupling effect is considered at this time. As another example, a current-carrying wire may be too near a tube shield, inducing an emf that causes current to flow in the shield. This current flow through the shield is a power loss that can be supplied only from the current-carrying wire.

When inductive coupling causes circuit imbalance or power loss, it usually is spoken of as stray coupling. The amount or degree of coupling depends directly on the relative positions of the conductors as well as their distance from each other. Figure 9-3 shows the effect of physical position on the degree of coupling. In A, the coupling is loose, inasmuch as the leads are crossing at right angles, and the least mutual inductance results. The coupling between the wires in B and C increases because of the greater amount of mutual inductance. Practical circuits are laid out with the shortest possible leads, well separated from one another and distant from the chassis and shields. If two wires must cross, they should cross at right angles, because in this manner the smallest mutual inductance results.

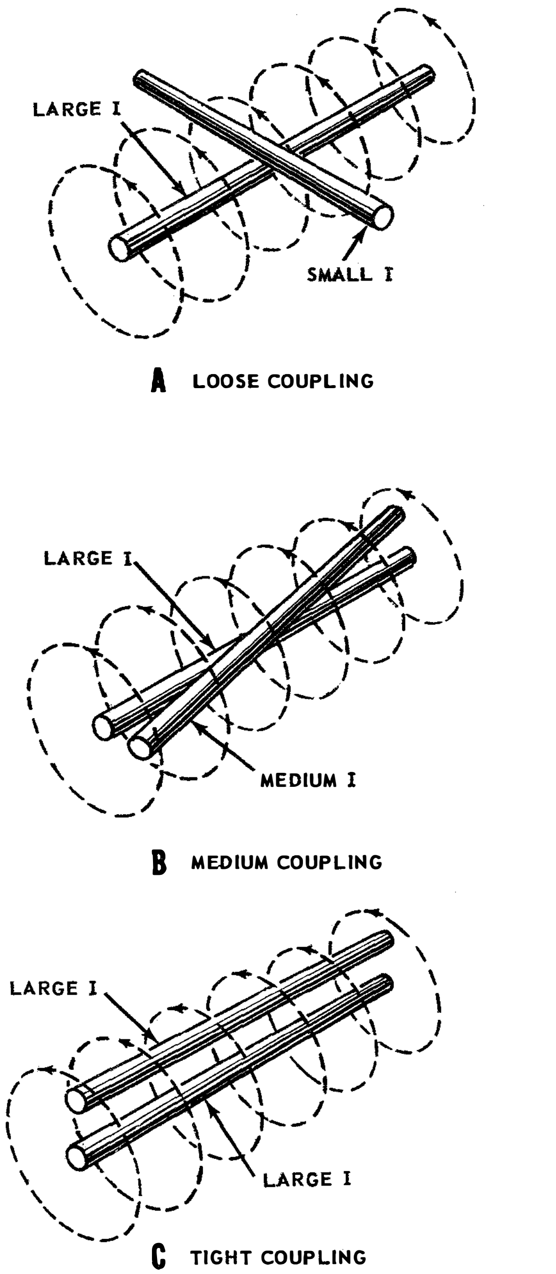

Figure 9-3.—Coupling effects at higher frequencies.

DISTRIBUTED CAPACITANCE

The term "distributed capacitance" refers to the capacitance between any point on a conductor and all surrounding objects. Capacitance exists between any two points that are at different electrical potentials. This capacitance exists whether the points of different potential are in different conductors or in the same conductor. Although the self-capacitance of a conductor is of relatively little importance, except in special circuits, the effect of the capacitance between two conductors must be taken into consideration at VHF/UHF frequencies. Distributed capacitance that exists between the parts of circuit elements and the electrodes of vacuum tubes, as well as between leads and switch contacts.

The actual value of distributed capacitance changes only slightly with frequency, but the reactance changes greatly. The formula for capacitive reactance ($X_c = \frac{1}{2\pi fC}$) shows that if the value of capacitance remains the same, increasing the frequency causes the capacitive reactance to decrease. Therefore, a small value of distributed capacitance at the lower frequencies offers a high reactance to the flow of a-c, but at VHF frequencies it offers a lower reactance. This effect often is undesirable when it occurs accidentally between two conductors in a circuit, but may be used deliberately to achieve series or parallel resonance in resonant line sections. The losses in distributed capacitance are lower than those in lumped capacitors because the dielectric is usually air, instead of a solid, and because the r-f resistance and distributed inductance values are smaller.

Undesirable Effects

An example of the manner in which distributed capacitance may upset the proper operation of a circuit is shown in figure 9-4. Assume that C_d represents a distributed, or stray, capacitance of 1 mmf appearing between ground and the lead from the coupling capacitor to the grid of tube V2. The stray capacitance C_d effectively shunts the 5000-ohm grid impedance Z_g. If an r-f signal at a frequency of 2 mc is traveling from the tank circuit of V1 to the grid of V2, the 1-mmf distributed capacitance offers a capacitive reactance of 79,618 ohms to the signal. This value is so high in relation to Z_g that its effect is negligible at this frequency and similar low frequencies. If, however, a 100-mc signal voltage is coming from the tank circuit of V1, the same 1-mmf stray capacitance offers only 1592 ohms of capacitive reactance. Now, the signal voltage sees a relatively low-impedance path across the stray capacitance,

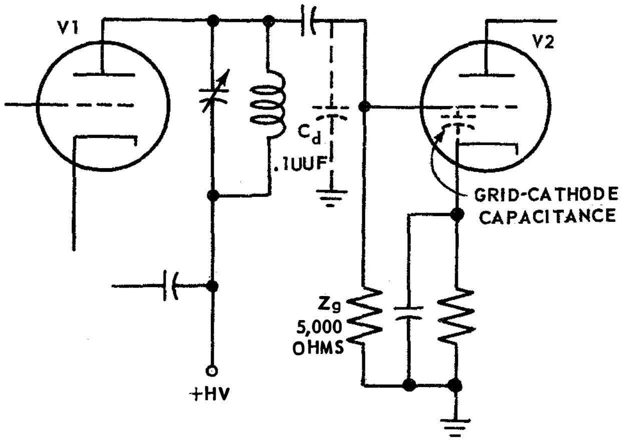

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Figure 9-4.—Effect of distributed capacitance at higher frequencies.

offering less than one-third the opposition of the grid impedance Z_g. Therefore, more than two-thirds of the signal voltage is shunted across this path and lost. If the frequency of the signal voltage is increased to 400 mc, the reactance drops to 398 ohms, and only a very small amount of the signal voltage reaches the grid impedance.

To keep the stray capacitance at a minimum, the circuit wiring is kept well spaced with short leads that run at right angles to one another whenever possible.

Desirable Effects

For certain applications, such as i-f amplification, a parallel LC (inductance-capacitance) circuit, resonant at a single frequency, is useful. A simple way of achieving this resonance is to wind a coil in such a manner that the total distributed capacitance is used to make the coil self-resonant at the desired frequency.

Part A of figure 9-5 shows the distributed capacitance that exists because of the difference of potential between adjacent turns of any coil. The sum of these small values is shown in part B as an effective value of capacitance in parallel with the lumped inductance of the coil. Although most inductors are wound to minimize the distributed capacitance some are designed to offer the necessary capacitance to provide a desired LC ratio. This design offers an advantage because the response of the tuned circuit can be made sharper than would be possible with lumped-property coils and capacitors.

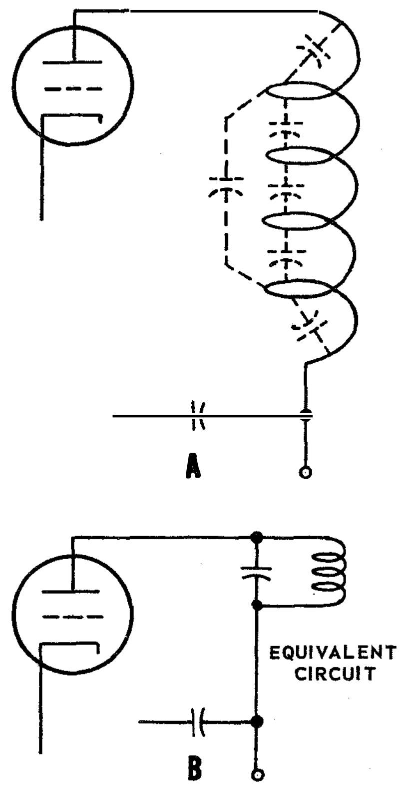

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Figure 9-5.—Parallel resonance; lumped inductance and distributed capacitance.

DISTRIBUTED RESISTANCE

The term "distributed resistance" seldom is used, because it is necessary to distinguish between the resistance offered to d-c and low-frequency a-c and the resistance offered to r-f currents at the higher frequencies.

Depending on the conductivity of the metal or alloy, all conductors have d-c resistance. It is distributed uniformly along conductors that are uniform in cross-sectional area, shape, and conductivity. Resistance to r-f, however, is caused by d-c resistance plus the effect of self-inductance, which is greater at the center of a conductor than at the surface. At the lower frequencies, this self-inductance has little effect on the flow of current because the values of inductive reactance are extremely small. As the operating frequency increases, the inductive reactance at the center of the conductor becomes higher, and the current seeks the lower-reactance path toward the surface, resulting in a current distribution that is not uniform.

Tendency of the current to flow on or near the surface of a conductor is called skin effect. As the frequency increases, less current flows in the center of the conductor and more flows on the surface. The result is that more current is forced through less conductor, with higher losses and more heating. Because the center of the conductor is not carrying current, the effect is the same as using a smaller conductor. The r-f resistance at VHF frequencies can amount to several times the d-c resistance of the same conductor.

Minimizing Skin Effect

Skin effect takes place regardless of the shape of the conductor, but it causes less r-f resistance in conductors having rectangular cross sections than in those that are circular, like common wire. Flat copper strip sometimes is used, but it is more expensive and not easy to work. Another means of reducing skin effect is the use of hollow or tubular conductors.

Litz wire, as it commonly is called, is made up of many strands of very fine enameled wire woven together. The current is divided among the strands, and the skin effect on any single conductor is extremely small. Litz wire is comparatively expensive, however, and is not widely used.

Probably the best method of avoiding losses from r-f resistance is by silver-plating the conductors. This method does not eliminate skin effect, but takes advantage of it. When the plated conductor carries r-f, skin effect takes place as usual. Now, however, the current is flowing in the silver plating, which has less d-c resistance than ordinary conductors; therefore, the r-f resistance is reduced considerably. In practice, plating is expensive, limiting its use.

The most common means of reducing r-f resistance is to use a hollow conductor or one of larger diameter. Again, this method does not eliminate skin effect. The depth to which the current penetrates is affected only by the frequency and the conductor material; consequently, when the diameter is increased, the current layer has the same thickness but more cross-sectional area in which to flow, reducing the effective r-f resistance.

LUMPED-PROPERTY COMPONENTS

A lumped-property component is an electronic part in which a definite amount of capacitance, inductance, or resistance exists, usually with relatively little of either of the other properties present. Capacitors, coils, and resistors used in radio equipment operating at frequencies below 30 mc generally are lumped-property components.

As the frequency of operation is raised, the electrical loss in lumped-property components increases, until a frequency is reached where this increasing loss cannot be tolerated. The increased loss is actually a combination of three distinct effects—dielectric loss, r-f resistance loss, and radiation loss.

Loss in even the best dielectric materials increases with frequency, because a definite amount of applied electrical energy is lost in each cycle, and the more cycles that occur in a unit of time, the more heat is generated in the dielectric.

The r-f resistance loss also increases with increasing frequency, because of skin effect.

Radiation loss occurs in any r-f circuit because of direct radiation from the parts. This loss usually is negligible, so long as the circuit is not more than about 1/10 of a wavelength in any physical dimension. With increasing frequency, however, it becomes impossible to scale the components down in physical size in proportion to the decreasing wavelength, and radiation losses increase. The addition of r-f shielding around the circuit also causes energy to be lost in heating the shield, rather than by radiation.

CAPACITORS

All capacitors, of any size, type, or construction, have characteristics that cause them to behave in a way unlike the theoretical ideal capacitor, which would have pure capacitance, and no inductance or resistance. Practical capacitors actually have some series inductance because of their leads and internal metallic foil plates. This inductance is effectively in series with the actual capacitance as shown in the approximate equivalent circuit of figure 9-6, where C represents the actual capacitance, L the inductance of each lead, and R the effective r-f series resistance of the leads and foils. Losses in the dielectric are represented by the shunt conductance, G. Below 10 mc, dielectric

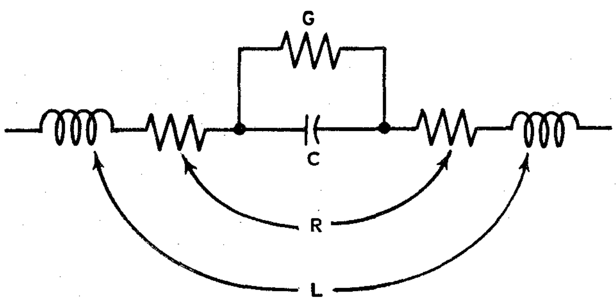

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Figure 9-6.—Equivalent high-frequency circuit of a capacitor.

losses are seldom serious, even in ordinary paper capacitors, and in high-quality mica and ceramic units it has no serious effects at the highest frequencies.

Because capacitors have a small but significant amount of inductance in series with the actual capacitance, there is a resonant frequency at which the reactances of the inductance and capacitance become equal and cancel each other. The reactance becomes capacitive below series resonance, and grows larger as the frequency decreases. The opposite effect takes place above resonance, where the reactance is inductive, and grows larger with increasing frequency.

The common types of electrolytic, mica, paper, and ceramic capacitors are subject to increasing losses as the operating frequency is increased. In electrolytic capacitors, these losses and the inductance of the leads and internal foil strips that form the plates make them practically ineffective as capacitors at frequencies above a few megacycles. Even in equipment operating below 30 mc, electrolytic capacitors usually are shunted with a suitable value of paper or mica capacitor, which bypasses the higher frequency currents around the electrolytic unit.

Paper capacitors also are subject to serious losses as the frequency is raised, but not to so severe an extent as in electrolytic units. The series inductance of paper units is large, and causes them to become series-resonant at frequencies ranging from 1 to 10 mc, depending on the capacitance and lead length.

Mica capacitors, because of their lower losses and smaller series inductance, have an extended range of usefulness. Average types become series-resonant at frequencies from 10 to 100 mc, depending on the capacitance value and lead length.

Ceramic capacitors are a more recent development and have improved properties in certain respects. Their losses are lower than those of mica units, and their design permits a much lower series inductance. As a result, their series resonance may be as high as 400 or 500 mc, which, together with their stability and low losses, makes them preferred in many VHF/UHF applications.

Improvements in Capacitors

Changes in the materials and design of capacitors have been made to adapt them for more effective performance at frequencies above 30 mc. In general, because capacitors do not behave as capacitors above their own resonant frequency, most of the improvements made have been with a view to raising the resonant frequency. The greatest improvement resulted from the development of ceramic materials that made possible ceramic-dielectric capacitors with only two plates, as compared with the many interleaved foils necessary in paper and mica units. Ceramics also made possible capacitors with various temperature coefficients, which can be used to improve the stability of critical circuits.

Various ceramic materials, such as barium and strontium titanates, have been found to have high dielectric constants and good dielectric strength. By plating or firing silver electrodes directly on thin plates of this dielectric material, air and moisture are prevented from getting between the plates of the capacitor. This method results in greatly improved stability. By varying the mixture of the ceramics, the temperature coefficient of the capacitor can be made negative, zero, or positive, as desired. Ceramic capacitors then can be used to compensate for frequency drift caused by changes in other components with changes in temperature. Skin effect is reduced by using short, heavy leads, and losses caused by surface leakage and humidity are minimized by sealing the surface with baked silicon lacquer. A similar process of plating or coating the silver electrode on mica also has been developed for the manufacture of mica capacitors, with considerable improvement in their stability and high-frequency performance.

INDUCTORS

All inductors have some distributed capacitance between turns, which appears as a small capacitance in parallel to the external circuit. When the applied frequency is increased to a point where the distributed capacitance of the coil resonates with the inductance, a new effect appears. The coil becomes a parallel-resonant circuit (fig. 9-7) to the external circuit connected to its terminals. The resistance in this equivalent circuit represents the losses incurred in practical coils. This self-resonant characteristic is used in many applications in VHF/UHF receivers. The inductor is made to resonate with its own self-capacitance, plus the tube input and stray circuit capacitance. This action eliminates the need for a separate tuning capacitor and provides the highest possible inductance-capacitance ratio, the largest load impedance, and the greatest stage gain.

Self-resonant inductors often are used in the i-f amplifiers of communication receivers. If adjustable tuning is required, it is accomplished by varying the inductance either by a switching arrangement or with an adjustable core (slug) of iron-dust-impregnated plastic.

In transmitter circuits, the inductor must handle considerable power without serious heating. This requirement calls for a coil of larger physical size and usually makes the use of iron-powder cores impractical because such cores tend to saturate magnetically, and lose efficiency as the power level increases. Transmitting inductors thus are usually of the air-wound, self-supporting type.

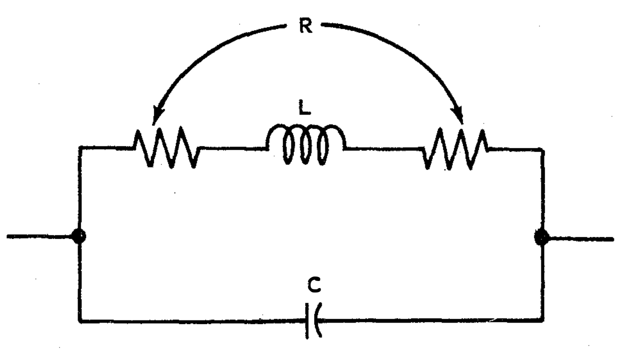

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Figure 9-7.—Equivalent circuit for inductor at high frequencies.

RESISTORS

The effects of increasing frequency on the performance of some types of resistors are such that the resistors cannot be used efficiently at frequencies of 30 mc and upward. Wire-wound resistors that are used at low frequencies become useless above this range because of unavoidable inductance and capacitance, which introduce unwanted reactive or resonant effects. Therefore, composition resistors made of finely divided carbon in a suitable binder are most commonly used in this frequency range.

For practical purposes, the simple equivalent circuit shown in figure 9-8 illustrates the effective impedance of a composition resistor at high frequencies. This equivalent circuit generally is used in the design of VHF and UHF circuits. The reciprocal of the conductance is R_p and is referred to as the parallel resistance. The total effective capacitance, C, is caused by the capacitance between the leads, and the effect of distributed capacitance.

Resistors made by depositing a thin layer of pure, finely divided carbon or a carbon-boron mixture on the surface of a ceramic or glass tube provide improved performance characteristics at all frequencies, particularly as to stability, and show less change in impedance with increasing frequency.

VHF EFFECTS ON TUBES

Although the basic principles of vacuum-tube operation are unchanged, certain factors that can be disregarded in tube operation below 30 mc become important at higher frequencies. The inductances of the electrode leads and the

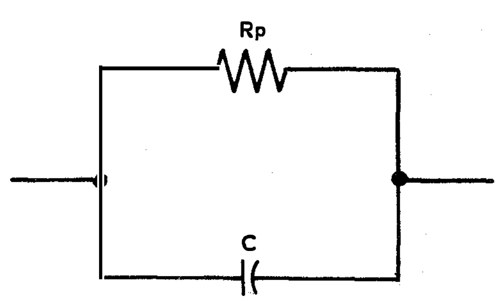

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Figure 9-8.—Equivalent circuit for composition resistor at high frequencies.

capacitances between electrodes are very small, but at higher frequencies their reactances become significant. Additionally, electrons do not travel instantaneously from the cathode to the plate, but require a transit time. This delay causes an in-phase grid current to flow, even though the grid is negative, and results in a loading effect across the input that reduces overall gain in all classes of tube operation.

Skin effect in the electrodes and electrode leads causes the r-f resistance to increase with frequency. Dielectric losses in the insulating electrode supports are increased, and some power is lost by direct radiation from the electrodes and their leads. The effect of these factors is to cause tube efficiency to become progressively lower as the operating frequency is increased. A tube operated as an amplifier at 50 mc, for example, gives less output for a given signal input than at 5 mc, even if the external circuits are equally efficient at both frequencies. Also, because these losses increase with frequency, there is a practical upper frequency limit beyond which the tube is not useful as an amplifier. If the same tube is operated as an oscillator, the high-frequency limit of operation will be about two-thirds to three-fourths that of the limit as an amplifier, because the tube no longer can supply sufficient output to make up the increased losses and still provide a useful output signal. These effects always are present in a vacuum tube, no matter what the operating frequency; but, as the frequency is raised, the effects increase and become so large that they place an effective upper limit on useful operation. Although it is unnecessary to learn new operating principles, it is important to understand how and why these characteristics that previously were disregarded become major limitations at frequencies above 30 mc.

As the wavelength is made shorter, it becomes comparable in length to the physical length and spacing of tube electrodes and leads. The apparent solution to this difficulty is to scale down the entire tube structure. There is a practical limit to this method, however, governed by the power-handling capacity that is required. New tube designs have been developed that successfully overcome one or more of the limitations without requiring such a drastic size reduction that mass-production methods of manufacture become impractical.

INTERELECTRODE CAPACITANCE AND LEAD INDUCTANCE

Inasmuch as any two points between which a difference of potential can exist are said to have capacitance, a small but significant value of capacitance must exist between any element of an electron tube and each of the other elements. Additional capacitances exist between the leads, particularly in those tubes in which the leads are brought out through a common stem to the base. When the tube is operating with normal applied voltages, the effective capacitances between electrodes are different from the capacitances when the cathode is not emitting. These differences are caused partly by expansion of the parts when the tube heats and partly by the electron stream.

When the tube is cold, the dielectric between electrodes is mostly vacuum, but in operation this vacuum is partially filled with a stream of electrons, resulting in a change in the dielectric constant. Naturally, this dielectric constant changes with variations in the electron stream. The capacitance values are measurable, and are listed in tube characteristics tables.

Because any conductor possesses self-inductance, the internal leads to the tube elements and the elements themselves, as well as the tube pins, have some inductance. Within a tube operating above 30 mc, for example, circuit calculations must take into consideration the effective values of inductance. This inductance is in series with the plate, grid, and cathode, and although the actual inductance of a lead usually is small, the reactance offered at frequencies of several hundred megacycles becomes appreciable.

Transit Time

Transit time is the length of time required for an electron to travel from the cathode to the plate in an electron tube. When the frequency is increased, the time of 1 cycle is shortened progressively, and the transit time can become a definite portion of the cycle. During this part of the cycle, the applied signal on the grid may go from positive to negative, or from an increasing to a decreasing value. The flow of electrons past the control grid causes a current to be induced in the grid that may flow into or out of the grid, depending on the relative grid voltage. This grid current flow absorbs power from the input signal, even though the grid is always negative, and has the same effect as if a shunt resistance and a shunt capacitance were connected across the grid and cathode of the tube. The loss of signal energy brought about in this manner is the most important effect of transit time, and the loss increases as the frequency increases.

Reducing Transit Time Effects

Transit time effects can be minimized by scaling down tube dimensions and increasing operating voltages. Miniaturization is utilized widely. Amplifiers designed for use above 30 mc usually have close interelectrode spacing. Many transmitting tube types are very small in proportion to their power ratings, and require cooling by forced-air draft.

Where close spacing is utilized, the cathode to grid distance is particularly important. Preventing the electrons from leaking from cathode to plate around the ends of the control-grid supports is important, because such leakage would result in increased transit times.

Screen-grid tube types have naturally shorter transit times than triodes and are used in many VHF/UHF equipments to reduce transit time effects.

MISCELLANEOUS EFFECTS

Other effects on electron tubes at VHF/UHF frequencies are caused by grid gas current, grid emission, and heat radiation.

Even in a well-manufactured vacuum tube there always are some molecules of gas, because it is impossible to produce a perfect vacuum. When electrons collide with these molecules, positive ions are created and are attracted to the negative control grid. This action causes a grid current to flow when the grid is negative. The grid current thus produced is small, but it has the effect of making the grid less negative, which is undesirable in view of the effects of input resistance in this frequency range.

Any metal emits electrons if heated sufficiently, although some are much more efficient in this respect than others. In scaled-down tubes suitable for use at frequencies higher than 30 mc, the grid is subjected to heating by the nearness of the cathode as well as by the inphase grid currents. Some electrons strike the grid even though it is negative, causing the possibility of secondary emission. As a result, there is likely to be both primary and secondary emission from the grid, which adds to the space charge and is undesirable because it varies erratically. This effect can be reduced by plating the grid with a metal that does not emit electrons easily. Gold is particularly effective and is used where the type of operation is critical enough to warrant the expense. Another method, somewhat less effective, is spraying the grid with finely powdered boron carbide.

The radiation of heat from the plates of air-cooled tubes becomes a factor of importance because the tube efficiency is reduced as the frequency is raised. For a given power input, a reduction of efficiency causes higher plate dissipation, which means that the input power must be reduced to keep the plate dissipation from going above the rated value and causing serious overheating. When the input power is decreased, however, the useful output power drops.

The most common method of improving the thermal radiation of the tube plate consists of coating the plate with finely divided carbon. The resultant dull-black surface is about 60 percent more efficient as a heat radiator than polished metal.

UHF TRANSMITTER MODEL TED

Any Navy ship equipped for UHF communications is almost certain to have aboard at least one model TED transmitter. The number of TED transmitters installed in the fleet far exceeds any other model of radio transmitter in any frequency range.

Comprising the series of TED transmitters are models TED and TED-1 through TED-9. Functionally the TED transmitters are the same. The circuit operation of each of the TED transmitters is generally the same, except for a minor change in the AVC circuit of the TED-2. This change does not alter the circuit operation sufficiently to warrant separate consideration. Also, there are minor differences in some mechanical details of the TED equipments. These differences are not discussed in this chapter.

GENERAL DESCRIPTION

Radio Transmitting Equipment, Navy Model TED (fig. 9-9) is used for a-m radiotelephone (A-3) and modulated-carrier wave (A-2) communications at frequencies from 225 to 400 mc.

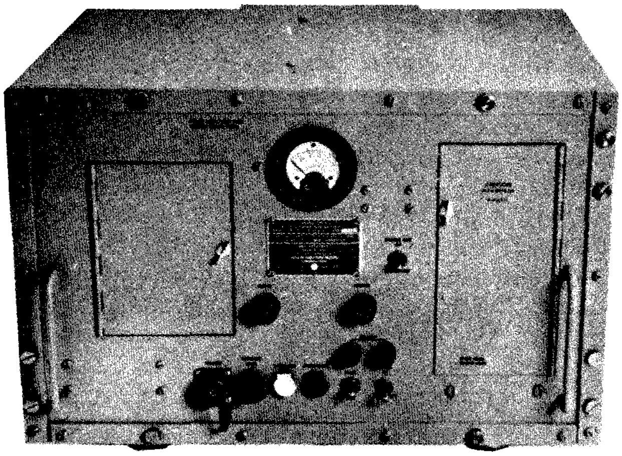

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Figure 9-9.—UHF radio transmitter, model TED.

These frequencies limit the reliable range of the equipment to approximately "line-of-sight" transmission.

Like any other radiotelephone transmitter, the TED can transmit radioteletypewriter signals when used with tone-shift keyer/converter AN/SGC-1A. (The AN/SGC-1A is described in chapter 10 of this training manual.)

Standard shipboard remote control units are needed to operate the transmitter from such circuit control locations as CIC and the bridge. In general, operation from a remote control unit consists of turning the equipment on or off, and using voice transmission, controlled by a microphone press-to-talk switch, or MCW transmission with a telegraph key. Operation at the actual transmitter location includes additional procedures, such as changing frequencies, tuning, monitoring meter readings, and so forth, as required for the transmitter's tactical use.

The transmitter includes a radiofrequency section, a modulator section, a power supply, a terminal box, and the cabinet (fig. 9-10). The r-f section, modulator section, and power supply all are contained in a drawer-type chassis and panel assembly. The power supply occupies the center of the transmitter chassis, and is attached to the front panel. The radio modulator and radiofrequency chassis are removable assemblies mounted to the left and right of the power supply. Small doors, one on either side of the front panel, provide access to the operating controls for the r-f and modulator sections (fig. 9-11). Connections between the power supply and the other two units are made through plugs and cables connecting the units.

The power supply section contains the power transformers, high-voltage rectifier tubes, low-voltage selenium rectifiers, filters, and bleeder resistors needed to produce all voltages required for transmitter operation. Also located on the power supply unit are control relays, which energize portions of the power supply to allow for the generation of the modulated carrier. These control relays also transfer the antenna from a receiver to the transmitter r-f circuits when the transmitter is keyed.

The meter, mounted on the front panel, is used to monitor various currents and voltages in the transmitter. Control switches, indicator lamps, and fuses, as well as microphone and handset jacks are also mounted on the transmitter front panel.

The radio modulator unit contains the audio transformers, tubes, and circuits required for a-m voice or MCW modulation of the r-f carrier. The speech amplifying and modulating circuits are supplemented by special circuits to provide volume expansion, AVC, and clipper-filter action, all of which considerably increase the average carrier sideband power under voice-modulated conditions. A 1000-cps oscillator is included for producing the MCW audio tone.

The radiofrequency chassis includes all of the electrical components required for generation of the r-f carrier. The master oscillator is crystal-controlled. Its fundamental crystal frequency is multiplied 12 times to produce output frequencies in the 225- to 400-mc frequency range.

Mountings are provided for four oscillator crystals. The crystal switch permits rapid selection of any one of the four frequencies. An access door on the r-f section front panel provides quick and easy substitution of crystals. For emergency operation at frequencies for which no crystal is available, the oscillator circuit can be operated without using a crystal, but with some loss in frequency stability.

The rear portion of the radiofrequency section is occupied by a blower (not shown), which provides forced-air ventilation.

The terminal box contains two terminal boards for external connections, an electrical noise suppressor, and receptacles for antenna and receiver coaxial cables. This terminal box is mounted on the back of the cabinet (as

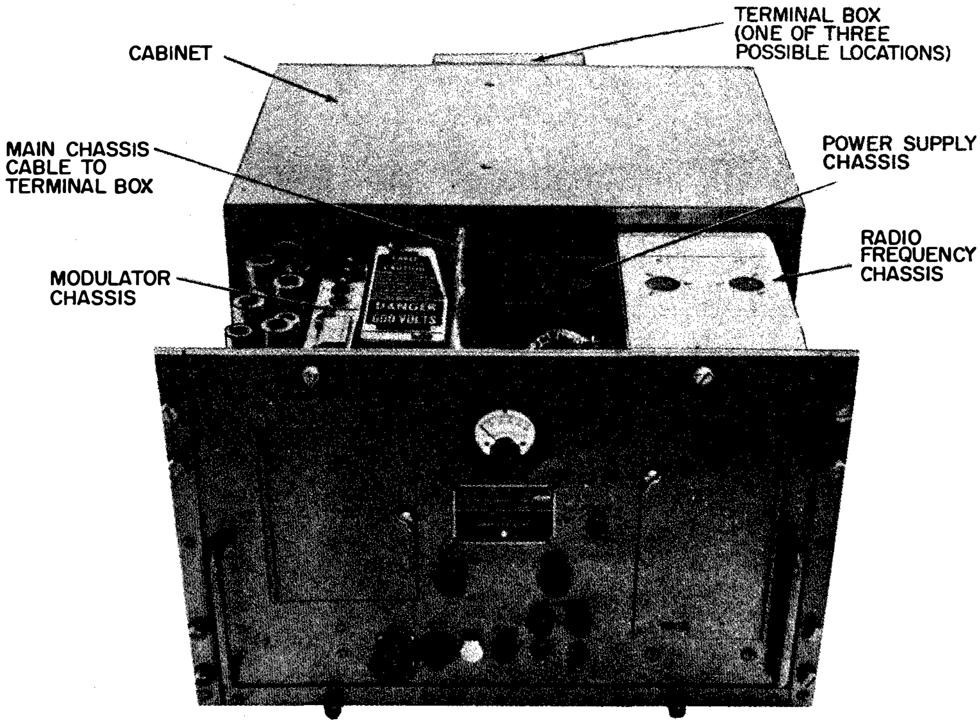

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Figure 9-10.—TED transmitter chassis partly removed from cabinet.

shown) or on either of the two sides, depending on particular installation requirements.

OVERALL FUNCTIONAL DESCRIPTION

A functional block diagram of the TED-9 radio transmitter appears in figure 9-12. The radiofrequency and modulator sections are described in the following paragraphs.

Radiofrequency Section

The crystal oscillator V113 generates an output frequency between 18.75 and 33.33 mc. This signal is doubled in frequency (37.50 to 66.67 mc) by doubler V114. The doubler (V114) output is amplified in V115.

A second doubler stage, V116, multiplies the 37.50 to 66.67 mc output of V115 to a frequency between 75.00 and 133.33 mc. This output is applied to a tripler-power amplifier stage, and V117 and V118 tubes are operated in push-pull. The tripler-power amplifier multiplies the V116 output to a frequency between 225 and 400 mc. This stage also amplifies the carrier output to approximately 15 watts. A tuned output filter minimizes the radiation of harmonics.

The r-f output reaches the antenna via an antenna relay mounted on the power supply chassis. During periods of transmission and reception, the relay functions to switch the antenna between the radio transmitter and the receiver being used.

Radio Modulator Section

The radio modulator section (lower part of fig. 9-12) contains circuits that amplify the speech or MCW tone to a level sufficient to cause 100 percent amplitude modulation of the r-f carrier. The radio modulator also contains circuits that function to increase the average carrier sideband power.

From either a remote control unit or local transmitter control, the speech input from a microphone enters the modulator unit at input transformer T101. It is amplified in the speech

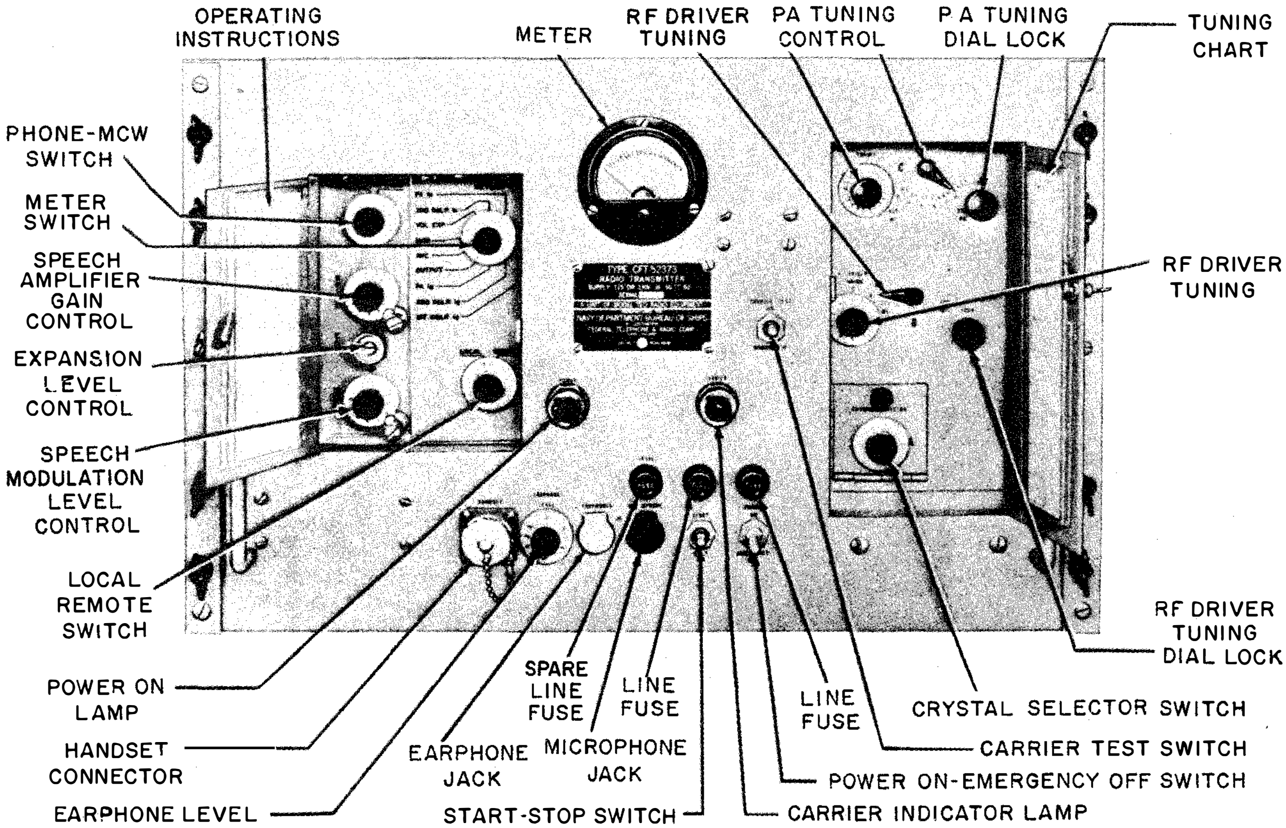

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Figure 9-11.—Front panel controls of UHF transmitter, model TED.

amplifier V101. In the OFF position, output on V101 passes through switch S103 to audio-amplifiers V104A and V104B. The output from V104B drives the push-pull modulator stage. V105 and V106, whose output variations are superimposed on the d-c input to the power amplifier (in the r-f section).

During MCW operation, switch S101 is in the MCW position, and the audio output from the MCW oscillator V109 is applied directly to the input of audioamplifier V104B. Less amplification is required for MCW signals than for voice signals because the oscillator input is considerably higher than the microphone input voltage level.

When switch S103 is placed in the ON position, the clipper (V103A and V103B), AVC amplifier V102A, and AVC rectifier V102B are connected into the audio channel. In this condition, the output from speech amplifier V101 is increased in amplitude by the AVC amplifier and applied to the clipper. The clipper stage clips the audio at a preset level so that the amplitude of the speech signal applied to the modulators (V105 and V106) remains fairly constant, thereby compensating for variations in voice amplitudes. Clipper V103 applies its output to the audioamplifiers V104A and V104B through switch S103 in the ON position. A low-pass filter in the output of the audioamplifiers attenuates all of the high-frequency components (above 3500 cps) that are present in the clipped audio signal to prevent modulation of the carrier by those frequencies. Thus, the average modulation level is increased, and the effect of voice level fluctuations is minimized.

The clipper circuit is aided by automatic volume control action provided by AVC rectifier V102B. This stage rectifies a portion of the output from AVC amplifier V102A and applies the rectified signal, as an AVC bias, to the speech amplifier V101. The AVC action helps

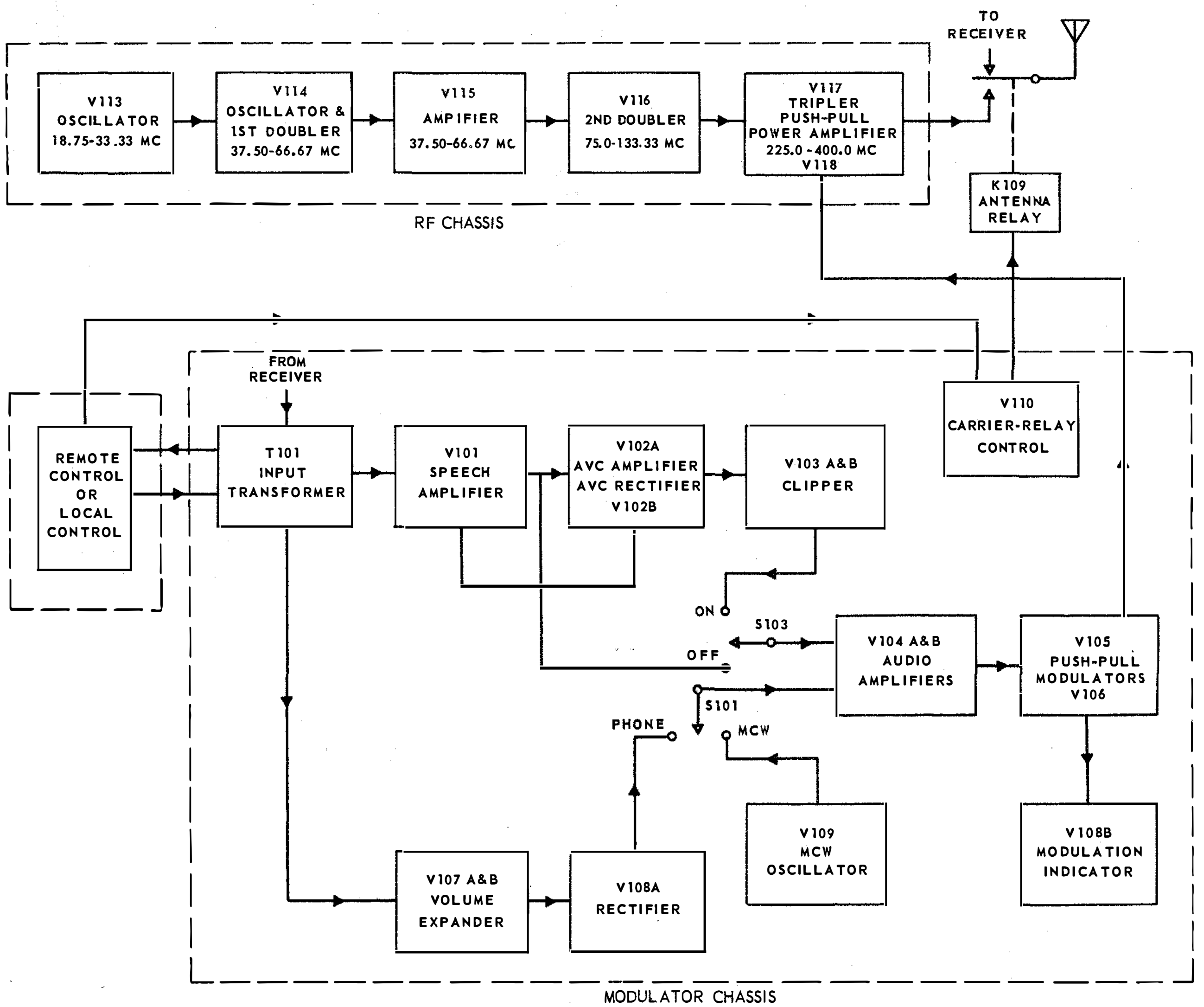

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Figure 9-12.—Functional block diagram of model TED-9 UHF transmitter.

maintain an audio level that is suitable for continuously efficient clipping by V103.

A volume expander circuit eliminates the transmission of background noise when the carrier is on but the operator is not speaking. The expander circuit is activated when switch S101 is in the PHONE position. The expander utilizes tubes V107A and V107B as well as V108A in an electronic control circuit, disabling audioamplifier V104B when the microphone input drops below a preset level. In the absence of microphone audio input (or when the microphone input drops below the preset level), a bias voltage keeps amplifier V104B cut off. When an audio signal of sufficient amplitude to trigger V107 is received, V107 produces a square wave output that is rectified by V108A. The V108A output decreases the bias on the audioamplifier, allowing the amplified audio signal to reach the modulator tubes V105 and V106.

A portion of the output from the modulator tubes is rectified by modulation indicator V108B for application to the radio transmitter meter circuit. The meter indicates the relative (average) modulating audio voltage.

The carrier-relay control tube V110 is operated by a keying relay when the microphone (or handset) press-to-talk switch is operated.

Tube V110 causes other control relays to operate. They, in turn, energize portions of the power supply. This action causes the generation of the modulated carrier and, by means of the antenna relay, transfers the antenna from the receiver to the output of the transmitter r-f circuits.

The audio signal from a receiver associated with the transmitter is impressed on one of the secondary windings of input transformer T101 in the modulator unit. The monitoring signal is fed into the earpiece of the operator's telephone handset, providing transmitter monitoring. This arrangement also provides sidetone (a local path between microphone and earphone). The receiver audio is turned off automatically by relay operation when the transmitter carrier is on.

Power Supply

The power supply utilizes conventional transformers, tube rectifiers, and filter circuits to develop the necessary high voltage for the plate and screen supplies. A selenium rectifier and filter circuit provides the necessary negative 42-volt supply for the bias and control circuits; an additional selenium rectifier produces a -12 volt d-c supply. The -12 volt supply is used to operate pilot lamps and as a source of microphone voltage for remote control operation.

UHF RECEIVER AN/URR-35A

Radio Receiving Set AN/URR-35A (fig. 9-13) is a double-superheterodyne communication receiver designed to provide reception of voice amplitude-modulated (A3) and MCW (A2) signals in the frequency range from 225 to 400 mc. This receiver is installed in greater quantity than any other as the companion receiver for the TED transmitter described in the previous section of this chapter.

DESCRIPTION OF MAJOR COMPONENTS

The circuit components of the AN/URR-35A receiver are grouped, on a functional basis, into five major sections: (1) preselector section, (2) IF/AF section, (3) power supply, (4) front panel, and (5) low-pass filtering section.

The first three major sections of the receiver are located within the chassis frame. The purpose of each of these sections is implied in the section name.

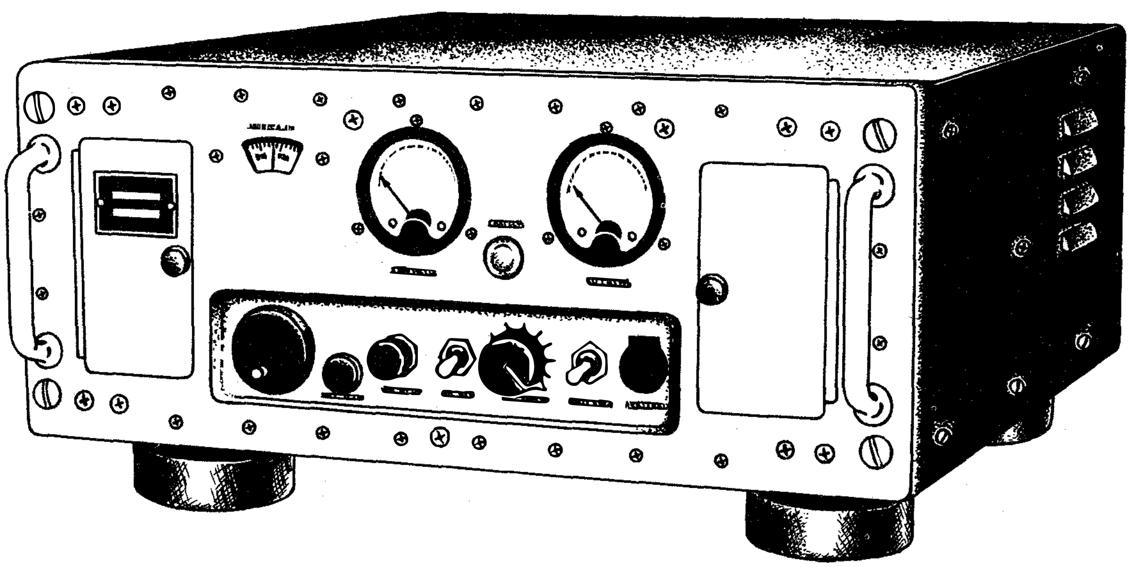

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Figure 9-13.—UHF receiver AN/URR-35A.

The front panel section is attached to the front of the chassis frame and contains all the controls and meters required for operation and monitoring of the receiver circuits.

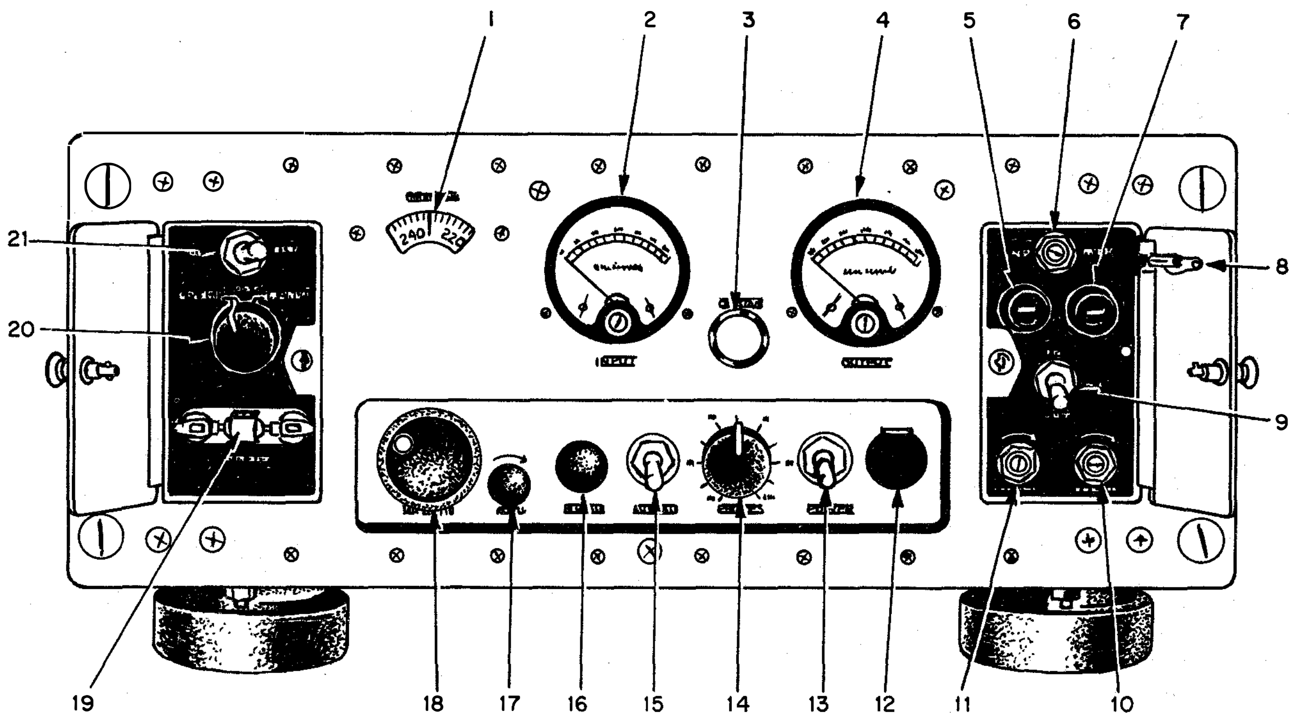
The low-pass filter section is attached to the rear wall of the receiver cabinet. This section contains r-f noise filter circuits for the power input and audio output circuits. It also has jacks for the antenna, a-c power, and audio output cable connections.

The AN/URR-35A is designed primarily for operation as a pretuned, single-channel, crystal-controlled receiver. The crystal holder and various receiver controls are located behind small doors to the left and right of the front panel (fig. 9-14).

With the proper crystal, any channel within the frequency range from 225 to 400 mc can be selected. Continuously variable manual tuning is also a feature of the receiver. Either of these two methods of operation is selected by an oscillator switch behind the left access door. A single tuning control is used for tuning to any frequency for either crystal-controlled or manual tuning operation.

BLOCK DIAGRAM ANALYSIS

The block diagram of the AN/URR-35A receiver (fig. 9-15) reveals that the receiver is of conventional design except for the dual-conversion feature. Because of the frequencies



1. MEGACYCLES DIAL
2. INPUT METER (M 501)
3. CRYSTAL INDICATOR LAMP (I503)
4. OUTPUT METER (M502)
5. FUSE (F 201)
6. INP. MTR. ADJUSTMENT (R 218)
7. FUSE (F202)
8. SPARE FUSE (F203)
9. N. L. SWITCH (S202)
10. SILENCER THRESHOLD CONTROL (R247)
11. A. F. LEVEL CONTROL (R 255)
12. HEADPHONES JACK (J 501)
13. POWER SWITCH (S502)
14. PHONES GAIN CONTROL (R502)
15. SILENCER SWITCH (S 501)
16. DIMMER CONTROL (R 501)
17. TUNING LOCK (E502)
18. TUNING CONTROL (C101) (C102)
19. CRYSTAL HOLDER (Y201)
20. OSC. SWITCH (S 203)
21. ALIGN.-REC. SWITCH (S201)

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Figure 9-14.—Front panel controls, UHF receiver AN/URR-35A.

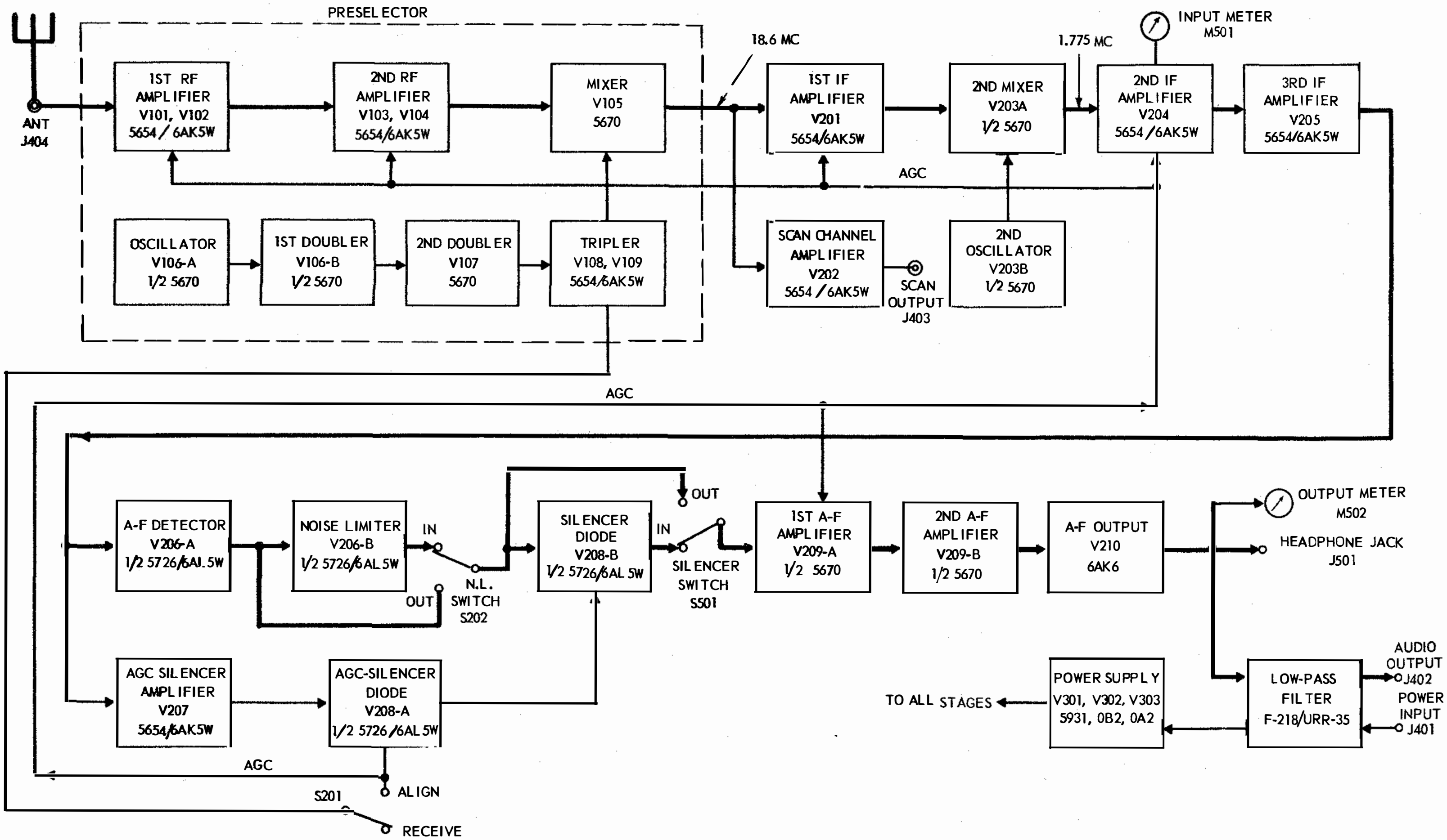

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Figure 9-15.—Block diagram of UHF receiver AN/URR-35A.

at which the receiver operates (225 to 400 mc), however, many special circuits are employed, which improve the overall efficiency of the receiver.

The received signal from the antenna is coupled via jack J404 to the first r-f amplifier, which comprises V101 and V102 in a push-pull circuit arrangement. The amplified output of V101 and V102 is applied to the second r-f amplifier (V103 and V104 in push-pull) and thence to the first mixer, V105. The local oscillator signal, derived from either manual or crystal-controlled oscillator stage V106A, is followed by three stages of frequency multiplication (V106B through V109).

The tuning arrangement for the two push-pull connected r-f amplifiers (V101 through V104) and the mixer stage V105 is geared to that of the local oscillator and multiplier stages to provide single-control tuning. This control is shown as No. 18 in figure 9-14.

The first local oscillator functions as either a crystal-controlled or self-excited circuit, depending upon the position of the OSC switch (No. 20 in fig. 9-14).

The first mixer V105 output signal, at a frequency of 18.6 mc, is fed to a first i-f amplifier V201, and to a scan-channel amplifier V202. The output of the first i-f amplifier is applied to the second mixer stage V203A.

A second local oscillator signal at 16.825 mc from V203B is applied to mixer V203A. The heterodyning process in V203A produces a 1.775-mc output from the second mixer.

The portion of the first mixer V105 output signal, applied to the scan-channel amplifier V202, is amplified in this stage. The V202 output is applied to scan jack J403, located on the low-pass filter section at the rear of the receiver cabinet. The purpose of the scan output is for use of a panoramic adapter when it is desired to view the received signal. This feature is not used in most AN/URR-35A installations.

The stages comprising V204 and V205 are conventional intermediate-frequency amplifiers. The i-f output from V205 is rectified and filtered in the a-f detector stage, V206A.

The stage to which the detector (V206A) output is coupled is determined by the setting of the silencer and noise limiter switches S501 and S202. With these switches in the position shown in the block diagram, the detector output is fed through noise limiter V206B and silencer diode V208B. The conducting or nonconducting condition of V208B is determined by the combined action of the AGC silencer amplifier V207 and the AGC silencer diode V208A. When both of the switches (S501 and S202) are in the OUT position (opposite the setting shown), the detector (V206A) output is applied through the switch contacts to the first audio-amplifier V209A.

The audio signal amplitude is increased in three stages of audioamplification, comprising V209A, V209B, and V210. The audio output stage applies its signal to the headphone jack J501 and to the output meter M502. This signal is applied also through the low-pass filter to the audio output jack J402.

All power necessary for operation of the receiver is obtained from a built-in power supply. This power supply can be adjusted to operate from either 105- , 115- , or 125-volt, 50 to 60 cps, single-phase power source. A power transformer and rectifier tube V301 produce the d-c voltage for the plates and screens of the amplifier tubes. Voltage regulation, required for best operation of the oscillator and various other stages, is accomplished by the two voltage regulator tubes V302 and V303. Bias voltage also is obtained from this regulated power source. Filament power is derived from separate windings of the power transformer. The input power, from jack J401, is filtered in the low-pass filter section to minimize radiofrequency interference.

UHF RECEIVER AN/URR-13A

Another UHF receiver installed as a companion receiver with the model TED transmitter is the AN/URR-13A. This receiver is not illustrated here because it is similar in size, appearance, and operating controls to the AN/URR-35A discussed previously. The AN/URR-13A presently is installed aboard ship in almost equal quantities with the AN/URR-35A.

Like the AN/URR-35A, the AN/URR-13A receives amplitude-modulated voice and MCW transmissions in the 225- to 400-mc frequency range. The AN/URR-13A is a single-channel, crystal-controlled receiver that also features continuously variable manual tuning. The essential difference between it and the AN/URR-35A is that it is a superheterodyne receiver, whereas the AN/URR-35A is a double superheterodyne; that is, it employs two frequency conversions.

UHF TRANSMITTER-RECEIVER AN/GRC-27A

The AN/GRC-27 and AN/GRC-27A are UHF transmitter-receiver sets, covering frequencies from 225 to 400 mc. The AN/GRC-27 is the shore station equipment, whereas AN/GRC-27A (shown in fig. 9-16) is the shipboard installation. Primarily, the AN/GRC-27A is used for UHF radiotelephone communication between ships, from ship to shore, and from ship to aircraft. It also has an MCW capability and, like the model TED, is used with the model AN/SGC-1A tone-shift keyer/converter for UHF radioteletypewriter communications. The AN/GRC-27A is operationally compatible for net operation with other radio sets in the UHF band, such as the TED transmitter and the AN/URR-13 and AN-URR-35 receivers previously described in this chapter.

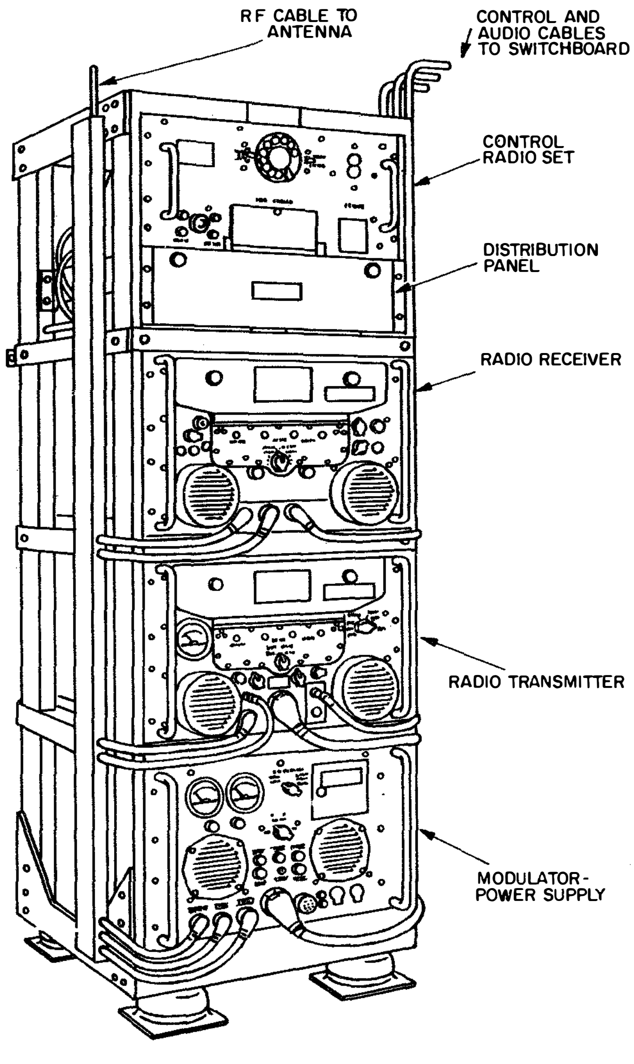

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Figure 9-16.—UHF transmitter-receiver set AN/GRC-27A.

Current shipboard installations of the AN/GRC-27A are fewer in number than the TED transmitter—AN/URR-35A receiver combination. The AN/GRC-27A occupies considerably more space than the TED with its companion receiver, but the transmitter section of the AN/GRC-27A features an output power of 100 watts compared with 15 watts for the TED transmitter. Additionally the AN/GRC-27A has other features, such as automatic tuning and channel selection. These characteristics are described and illustrated in the following section.

GENERAL DESCRIPTION

The AN/GRC-27A comprises a transmitter, receiver, modulator-power supply, distribution panel, control radio set, and the mounting rack. (See fig. 9-16.)

The transmitter normally generates a radio-frequency carrier in a range from 225.0 to 399.9 mc, with a nominal power output of 100 watts over this range. The transmitter has 3 crystal-controlled oscillators (frequency generators), which employ a total of 38 crystals. The combination and multiplication (synthesizing) of these 38 crystal frequencies make it possible to produce 1750 frequencies spaced at 100-kc intervals from 225.0 to 399.9 mc. Any 10 of these 1750 frequencies can be preset manually by a series of selector switch dials (calibrated in megacycles) in 100-kc increments. Any 1 of these 10 frequencies (channels) can be selected automatically, either locally or from a remote station. Automatic selection of a preset channel is accomplished in 2 to 7 seconds by a combined autopositioner drive system and a servosystem.

The modulator-power supply provides the transmitter with all necessary operating and control voltages, and supplies amplitude modulation power (either voice or MCW tone) for the transmitter. The transmitter output includes both upper and lower sidebands generated when the carrier is amplitude-modulated.

The receiver normally operates on any 1 of 1750 frequencies, spaced at 1-kc intervals from 225.0 to 399.9 mc. The receiver employs a triple conversion superheterodyne system using crystal-controlled oscillators. There are a total of 38 crystals in a synthesizer system. Any 10 channels of the 1750 frequencies can be preset manually. Moreover, any 1 of the 10 can be selected automatically, either locally or from a remote station.

Automatic channel selection in the receiver is accomplished by a frequency selector and autopositioner system similar to that in the transmitter. A motor-driven system of gear trains operates the various crystal switches and tuning mechanisms to permit rapid change of operating frequency. Here again, channels are shifted automatically in 2 to 7 seconds.

The receiver is designed for use with directional or omnidirectional antennas having a characteristic impedance of 52 ohms. Audio output circuits for operation of loudspeakers and for operation into telephone lines are built into the receiver. A special output circuit for direction-finding applications is provided also. The receiver is equipped with automatic volume control, automatic noise limiter, and carrier-operated squelch circuits.

The preset channels for the transmitter or the receiver are selected by operating a channel selector switch on the front panel of the respective units or by telephone-type dials on associated radio set control facilities.

The radio set control unit adapts the control circuits of the AN/GRC-27A to the standard 12-wire shipboard remote control system. The control unit provides for the control of power for Radio Set AN/GRC-27A, starting and stopping the modulator-power supply, automatic channel selection in the transmitter and receiver, local or remote control of the transmitter, and squelch adjustment for the receiver.

RECEIVER BLOCK DIAGRAM

The R-278B/GR receiver of Radio Set AN/GRC-27A and receiver operating controls can be observed in detail in figure 9-17. It will be helpful to the reader to relate the various receiver controls with their associated control circuits as they are discussed in this chapter.

The block diagram (fig. 9-18) reveals that the receiver consists of four major sections: (1) a multichannel receiver section, (2) a frequency selector unit, (3) an audioamplifier section, and (4) a power supply.

The multichannel receiver section normally operates on any 1 of 1750 frequencies in the frequency range from 225.0 to 399.9 mc as discussed. The frequency selector unit, which is controlled by switches on the front panel of the receiver, automatically tunes the multichannel receiver to any 1 of 10 preset channels. The audioamplifier section increases the amplitude of the audio before it is applied to the loudspeaker or telephone line output circuits. The power supply furnishes all voltages required by the various circuits of the receiver.

The receiver signal from the antenna is amplified in two stages of r-f amplification, V101 and V102. (See functional block diagram, fig. 9-18.) The output of the r-f amplifiers is applied to the first mixer stage V401. The local oscillator signal is derived in a main oscillator stage V201. This stage contains 18 crystals, and operates in the range from 26.67 to 38.89 mc. The oscillator is followed by two frequency multipliers (V301 and V302) and by three amplifier stages (V303, V304, and V305). The V305 output is the first local oscillator injection signal, and is in the frequency range from 180 to 350 mc.

The main oscillator V201 is crystal-controlled by any 1 of 18 crystals. In order to produce the required intermediate frequencies over the range 220.0 to 399.0 mc, the output of the first injection system is varied from 180.0 to 350.0 mc in 18 steps of 10 mc each. This variation is accomplished by switching the oscillator crystals.

Unlike most mixer stages, the first mixer (V401) output is not always at the same frequency. Instead, the mixer output may vary from 40.0 to 49.9 mc for each crystal used in the main oscillator. For example, the mixer V401 output changes from 40.0 mc (when the receiver input frequency is 220.0 mc and the first injection frequency is 180.0 mc) to 49.9 mc when the received signal is 229.9 mc and the injection signal is 180.0 mc.

When the receiver total frequency coverage is considered (220 to 399.9 mc), you will note that a 5-mc increase over the normal operating range is obtained. From this 5-mc increase, the first injection synthesizer system produces 50 additional intermediate frequencies. Thus, the receiver can accept and reproduce

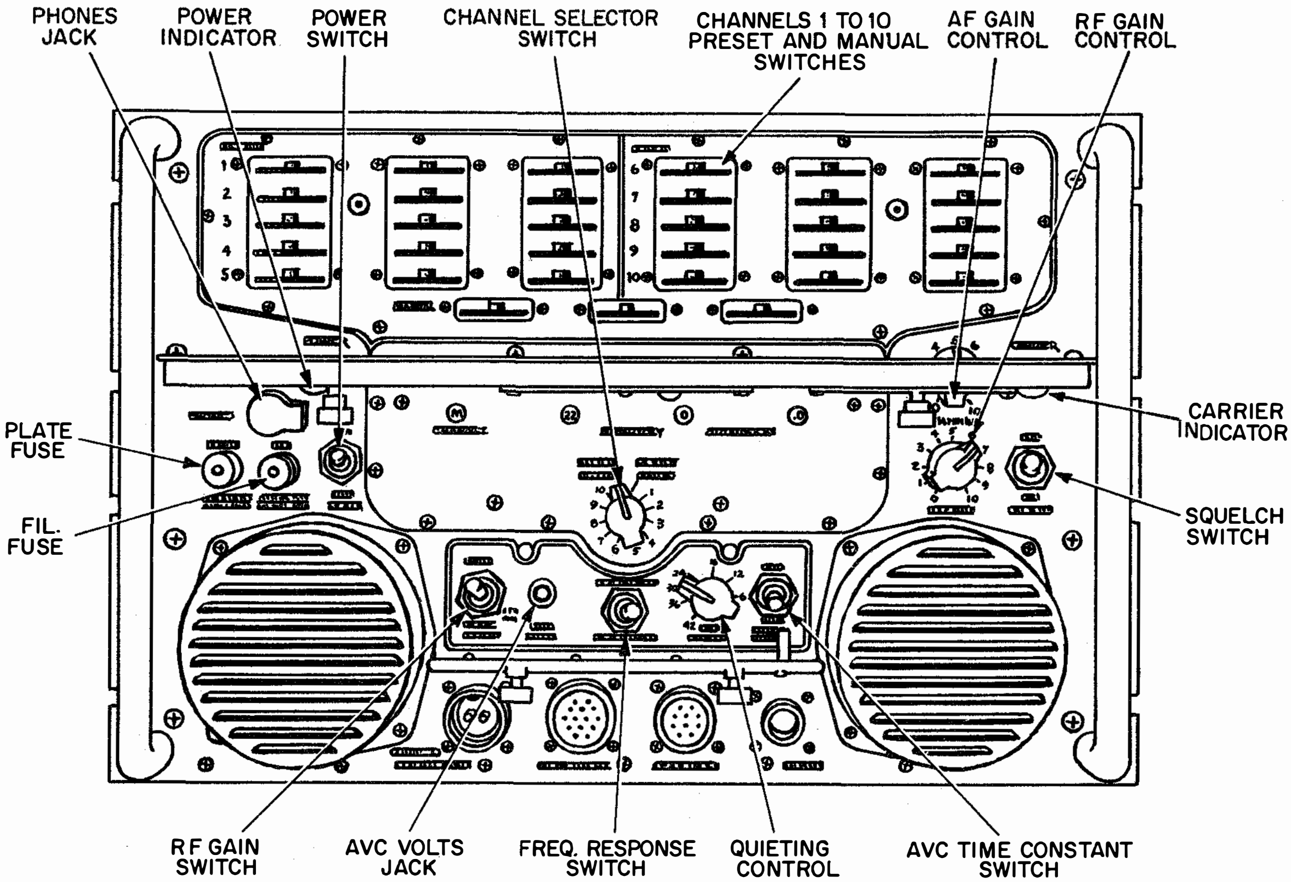

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Figure 9-17.—Front panel controls of AN/GRC-27A UHF receiver R-278B/GR.

50 additional frequencies. The following discussion shows how these frequencies are derived.

If the receiver input frequency were 225.0 mc, the injection frequency from the first injection system would be 180.0 mc and the mixer V401 output signal would be 225.0 mc minus 180.0 mc or 45.0 mc.

If the receiver input frequency were 220 mc, the injection frequency would still be 180.0 mc, and the mixer output signal would be 220.0 mc minus 180.0 mc or 40.0 mc.

Because the receiver is tuned in 100-kc increments, the 5-mc increase in frequency range at the mixer output provides:

$$\frac{5.0 \text{ mc}}{100.0 \text{ kc}} = \frac{5X10^6}{1X10^5} = 5X10^1 \text{ or } 50$$

additional frequenices, which may be selected at the receiver input.

The method of tuning the receiver is as follows: The frequency selection unit (fig. 9-18) has the 3 output shafts, which by mechanical drive, select the proper crystals and tune various circuits to establish a particular operating frequency. These output shafts are called the 10-mc, the 1-mc, and the 0.1-mc shafts, respectively. The 10-mc shaft rotates in 18 incremental steps, each increment representing 1 mc. The 0.1-mc shaft rotates in 10 incremental steps also, each step representing 0.1 mc.

The r-f amplifiers V101 and V102 may be tuned in 18 incremental steps by the 10-mc shaft and in 10 incremental steps by the 1-mc shaft. For each position of the 10-mc switching shaft, the 1-mc shaft can be rotated through 10 positions, thereby tuning the r-f amplifiers to 10 different frequencies for each position of the 10-mc shaft. In this manner, the r-f

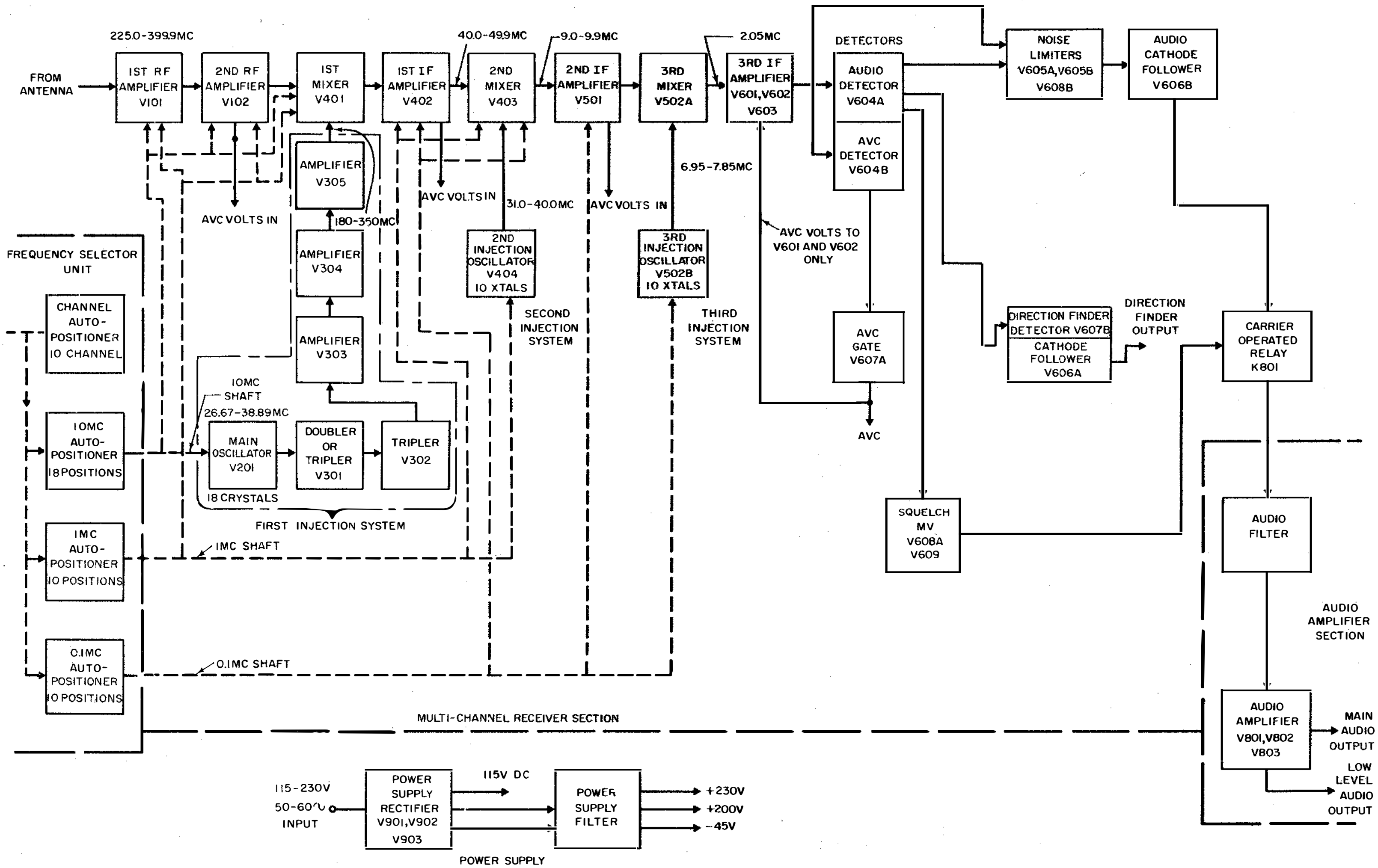

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Figure 9-18.—Block diagram of AN/GRC-27A UHF receiver R-278B/GR.

amplifiers can be tuned to 180 frequencies in steps of 1 mc.

The antenna input signal is amplified in the first and second r-f amplifiers (V101 and V102) and fed to the first mixer V401. The r-f signal input to the first mixer is heterodyned with the input signal from the first injection system to produce the first intermediate frequency between 40.0 to 49.9 mc.

The first injection system (comprising the main oscillator and frequency multiplier-amplifier stages) is tuned in 18 steps of 10 mc by the 10-mc output shaft. This shaft also operates the main oscillator crystal selector switch to select one of 18 crystal units (not shown). The first injection system output is fed from amplifier V305 to the first mixer stage V401. The signal from the first mixer (between 40.0 and 49.9 mc) is amplified in the first i-f amplifier V402.

The first i-f amplifier V402 employs two permeability tuned transformers, one at the input to the stage and the other at the output. The powdered iron cores of these transformers are driven by the 1-mc and 0.1-mc shaft. Rotations of these shafts are combined in a differential tuning mechanism to produce 100 steps of 0.1 mc. The first i-f amplifier output is applied to the second mixer V403.

The crystal selector switch and tuned circuits of the second injection oscillator V404 are controlled by the 1-mc shaft. The 31- to 40-mc signal from the second injection oscillator V404 is heterodyned in the second mixer V403 with the 40.0- to 49.9-mc injection signal from V402. The difference frequency (9.0 to 9.9 mc) is fed to the second amplifier V501.

The second i-f amplifier V501 is tuned in 10 steps of 0.1 mc by the 0.1-mc shaft. The 9.0- to 9.9-mc output from the second i-f amplifier is fed to the third mixer V502A.

The third injection oscillator V502B is also tuned in 0.1-mc steps by the 0.1-mc shaft. The heterodyning frequency from the third injection oscillator V502B is between 6.95 and 7.85 mc. The final heterodyning process in the third mixer produces a 2.05-mc intermediate frequency. The third mixer output is amplified in three stages of i-f amplification, comprising V601, V602, and V603.

To summarize the tuning action, assume that a frequency of 395.5 mc is to be selected. (See fig. 9-19.) The frequencies throughout the receiver tuning stages would be as follows:

r-f amplifier	395.5 mc
1st injection system	350.0 mc
1st i-f amplifier	45.5 mc
2nd injection system	36.0 mc
2nd i-f amplifier	9.5 mc
3rd injection system	7.45 mc
3rd i-f amplifier	2.05 mc

Two detector stages are employed in the receiver. Audio detector V604A is used to rectify and filter the audio component of the received signal. The AVC detector V604B is used to produce a d-c (AVC) control voltage for various amplifying tubes. The audio signal from V604A is routed through noise limiter stages V605A, V605B, and V608B. These stages reduce any spurious noise appearing in the received signal.

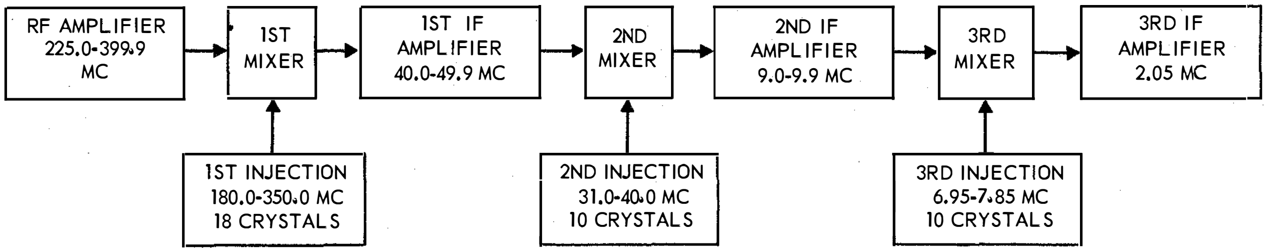
The AVC detector V604B and the AVC gate V607A produce the AVC control signal that is applied to the r-f and i-f stages of the receiver to maintain the audio output level nearly constant for wide variations in the amplitude of the r-f input signal.

The squelch circuit (V608A and V609) produces a d-c voltage to operate the carrier operated relay K801. This relay functions to increase the audio signal amplitude to the filter (attenuator quieting control) in the audio path whenever a signal is received.

The direction-finder stages of the receiver (V607B and V606A) make possible the use of the receiver with a direction-finder system such as the AN/URD-6 radio direction finder. This feature of the receiver is not required aboard ship in the normal communication applications of Radio Set AN/GRC-27A. Hence, its operation is not described in detail in this chapter.

When the carrier-operated relay is energized, the audio signal from the audio filter is amplified in two stages (V801 and V802 and V803). Twin triode V801 comprises two cascade-connected, single ended audioamplifiers, and V802 and V803 are connected in a push-pull amplifier arrangement.

Two output circuits are provided. They are referred to as the main audio and the low-level audio outputs. The main audio output circuit delivers approximately 3 watts into a 600-ohm balanced load. The low-level audio output is approximately 10 milliwatts.



DIAL READING	RF BAND MC	INJ. FREQ. MC	CRYSTAL FREQ. MC	MULT. FACTOR
22	220.0 - 229.9	180.0	30.0000	6
23	230.0 - 239.9	190.0	31.6667	6
24	240.0 - 249.9	200.0	33.3333	6
25	250.0 - 259.9	210.0	35.0000	6
26	260.0 - 269.9	220.0	36.6667	6
27	270.0 - 279.9	230.0	38.3333	6
28	280.0 - 289.9	240.0	26.6667	9
29	290.0 - 299.9	250.0	27.7777	9
30	300.0 - 309.9	260.0	28.8888	9
31	310.0 - 319.9	270.0	30.0000	9
32	320.0 - 329.9	280.0	31.1111	9
33	330.0 - 339.9	290.0	32.2222	9
34	340.0 - 349.9	300.0	33.3333	9
35	350.0 - 359.9	310.0	34.4444	9
36	360.0 - 369.9	320.0	35.5555	9
37	370.0 - 379.9	330.0	36.6667	9
38	380.0 - 389.9	340.0	37.7778	9
39	390.0 - 399.9	350.0	38.8889	9

DIAL READING	1ST IF BAND MC	CRYSTAL AND INJ. FREQ. MC
0	40.0 - 40.9	31.0
1	41.0 - 41.9	32.0
2	42.0 - 42.9	33.0
3	43.0 - 43.9	34.0
4	44.0 - 44.9	35.0
5	45.0 - 45.9	36.0
6	46.0 - 46.9	37.0
7	47.0 - 47.9	38.0
8	48.0 - 48.9	39.0
9	49.0 - 49.9	40.0

DIAL READING	2ND IF FREQ. MC	CRYSTAL AND INJ. FREQ. MC
0	9.0	6.95
1	9.1	7.05
2	9.2	7.15
3	9.3	7.25
4	9.4	7.35
5	9.5	7.45
6	9.6	7.55
7	9.7	7.65
8	9.8	7.75
9	9.9	7.85

50.67

Figure 9-19.—Frequency diagram for multichannel receiver section, AN/GRC-27A UHF receiver R-278B/GR.

Frequency Selector System

The R-278B/GR radio receiver features a frequency selector system that tunes the receiver mechanically to any 1 of 1750 available frequencies. A block diagram of the frequency selector system is shown in figure 9-20. Essentially, the frequency selection system consists of two main parts, the preset panel and the autopositioners.

The preset panel provides switches for presetting 10 automatically tunable channels and for setting up one manual channel.

The autopositioner is an electromechanical device actuated by operating a channel selector switch located on the front panel of the receiver. It also may be actuated by remote control facilities. The autopositioner tunes the receiver to a desired channel selected from the 10 preset channels. The manual channel can be selected only from the panel-mounted channel selector switch (fig. 9-17).

Preset Panel

The preset panel (fig. 9-20) has 33 rotary switches. For purposes of setting up channels, these switches are arranged in 11 horizontal banks of 3 switches each. The "hundreds" and "tens" of megacycle frequencies are set up on the first bank, the "units" are set up on the second bank, and the "tenths" on the third bank.

To illustrate, if a frequency of 245.6 mc is to be selected, the "hundreds" and "tens" mc switch should be set to 24, the "units" switch to 5, and the "tenths" switch to 0.6. By combining the setting of the 3 horizontal rows of switches, the frequency of each of the 11 channels can be read directly on the front panel of the receiver.

The manual channel is set up the same as the other 10 channels, except that it is impossible to select the manual channel from a remote position. This channel is reserved for operation at the transmitter site.

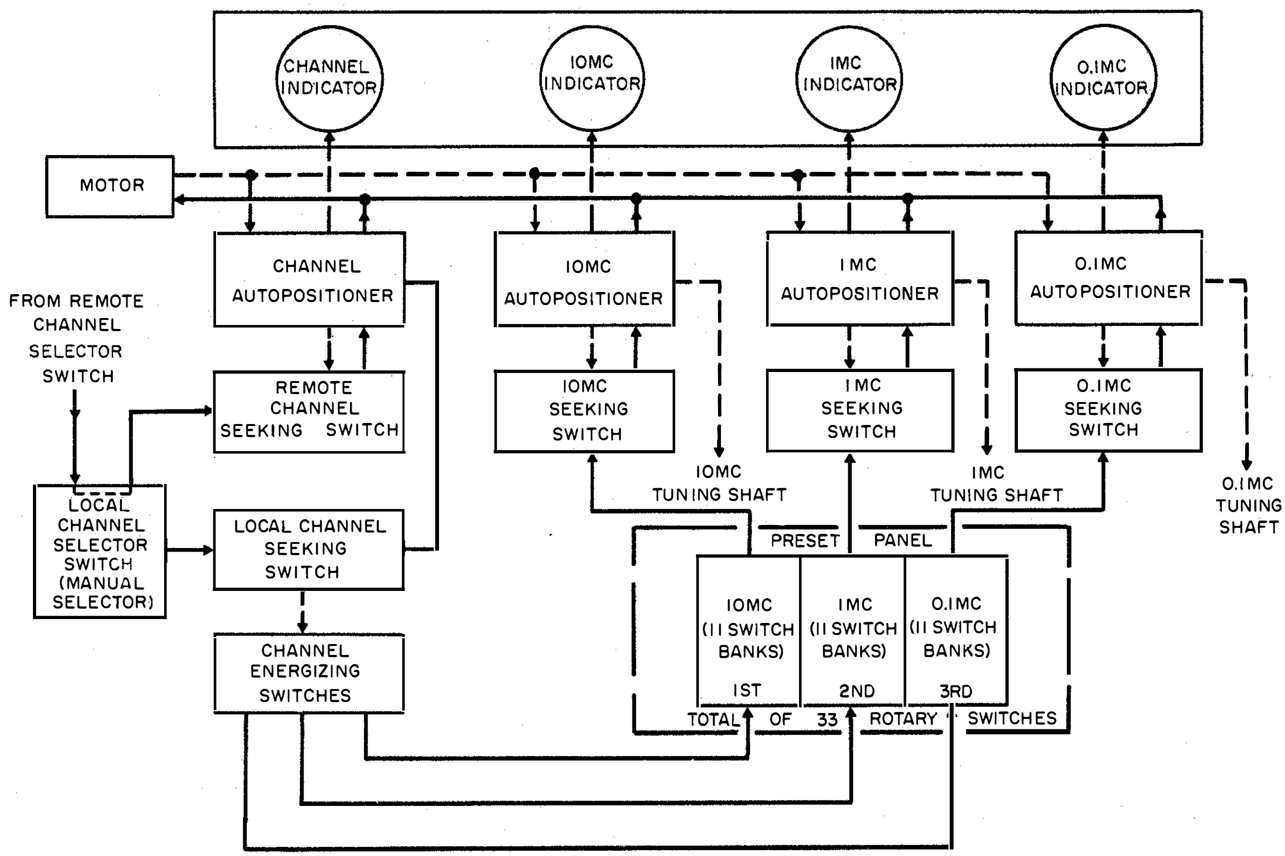


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Figure 9-20.—Receiver frequency selector system, block diagram.

Autopositioner

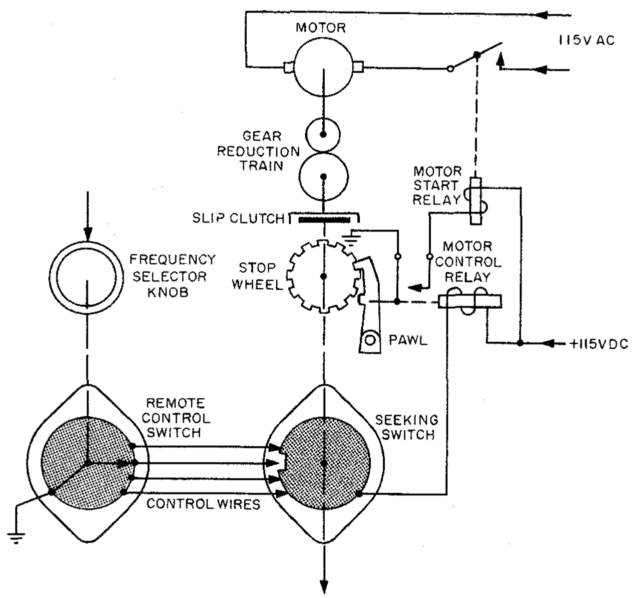
In addition to the definition given earlier, the autopositioner can be defined as a motor-driven mechanism that positions a shaft to any one of a number of preset positions. The basic elements of an autopositioner are shown in figure 9-21.

The autopositioner consists of a motor and gear reduction, a slip clutch, a rotary shaft to which is fastened a notched stop wheel, a pawl that engages the notches of the stop wheel, and a relay that actuates the pawl and operates a set of electrical contacts to start and stop the motor.

Associated with each autopositioner is an electrical control system consisting of a control switch and a corresponding symmetrical "seeking" switch driven by the autopositioner shaft. This control system is designed so that when the control switch and seeking switch are not set to the same electrical position, the autopositioner is energized and operates to drive its shaft (and the driven elements to which it is coupled) to the proper position to restore the symmetry of the control system.

When the control and seeking switches are in corresponding positions, which represents an open circuit between the two switches, the motor control relay is deenergized (as shown), the pawl is engaged in a notch on the stop wheel, and the motor is not energized. In this position, the autopositioner is at rest.

If the operator changes the position of the remote control switch, the symmetry between the remote control and seeking switches is upset. In this condition, power is applied through the seeking switch to the motor control relay, causing this relay to become energized. The current through the solenoid of the motor



32.113
Figure 9-21.—Autopositioner, basic elements.

control relay exerts a magnetic attraction on the pawl, lifting the pawl out of the notch on the stop wheel. The motor control relay contact arm is grounded as the pawl is removed from the notch. A ground is applied simultaneously to the solenoid of the motor start relay. Operation of the motor start relay closes another set of contacts that apply power to the motor.

As the motor turns, it drives the autopositioner shaft and the rotor of the seeking switch. When the seeking switch reaches the point corresponding to the new position of the remote switch, the motor control relay circuit is opened again (as shown). The pawl drops back into a notch on the stop wheel to stop the shaft rotation, and at the same time the ground is removed from the motor start relay. The contacts, which were applying the 115-volt a-c power to the motor, are now released (to the position shown), and the motor coasts to a stop, dissipating its energy in the slip clutch.

The seeking switch of the control circuit is adjusted to open the relay shortly before the stop wheel reaches the point where the pawl engages the proper notch. The relay contacts that control the motor are operated mechanically by the pawl arm so that they do not open until the pawl drops into the notch.

Note that the slip clutch between the motor and autopositioner absorbs the energy of the motor as it coasts to a stop. With more than one slip clutch, the same motor can drive an equal number of autopositioners, either simultaneously or independently. The frequency selector unit (fig. 9-20) has four autopositioners: the channel, 10-mc, 1-mc, and 0.1-mc autopositioners. The channel autopositioner energizes the other three through the local channel seeking switch, channel energizing switches, and preset panel. When the channel autopositioner control relay is operated by the control circuit, it removes power from the other three autopositioner relays. This action prevents operation of these relays until the channel autopositioner completes its operation. The 10-mc, 1-mc, and 0.1-mc autopositioners have output shafts that tune the receiver to the desired operating frequency.

RADIO TRANSMITTER T-217A/GR

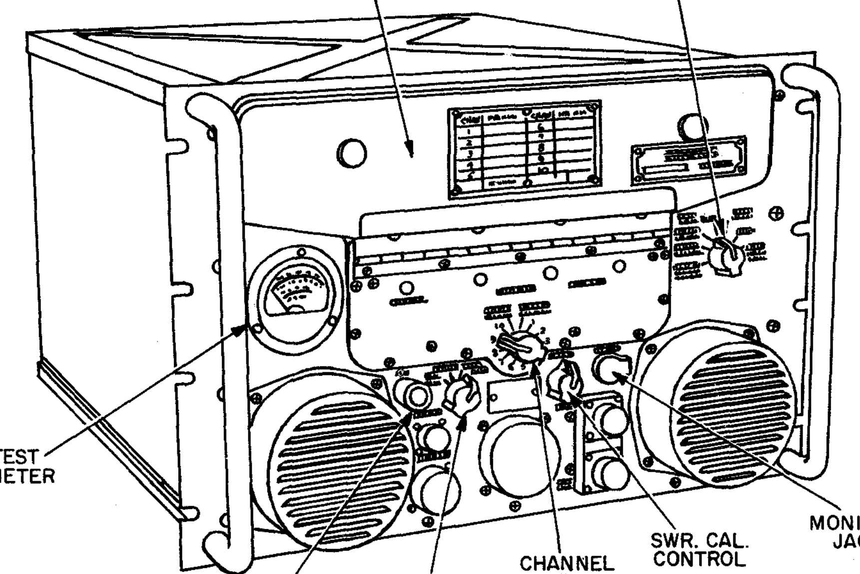
The T-217A/GR radio transmitter and its associated modulator-power supply MD-129A/GR (fig. 9-22) constitute the radio transmitting installation of Radio Set AN/GRC-27A. This transmitter normally delivers a nominal output power of 100 watts, either tone- or voice-modulated, in the frequency range of 225.0 to 399.9 mc. Like the receiver, the transmitter has a maximum frequency range of 225 to 399.9 mc.

A functional diagram of the transmitter and modulator-power supply is shown in figure 9.23. It can be seen that the transmitter is essentially a frequency generating system, an exciter and driver, and a power amplifier. The modulator-power supply provides the transmitter with power, and voice or tone modulates the output stage of the transmitter.

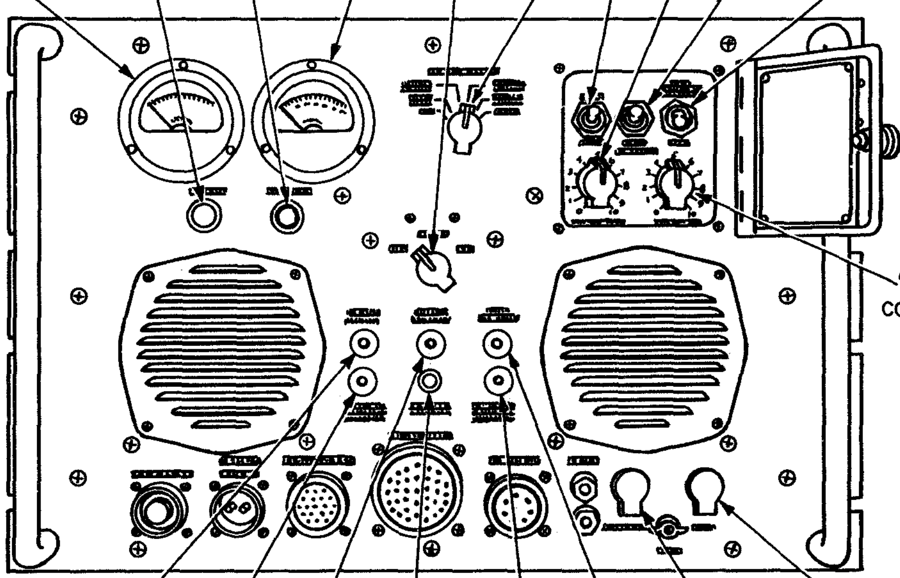
Frequency Selection System

The radio transmitter uses a frequency selector system that automatically tunes the multichannel transmitter to any 1 of 1750 crystal-controlled frequencies in the range from 225.0 to 399.9 mc. The frequency selector system (fig. 9-24) in the transmitter is identical with the system used in the radio receiver. (A block diagram of the receiver frequency selector system was shown in figure 9-20.)

A

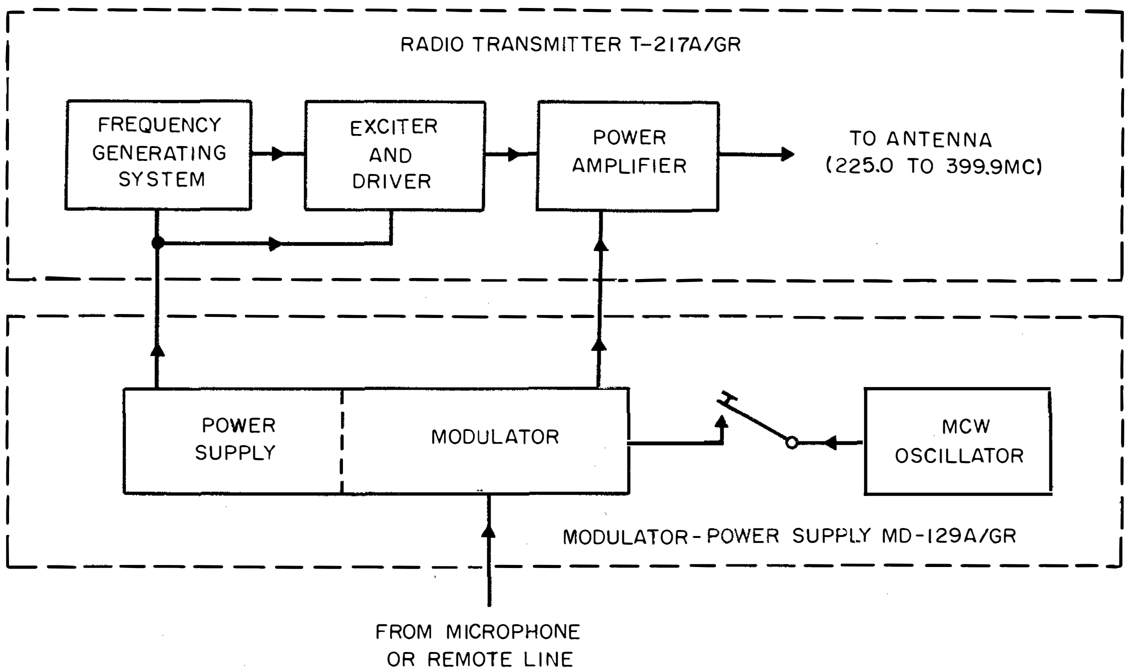


B



32.122

Figure 9-22.—UHF radio transmitter and modulator-power supply units of AN/GRC-27A.



32.123
Figure 9-23.—Functional diagram of transmitter and modulator-power supply units, AN/GRC-27A.

Block Diagram

The main oscillator V201 (fig. 9-24) generates the basic frequency for the transmitter. The oscillator employs 18 crystals selected by the 10-mc autopositioner to tune the oscillator from 31.111 to 45.0-mc. This circuit is referred to also as the 10-mc frequency generator because the output frequency of V201 is changed once for each 10-mc change in the transmitter output frequency.

The 31.111-mc to 45.0-mc output of the main oscillator is doubled or tripled in frequency multiplier V301. Pentode V301 operates as a doubler circuit when the output frequency of the transmitter is 299.9 mc or below. For frequencies above 299.9 mc, V301 triples the oscillator original. The output of V301 is tripled in a second frequency multiplier, V303. Amplifiers V302, V304, and V305 are also a part of the frequency multiplier-amplifier.

The frequency multiplier-amplifier produces 1 of 18 frequencies, spaced at 10-mc intervals. These frequencies are 200 to 370 mc and are delivered to mixer V406.

The heterodyning frequency for the mixing section in V406 is obtained in the following manner: The 1-mc frequency generator V404 contains 10 crystals selected by the 1-mc autopositioner. This stage generates any 1 of 10 frequencies at 1-mc intervals in the 18-mc to 27-mc frequency range. The frequency generated is determined by the crystal selected and also by the timing of the V404 output circuit by the 1-mc autopositioner.

A second frequency generator, referred to as the 0.1-mc frequency generator V402, contains 10 crystals selected at intervals of 0.1 mc. The frequency range is from 2.0 to 2.9 mc, as determined by the selected crystal.

The output frequencies of frequency generators V404 and V402 are heterodyned in mixer V401 to produce the sum frequency of 20.0 to 29.9 mc. This sum frequency output is amplified in V403 and V405, then is fed to mixer V406.

The incoming frequency (200 to 370 mc) from the frequency multiplier-amplifier and the output from V405 (20.0 to 29.9 mc) is heterodyned in V406 to yield the sum frequency of 225.0 to 399.9 mc. Because of the tuning differential between the 1-mc and 0.1-mc frequency generators, the output from mixer V401 can be any of 100 frequencies.

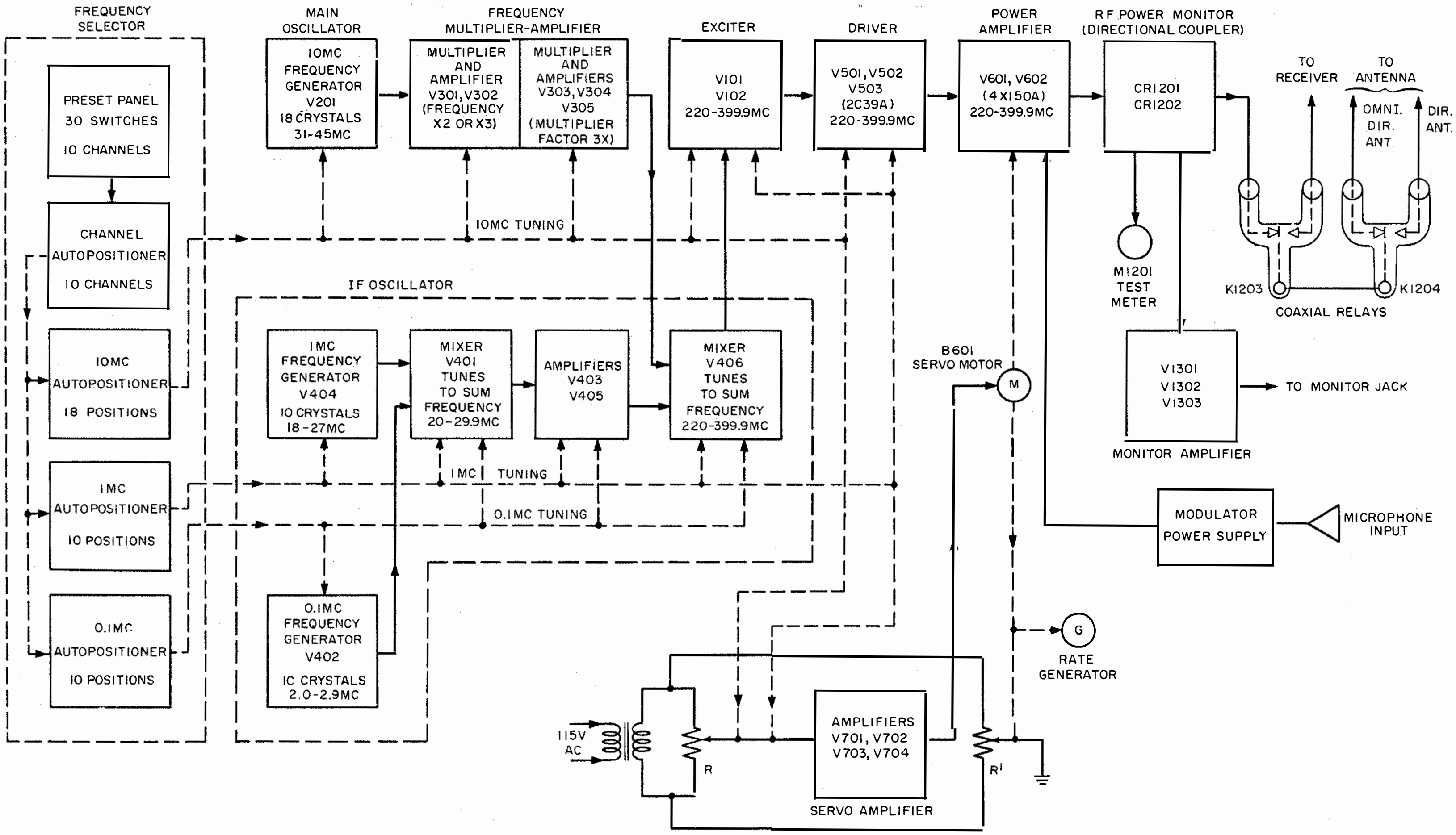


Figure 9-24.—Transmitter unit of AN/GRC-27A, functional block diagram.

32.124

The signal from mixer V406 is amplified in the exciter, which comprises V101 and V102. The exciter output signal from V102 is amplified in three stages (V501, V502, and V503). The exciter and driver stages are tuned by the 10-mc and 1-mc autopositioners in 1-mc steps from 225.0 to 399.9 mc. The amplifier stages in the exciter and driver are tuned to the center frequency of each 1-mc band. The bandpass of these stages is broad enough to amplify the 0.1-mc variations.

Pentodes V601 and V602 amplify the driver (V503) output signal to produce a nominal output power of 150 watts. A servosystem, which utilizes servomotor B601, is used to tune the power amplifier throughout the frequency range of the transmitter. The servoamplifier circuit receives its error signal input from a servobridge.

A basic representation of the tuning bridge includes potentiometers R and R's. Both resistors are connected across the 115-volt a-c line input. Actually, this load across the bridge consists of the input circuit to the grid of the first amplifier V701 (not shown). Because the input circuit to V701 is grounded, the load across the bridge is connected between the arms of R and R's. Note that the arm of R is positioned by the 1-mc and 1-mc autopositioner shafts, and that the arm of R' is positioned by a mechanical connection to the servomotor.

If the power amplifier is on frequency, the potential at the arm of R is the same as on the arm of R' and the voltage difference across the load (V701 input) is zero. The bridge is therefore balanced, the motor is not turning, and the error signal is zero. If the balance of the bridge is upset, however, as happens when a new channel is selected, the 10-mc and 1-mc autopositioners move the arm of R in an attempt to select the new frequency. Thus, the bridge becomes unbalanced when the potential at the arm of R differs from that at R'. This potential difference represents the error signal that is applied to the input of V701.

The output of V701 is amplified in V702, V703, and V704. The amplified output drives the servomotor B601, which tunes the power amplifier mechanically. Simultaneously, the servomotor drives the arm of R' until its position corresponds to the new position of R.

The direction of the error signal is determined by the direction of movement of R from its zero error position. The direction of rotation of the servomotor also is determined by the direction of the error signal.

The output of the power amplifier is fed through coaxial filters (not shown in the block diagram). These filters employ 5 tuned stubs to discriminate against frequencies above 450 mc. The output of this filter is connected to the r-f power monitor.

Two directional couplers are used in the r-f power monitor to provide two sampling voltages. The output from one directional coupler is used to indicate power output, to supply an input to the monitor amplifier, and to calibrate a standing wave ratio indicator. From the other directional coupler the output provides standing wave ratio indication in conjunction with test meter M1201 by measuring reflected power.

The signal from the r-f power monitor is passed to the antenna transfer relay K1203. This relay works in conjunction with the push-to-talk circuit, transferring the antenna from the receiver to the transmitter when the push-to-talk circuit is energized. The circuitry is so arranged that the antenna is transferred before the high voltage is applied to the transmitter.

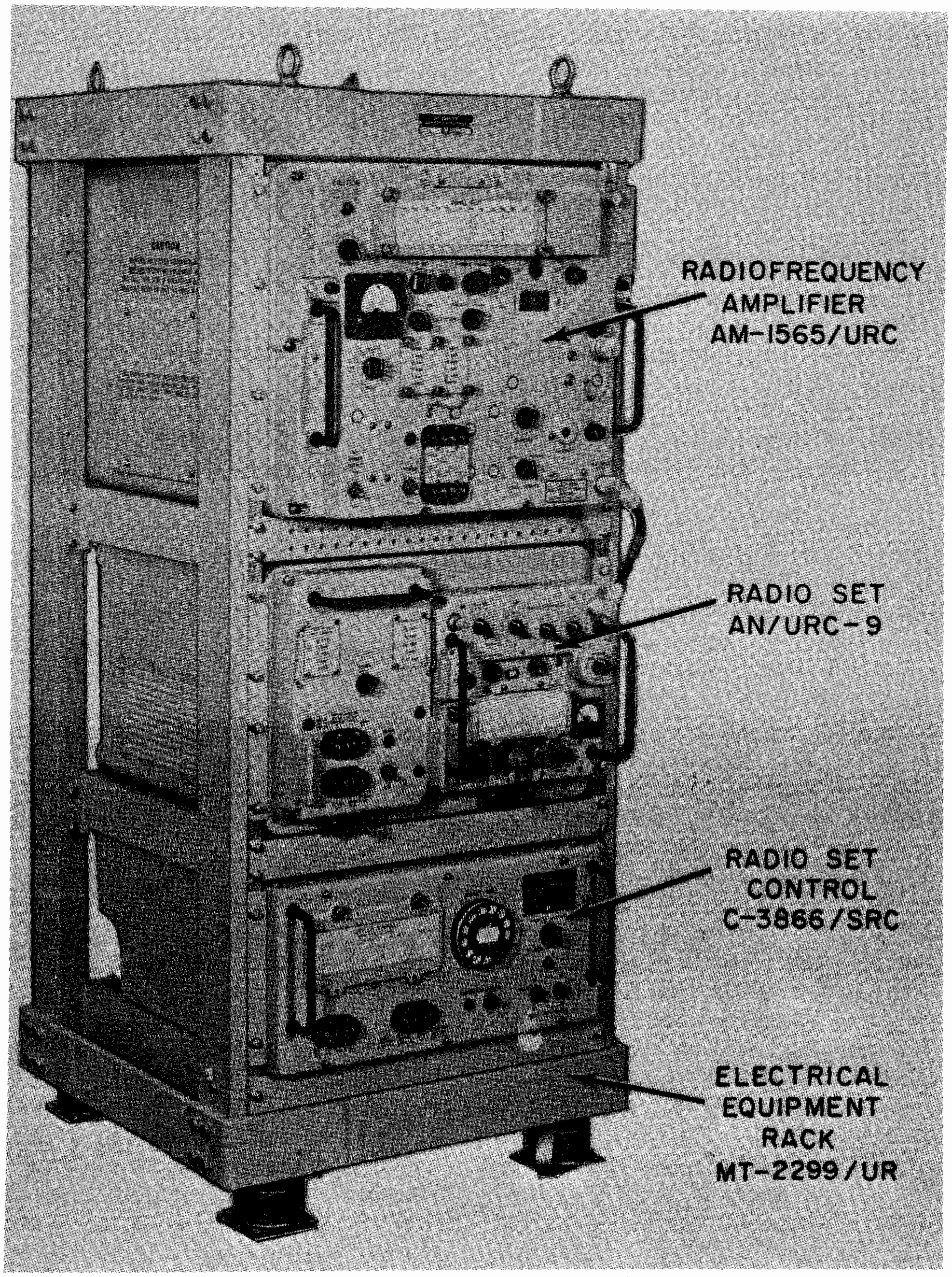
A directional or omnidirectional antenna selected by K1204 may be used with the transmitter. The transmitter output is fed from K1203 through K1204 to the selected antenna.

AN/SRC-20 AND -21 UHF TRANSCEIVERS

Radio Sets AN/SRC-20 and AN/SRC-21, shown in figures 9-25 and 9-26, are designed for shipboard or fixed station operation. These sets provide amplitude modulation (AM) and modulated continuous wave (MCW) on any of 1750 channels spaced 0.1 mc apart in the 225-mc to 399.9-mc range. Of the 1750 channels, 19 can be preset. Complete control, including the selection of preset channels, can be exercised from up to a maximum of 4 remote control points. Additionally, circuits are incorporated that permit the connection of two sets for two-way automatic retransmission.

The AN/SRC-20 radio set is composed of radiofrequency amplifier AM-1565/URC, radio set AN/URC-9, and radio set control C-3866/SRC. The AN/SRC-21 radio set is composed of the latter two units only.

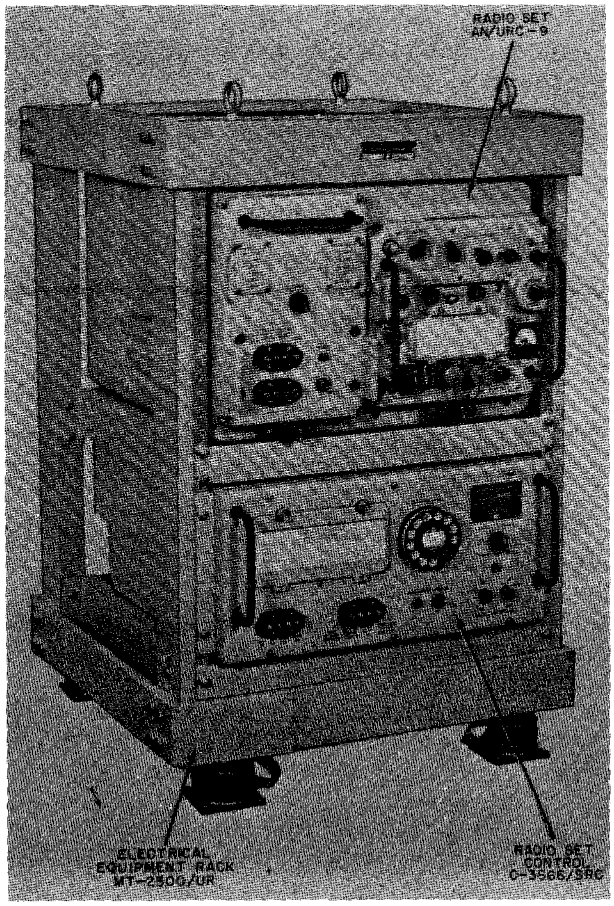
The sets have three modes of operation: normal, retransmit, and tone. Provision is



50.160

Figure 9-25.—Radio set AN/SRC-20.

made for operation with broadband equipment in the normal and retransmit modes. The preset channels can be dialed directly on the radio control set or any one of up to four remote control units. The minimum carrier output of the AN/SRC-20 is 100 watts, with modulation capability of 80 percent. For the AN/SRC-21 the minimum carrier output is 16 watts, with a modulation capability of 80 percent.



50.161
Figure 9-26.—Radio set AN/SRC-21.

RADIOFREQUENCY AMPLIFIER AM-1565/URC

The AM-1565/URC radiofrequency amplifier, a linear UHF amplifier, operates class AB1. The amplifier supplies a minimum of 100 watts of radiated power over a frequency range of 225.0 to 399.9 mc. The r-f amplifier is continuously tunable over the frequency range. A dial calibrated in frequency and a logarithmically calibrated dial are provided to allow presetting of channels. Radiofrequency excitation is controlled automatically by an attenuator that compensates for variation in the exciter output of the AN/URC-9.

The AM-1565/URC is composed of the following functional groups; power amplifier, servoamplifier, drive control regulator, power supply, autopositioner, and the front panel.

The signal from the AN/URC-9 passes through a variable attenuator to the r-f amplifier. After amplification, the signal passes through a directional coupler (used to monitor forward and reverse antenna power) and a low-pass filter (used to minimize harmonic radiation) to the antenna.

During receive, the signal passes from the antenna to the input of the AN/URC-9.

The drive regulator circuits, in conjunction with the ferrite attenuator and front panel controls, compensate for variations in exciter output and drive requirement over the frequency range. This allowance is made by sensing the voltage output of the r-f amplifier, or a manual control, to change the r-f conducting properties of the variable attenuator.

Automatic tuning of the r-f amplifier is performed by a servosystem together with the autopositioner and preset channel potentiometers. The autopositioner, operated by front panel control, forms an unbalanced a-c bridge between the preset potentiometer of the desired channel and the servo circuits. As the servosystem seeks the new null position, the servomotor drive shorting contact rings in the resonant cavities of the r-f amplifiers until proper cavity length is obtained. The servo uses a rate generator feedback system to prevent hunting and oscillation.

RADIO SET AN/URC-9

The AN/URC-9 radio set is a triple-conversion superheterodyne transceiver, which can send and receive amplitude-modulated (A3) and MCW (A2) signals.

During normal receive, the signal from the antenna passes through the AM-1565/URC unit in the AN/SRC-20. In the AN/SRC-21, the signal goes direct to the r-f and PA assembly where the signal is amplified and mixed with a frequency (injected by the frequency multiplier oscillator) to obtain a difference frequency in the 20.0 to 29.9 mc range. This latter signal is passed to and amplified in the first amplifier. The resulting signal is mixed with a signal in the range of 17 to 26 mc from the crystal-controlled oscillator in the first i-f amplifier. The difference frequency, in the range of 3.0 to 3.9 mc, is passed to the second i-f amplifier, where it is mixed with the third injection frequency in the same range but a difference of 500 kc.

This signal is applied through a 500-kc filter to the third i-f amplifier. The third frequency is always 500 kc. The resulting signal is demodulated, passed through a noise limiter, again amplified, and applied to the audioamplifier and modulator assembly. The audio signal is then amplified and sent to the local and remote headsets.

During normal transmit, the push-to-talk switch on the microphone operates relay circuitry. This circuitry grounds the key line from the AM-1565/URC and switches particular circuits in the RT-581/URC-9, allowing the set to operate as a transmitter.

Operation in the retransmission mode requires interconnection of two sets, because a transceiver cannot transmit and receive concurrently. When two sets are connected in this manner, the reception of a signal of the proper level causes the alternate set to operate as a transmitter. This interchange is done by connecting the squelch circuitry to operate when a carrier is received. When a signal is received on one set, it is used to modulate the transmitter output of the alternate set. The audio signal appears at the headsets of the first set and an audio sidetone appears at the headsets of the alternate set.

Frequency Selection

Information is transferred electrically from the channel selector switch to the frequency selector subassembly. There, it is converted to mechanical tuning information for tuning the various oscillators and amplifiers in the radio set. Five accurately positioned tuning shafts, driven by the frequency selector, automatically tune the set to the desired frequency. This process requires from 1 to 5 seconds. The exact time depends upon the sequence of frequency selection.

RADIO SET CONTROL C-3866/SRC

The C-3866/SRC radio set control enables a radio operator to select any 1 of the 19 preset radio channels remotely. It contains a front panel telephone-type dial and the relays necessary to operate an interval stepping relay for channel selection. For setting the squelch level of each radio channel, 19 squelch level potentiometers are available. A local-remote transfer switch controls functions to the remote stations.

To dial any radio channel higher than channel 10, the operator must first dial the letter A, then dial the last digit in the channel number. To dial channel 14, for example, dial A and then the number 4.

VHF TRANSMITTERS

It was explained earlier in this chapter that shipboard communications in the VHF range are no longer used as extensively as in the UHF band. Reduction in usage has resulted in rather limited VHF installations in the active fleets. Two shipboard VHF transmitters, the AN/URT-7 and model TDQ, are described briefly here.

VHF TRANSMITTER AN/URT-7

Radio transmitter AN/URT-7 functions the same as the transmitters of the model TED series, except that the AN/URT-7 operates in the 115- to 156-mc range. In many instances, the component sizes and schematic nomenclatures are identical.

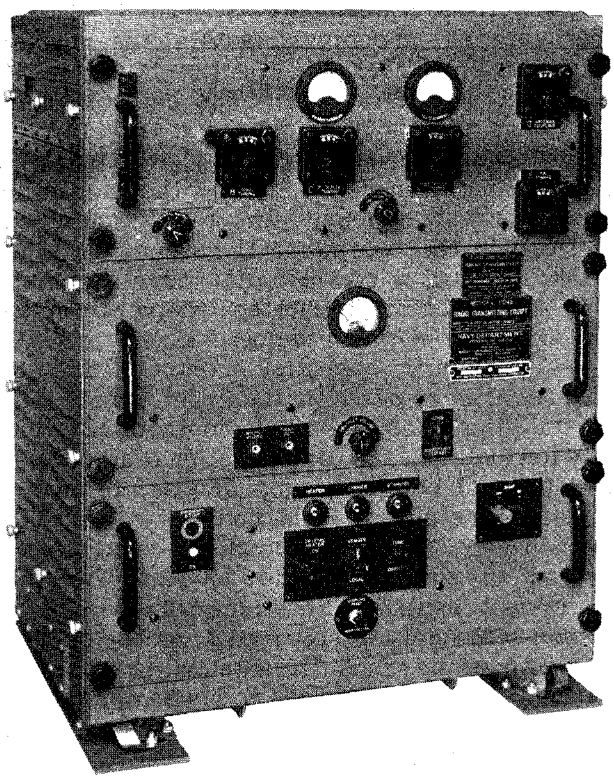
Because the operating frequency range of the AN/URT-7 is lower than that of the model TED series, fewer frequency multiplier stages are needed in the r-f chassis of the AN/URT-7. In the AN/URT-7, one doubler stage and one tripler stage are used to yield a total frequency multiplication of six. In the model TED transmitters, two doubler stages and one tripler stage produce a total multiplication of 12 times the oscillator frequency. In all other respects, the AN/URT-7 and the transmitters of the model TED series are generally the same.

Because of similarities in size, appearance, and operating controls of these two transmitters, the AN/URT-7 is not illustrated in this chapter.

VHF TRANSMITTER MODEL TDQ

The VHF transmitter model TDQ (fig. 9-27) currently is being replaced by the AN/URT-7, although the TDQ still is installed in sufficient quantity that it will continue in service for several years. Like the AN/URT-7, the model TDQ provides voice transmission and MCW radiotelegraph transmission in the portion of the VHF band from 115 to 156 mc.

The TDQ transmitter has a power output of 45 watts, compared with 30 watts for the AN/URT-7. The modulator unit is capable of voice modulating the carrier up to 100 percent



50.71
Figure 9-27.—VHF transmitter model TDQ.

with good quality. During MCW emission, the carrier is modulated 85 percent with a 1000-cycle tone supplied by an audio oscillator located in the modulator unit.

Description of Units

The TDQ transmitter consists of three units. They are, from top to bottom in figure 9-27, the radiofrequency unit, modulator, and power supply.

The radiofrequency unit consists of an oscillator, two tripler stages, and a power amplifier stage. The crystal-controlled oscillator operates at one-ninth the output frequency. Crystals for the TDQ transmitter are in the range from 12.8 to 17.3 mc. The crystal oscillator frequency is multiplied in the first tripler stage to frequencies between 38 and 52 mc. In turn the output of the first tripler is multiplied in the second tripler stage to obtain the output frequency range of 115 to 156 mc. A push-pull beam power amplifier is used in the final stage. The output of this stage is coupled to the transmission line through a coupling loop. The coupling may be varied, as required, for different operating frequencies. The antenna circuit has a transfer relay that automatically switches the antenna transmission line to a receiver when transmission is not taking place. Also the r-f unit contains a blower for forced air circulation in the r-f amplifier.

The modulator unit contains a speech amplifier stage and a modulator stage, a modulation limiter, an audio oscillator, a carrier delay stage, and a 275-volt d-c power supply. The modulation limiter automatically limits the output of the speech amplifier to prevent overmodulation of the carrier wave. It operates in a manner similar to radiofrequency automatic volume control circuits. The audio oscillator produces the 1000-cycle tone for MCW telegraph transmission. Its output is fed into the speech amplifier. The carrier delay circuit prevents shutdown of the carrier for 1 second after each keying impulse. It thus keeps the carrier on the air during key-up conditions when sending MCW code telegraphy. The 275-volt power supply in the modulator unit provides the intermediate voltage for the audio tube plate voltage and modulator and r-f tube screen grid voltages.

The power unit contains a 425-volt rectifier section, and a 12-volt rectifier section. The 425-volt section supplies d-c plate voltage to the modulator tubes and all the r-f tubes, as well as screen voltage to the power amplifier tube. The rectifier filament transformer has additional windings to provide filament voltage for the remaining tubes in the transmitter. The high-voltage rectifier is disconnected automatically to provide standby operation when transmission is not taking place. When this rectifier ceases operation, a green pilot light on the power unit panel goes out. The 12-volt rectifier is a dry-disk type. Its output voltage operates the microphone and a carrier control relay.

VHF RECEIVERS

Two models of VHF receivers currently are used aboard ship. They are the AN/URR-21 and the AN/URR-27. Of these two, the AN/URR-27 is installed in greater quantity and is described first in the following discussion.

VHF RECEIVER AN/URR-27

Radio Receiving Set AN/URR-27 (fig. 9-28) provides for reception of amplitude-modulated voice and MCW transmission in the 105- to 190-mc frequency range. Note that this range of frequencies slightly exceeds that of the VHF transmitters, which cover a band from 115 to 156 mc. This extra coverage, above and below the transmitter frequency range, has no practical worth, thus it is effectively wasted.

The AN/URR-27 is a superheterodyne receiver, designed primarily for operation as a pretuned, single-channel, crystal-controlled receiver. Continuously variable manual tuning is also available. A single tuning control is used for tuning to any frequency for either crystal-controlled or manual tuning operation. Either of these two methods of operation may be selected by means of the CRYSTAL-MANUAL switch on the front panel.

The receiver has a built-in power supply, which can be adjusted to operate from 110- , 115- , or 120-volt, 50- to 60-cycle, single-phase power sources. The audio output and power source input connections to the receiver are filtered to limit possible radiofrequency interference.

Equipment Arrangement

The circuit components are grouped, on a functional basis, into five major sections: the preselector, IF/AF, power supply, cable filtering, and front panel sections. The first three sections are assembled within the chassis frame, and the front panel section is attached to the front of this frame. The cable filtering section is mounted against the rear wall of the cabinet. The preselector section consists of the r-f amplifier-converter and the oscillator-multiplier subsections. The ganged tuning capacitors in the two subsections are geared together through a common dial drive assembly. This action permits tuning the receiver by means of a single front-panel tuning control.

All primary operating controls and the meters are mounted on the front panel. The crystal, the fuses, and those controls requiring only periodic change for operational adjustment are in panel compartments accessible through hinged doors at the right and left sides of the front panel. The panel-mounted controls are located as shown in figure 9-29. Trimmer adjustment controls are accessible when the chassis assembly is removed from the cabinet.

Cable connections for antenna, power input, and audio output are made to connectors on the underside of the cable filtering section attached to the rear of the cabinet.

VHF RECEIVER AN/URR-21

Radio Receiving Set Model AN/URR-21 (fig. 9-30) provides reception of amplitude-modulated

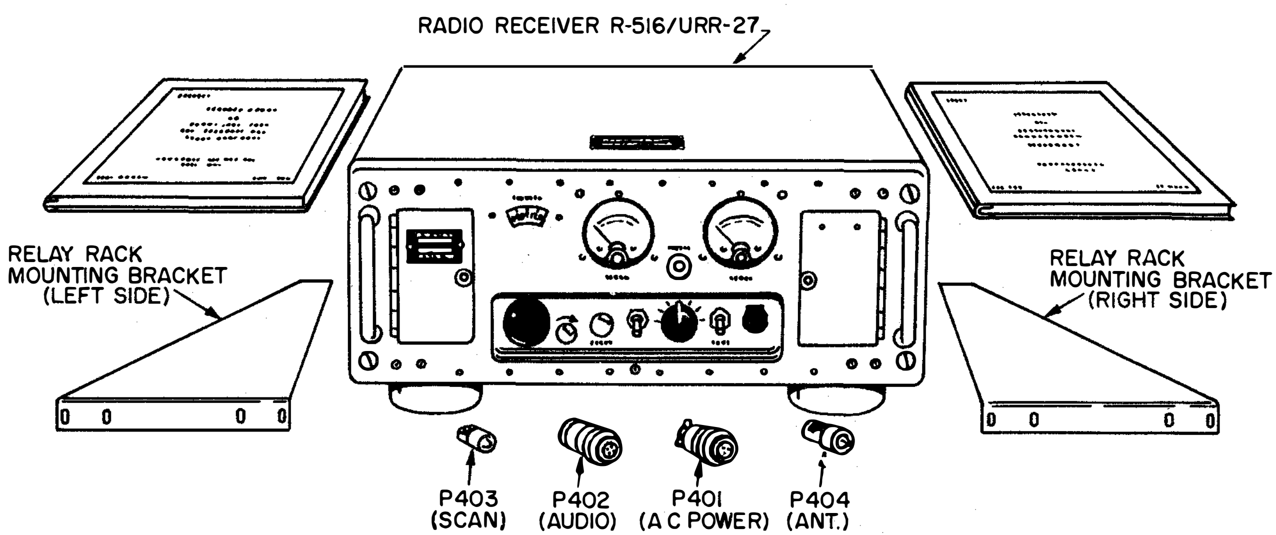


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Figure 9-28.—VHF receiver AN/URR-27.

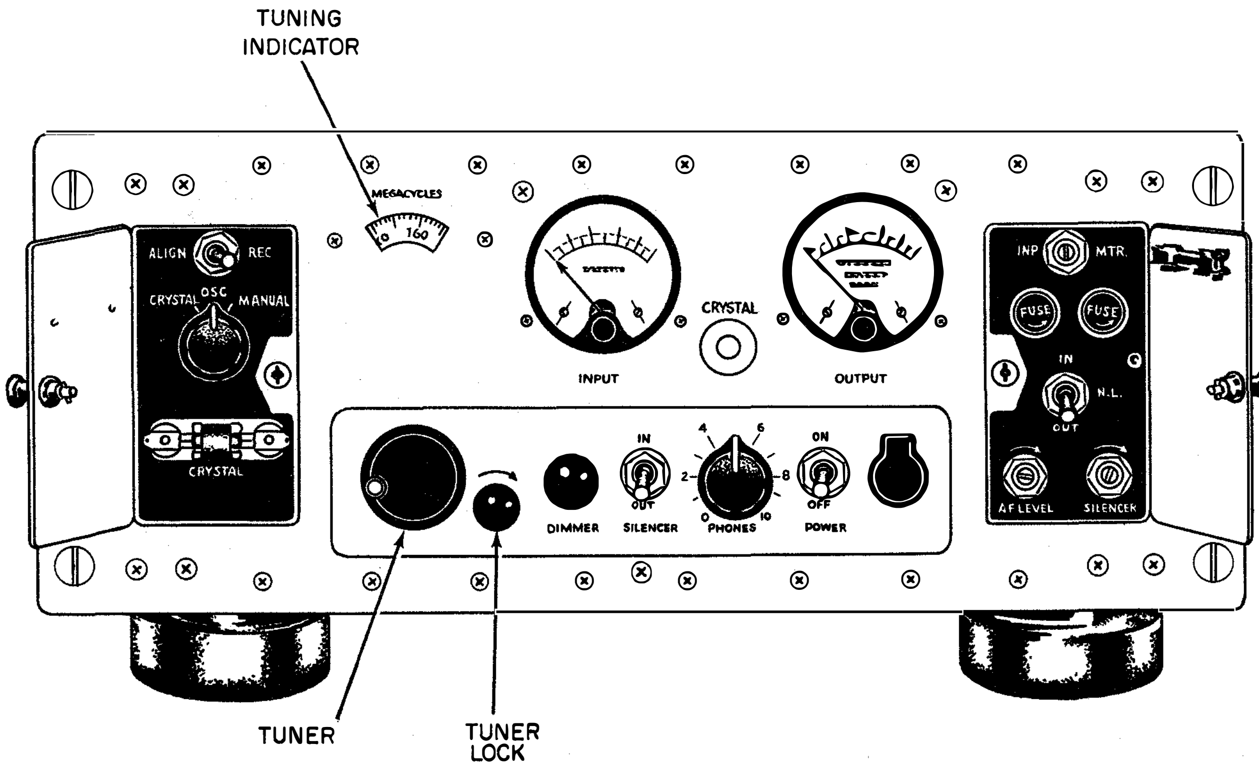

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Figure 9-29.—Front panel controls of VHF receiver AN/URR-27.

voice radiotelephone signals in the range 115 to 156 mc. The receiver operates on the superheterodyne principle. However, the addition of crystal control, additional i-f amplification, and squelch circuit minimizes drift over long operating periods, increases signal sensitivity, and provides quiet operation.

The receiver accommodates four quickly selectable preset crystal channels in conjunction with an r-f amplifier to produce a 12-mc intermediate frequency that is amplified and detected in conventional manner. Special features, in addition to crystal-controlled operation, include a front panel dial detent mechanism for rapid selection of channels, high stability, and continuous tuning of all r-f circuits by means of a single dial mechanism. The dial detent mechanism permits setting the dial to any one of four positions corresponding to the four crystal-controlled channels. The detent mechanism is continuously adjustable so that any four channels within the tuning range may be used.

Description of Units

The AN/URR-21 receiver consists of three functional units, a preselector, IF/AF amplifier, and the power supply unit. These three chassis are bolted together and slide into the cabinet as a single unit.

The preselector chassis contains all of the r-f circuit elements from the antenna through the primary of the first i-f transformer. Circuits contained in the preselector unit are an antenna input stage, one r-f amplifier, a crystal oscillator, two frequency tripler stages, a mixer, and the primary of the first i-f transformer. Crystals for the four operating channels are mounted in sockets on top of the chassis. They are shielded by a removable metal cover.

The IF/AF amplifier chassis consists of the intermediate-frequency amplifier, its associated detection and control circuits, and the audio-frequency amplifier. The controls and meters for these circuits are mounted on the front panel. Because of the large number of i-f

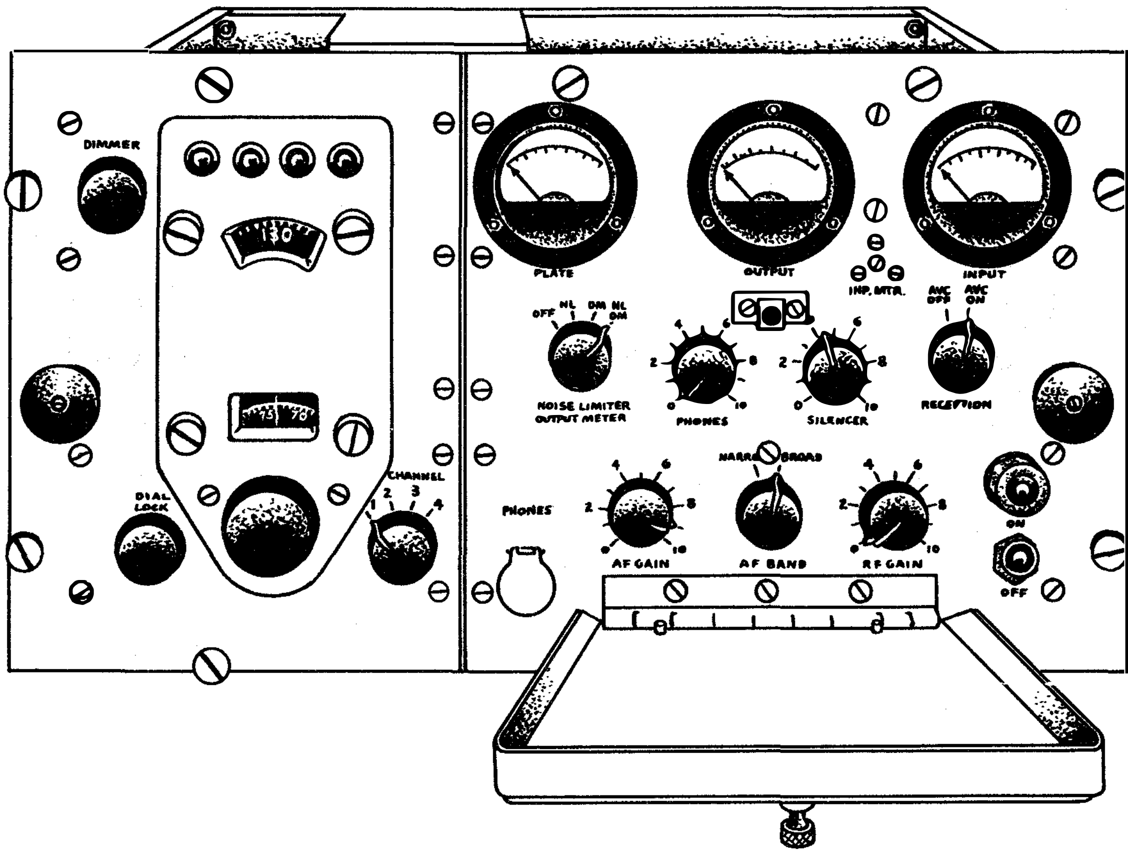

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Figure 9-30.—VHF receiver AN/URR-21.

stages in this unit, it was necessary to arrange will wiring and components for a minimum of common coupling, either through proximity of parts or through ground circuits. In order to mount most of the resistors and capacitors on terminal strips, two large terminal boards with uninsulated leads are arranged for minimum coupling and the most direct connections possible under the circumstances.

The chassis for the power supply unit contains all the components for furnishing power to the receiver. On its top are mounted the power transformer, filter chokes, filter capacitors, and rectifier and regulator tubes. The fuses and the receptacles for power input, antenna, and audio output are mounted on the rear. The line filter is mounted underneath the chassis on a small terminal board.

CHAPTER 10

TERMINAL EQUIPMENT

This chapter presents the telegraph terminal equipment used with transmitters and receivers described in other chapters of this manual. Included are keyers and converters necessary for radioteletypewriter transmission and reception. Although teletypewriters are included in terminal equipment by definition, they are not covered in this chapter. Modern shipboard teletypewriters are discussed in detail in chapter 12.

SHIPBOARD RATT SYSTEMS

The Navy uses two basic radioteletypewriter systems aboard ship. One, the tone-modulated system, if for short-range operation whereas the other, the carrier frequency shift system, is for long-range operation. Descriptions of both systems are given in Radioman 3 & 2 and are not repeated here.

FREQUENCY SHIFT KEYER KY-75/SRT

A separate keyer unit is needed to transmit frequency shift RATT signals when using some of the older high-frequency transmitters, such as models TBK and TBL. All the newer transmitters, such as the AN/SRT-14, -15, -16 series, AN/URC-32, and AN/WRT-2, described in other chapters of this training manual, have the keyer circuitry built into the transmitter. Continued reliable service of the older transmitters, however, requires limited installations of frequency shift keyers in the fleet.

The frequency shift keyer most commonly used aboard ship is the model KY-75/SRT, shown in figure 10-1. An identical keyer, intended for shore station use, is the KY-58/GRT. The KY-58 keyer is mounted in a mobile cabinet for easy portability. The following description of the KY-75/SRT keyer applies also to the KY-58/GRT.

GENERAL DESCRIPTION

The KY-75/SRT frequency shift keyer is a calibrated frequency shift exciter in which signaling is accomplished by shifting a constant amplitude carrier between two fixed frequencies. The two frequencies represent marking and spacing conditions of the teletypewriter code.

For radioteletypewriter operation, the keyer functions so that current impulses from the teletypewriter keyboard produce a marking signal. This action causes the transmitter to emit a frequency above its mean frequency. Conversely, opening of contacts on the keyboard produces a spacing signal. The spacing signal, or open keyboard, causes the transmitter to emit a frequency below its normal assigned frequency.

The primary purpose of the frequency shift keyer is to replace the conventional exciter of the CW transmitter with a source of r-f excitation that can be shifted (in frequency) a small amount upward and downward to produce r-f telegraph code. The unit responds to both neutral (d-c) and polar input signals. Neutral signals cause a current flow in the line during the marking conditions, and no current flow during the spacing condition. Polar signals allow current in one direction through the line for mark, and in the opposite direction for space. The keyer is used principally for comparatively long-distance communications in the high-frequency range.

The keyer is composed of two subunits, which are the modulator-power supply and the amplifier-oscillator. The modulator-power supply (lower panel) incorporates the power supply and all modulator circuits up to but not including the reactance tube (discussed later). The amplifier-oscillator section (upper panel) comprises the crystal oven, reactance tube, 200-kc oscillator, and all r-f circuits and controls. All frequently used operating controls are located

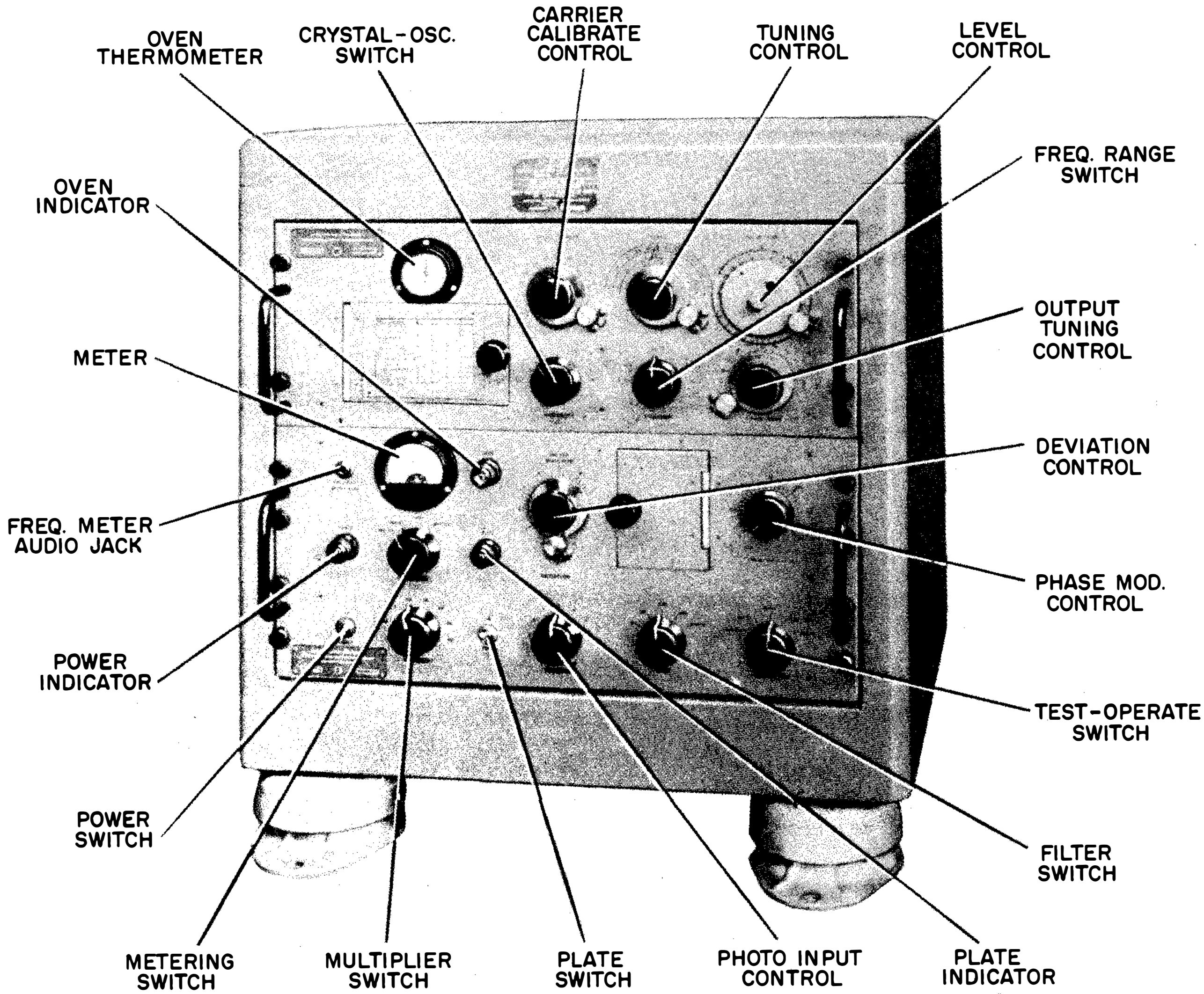

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Figure 10-1.—Frequency shift keyer KY-75/SRT.

on the front panel. Semioperating controls are mounted on a subpanel behind the front panel.

BLOCK DIAGRAM

The input radiofrequency to the frequency shift keyer must be derived from an external oscillator, such as the master oscillator of the transmitter, or from the self-contained crystal oscillator (fig. 10-2). The overall output frequency range of the keyer is 1.0 to 6.7 mc. Because the r-f input is mixed with a 200-kc signal from the frequency-modulated oscillator to obtain the sum frequency, the input frequency must range from 0.8 to 6.5 mc.

The frequency of the 200-kc oscillator is frequency-modulated by the balanced reactance modulator. The reactance modulator varies the amount of reactance across the oscillator tuned circuit, causing oscillator frequency to increase or decrease a small amount in response to mark and space signals.

The magnitude of the frequency shifts is adjustable over a range from 0 to ±500 cps or 1000 cps total shift. The transmitter frequency usually is adjusted for an 850-cycle shift,

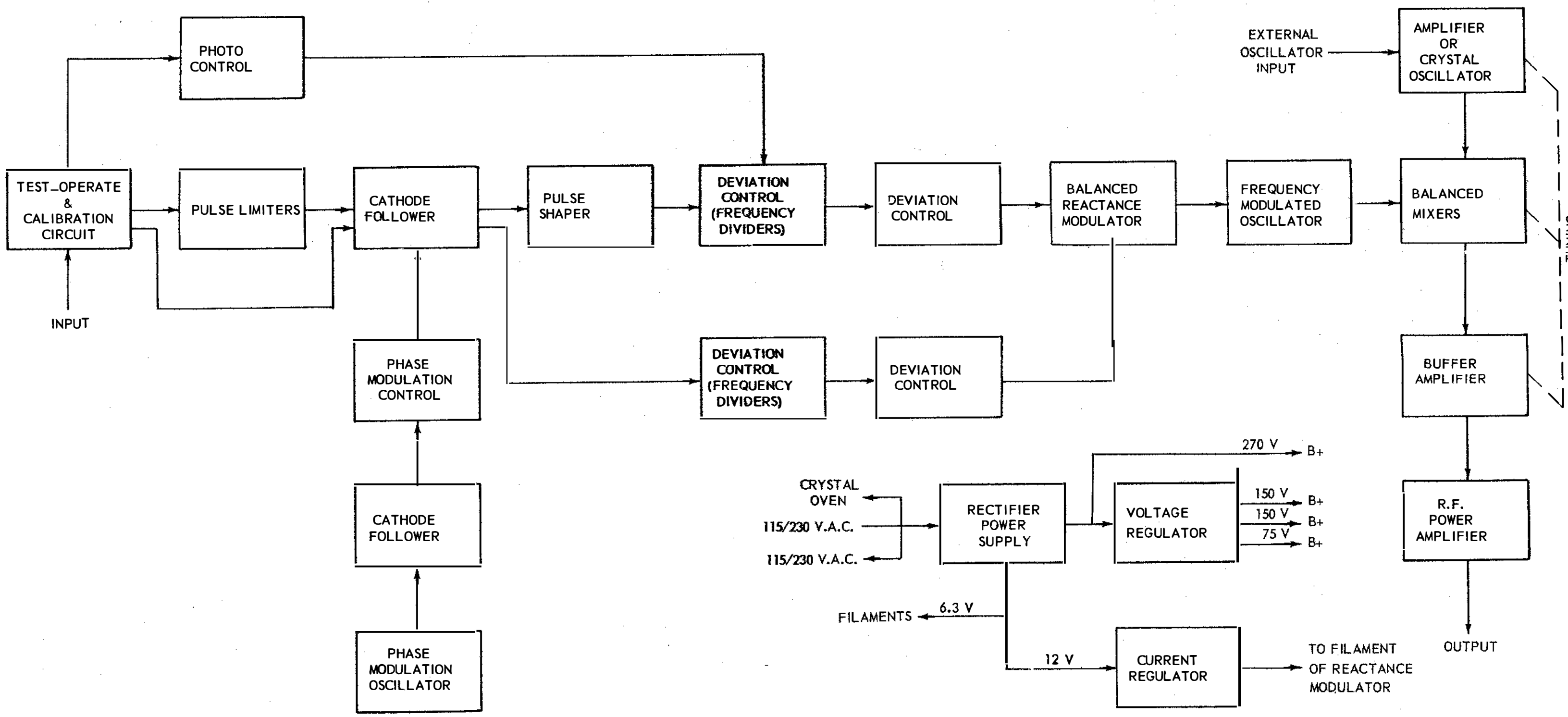

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Figure 10-2.—Frequency shift keyer, block diagram.

which means that the mark signal is 425 cycles above assigned frequency, whereas the space signal is 425 cycles below the carrier. The equipment is capable of being keyed up to 240 dot cycles (transitions from mark to space and vice versa) per second.

The radiofrequency output of the crystal oscillator and the frequency-modulated output of the 200-kc oscillator are combined in the balance mixer circuit. The frequency of the crystal oscillator is balanced out. Therefore, only the sum and difference frequencies resulting from mixing the two oscillator frequencies are present in the output of the balanced mixers. The circuits of the balanced mixers are tuned to the sum frequency.

The buffer amplifier serves to isolate or permit light loading at the balanced mixer output circuit, providing greater discrimination against unwanted modulation components. A ganged tuning control simultaneously tunes the output of the crystal oscillator, balanced mixers and buffer amplifier. The power amplifier supplies an output of 6 watts into a 75-ohm noninductive resistive load.

The test-operate and calibrate circuit comprises a five-position switch utilized to select the circuit arrangement required for frequency shift or facsimile operation. It also selects the arrangement required to perform alignment adjustments for carrier, mark and space.

Two diode pulse limiters are employed to furnish a modulating wave effectively free from amplitude and wavefront variations of the incoming telegraph signal. The output of the second limiter is coupled to a cathode follower, which acts as an impedance transforming device to match the low-impedance pulsing circuits to relatively high-impedance calibration circuits.

The phase modulation oscillator supplies a 200-cycle phase shift signal, which provides a means of reducing effects of selective fading during adverse operating conditions. Phase modulation, which causes a slight shift in frequency, normally is not used if the total frequency shift between mark and space signals is less than 600 cps or if the dotting speed is faster than 35 dot cycles per second. The phase-modulation control provides a means of adjusting the shift in phase from 0 to 1 radian (57.3°).

The frequency shift signal transitions are wave-shaped to restrict sideband radiation by means of four low-pass filters incorporated in the pulse shaper. If the square waves from the limiting circuit are rounded before being passed to the reactance modulator, fewer sidebands are generated because of the partial elimination of the harmonic content of the square wave. The reduction of sidebands permits the assignment of closer radio channel spacing for telegraph operation with the keyer.

During high-frequency transmission, when r-f carrier frequency is multiplied by some factor in the transmitter, the amount of deviation of frequency shift is multiplied simultaneously by the same factor. It therefore becomes necessary to reduce the amount of deviation by a factor equal to the multiplication factor of the transmitter. This action is accomplished by the deviation multiplier, which provides a means of dividing frequency deviation by a factor of 1, 2, 3, 4, 6, 8, 9, or 12. Thus, the transmitter output is held to a certain present deviation regardless of the frequency multiplication employed in the transmitter.

The deviation control circuits act to keep wave-shaping termination at a fixed value. The calibrated dial of the deviation control reads the actual amount of deviation realized at the output of the transmitter.

When the test-operate switch is placed in PHOTO position, the equipment is in readiness for facsimile operation. Photo facsimile operation is similar to frequency shift key (FSK) operation, except that during photo operation, limiting and wave-shaping circuits are not utilized. The photo control circuit provides a means of adjusting photo input voltages.

The power supply contained in the modulator-power supply is designed to operate from a 115- or 230-volt, a-c, single-phase, 60-cycle input source. The supply furnishes 270 volts d-c at 220 ma, 4.35 amp at 6.3 volts a-c, 0.6 amp at 12.0 volts a-c, and 3 amp at 5.0 volts a-c. A 5.0-volt winding furnishes filament voltage for the rectifier tube.

COMPARATOR-CONVERTER GROUP AN/URA-17

Comparator-Converter Group AN/URA-17 (fig. 10-3) is a completely transistorized equipment. It is designed to perform the same functions in the frequency shift RATT receiving system as the AN/URA-8B (described later).

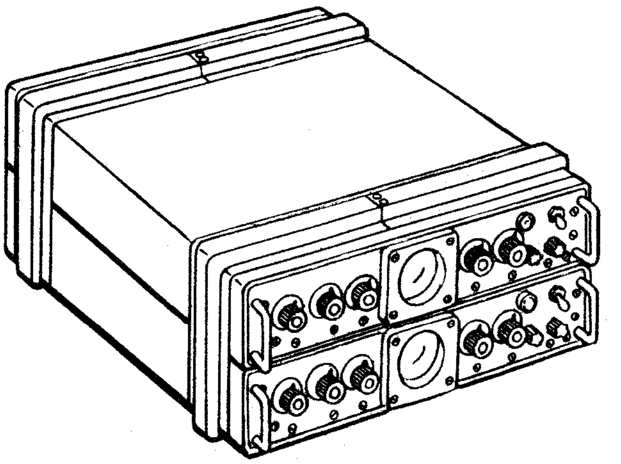

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Figure 10-3.—Comparator-converter group AN/URA-17.

GENERAL DESCRIPTION

The AN/URA-17 consists of two identical converter units, one of which is shown in closeup in figure 10-4. Each converter has its own comparator circuitry. This design feature achieves a considerable reduction in size from model AN/URA-8B, wherein the comparator occupies a separate chassis. The physical size of the AN/URA-17 is further reduced through use of semiconductors and printed circuit boards. The complete equipment is less than half the size of the AN/URA-8B.

The comparator-converter can be operated with two radio receivers in either space diversity or frequency diversity receiving systems. When conditions do not require diversity operation, each converter can be used separately with a single receiver for reception of frequency shift RATT signals. In this latter usage, the two converters can be operated in two independent communication circuits.

For diversity operation, the function switch (fig. 10-4) on both converters must be placed in the diversity position. The teletypewriter may be connected to either converter.

BLOCK DIAGRAMS

The simplified block diagram, figure 10-5, indicates the basic functions of converting the r-f frequency shift signal into a signal for controlling the d-c loop of the teletypewriter. The frequency shifts of the audiofrequency output of the radio receiver are converted into d-c pulses by action of the audiofrequency discriminator. The d-c pulses are fed into the loop keyer, which opens and closes the d-c loop of the teletypewriter in accordance with mark and space characters received.

The principal functions of the circuits of the complete equipment are represented in figure 10-6. Two receivers and a teletypewriter are also shown, connected for diversity operation. The two converters are identical. One is shown as a single block for simplicity. The complete schematic diagram of the converter can be found in Comparator-Converter Group AN/URA-17, NavShips 94028.

FUNCTIONAL SECTIONS

Each converter of the AN/URA-17 is a single unit whose filters and transformers are mounted

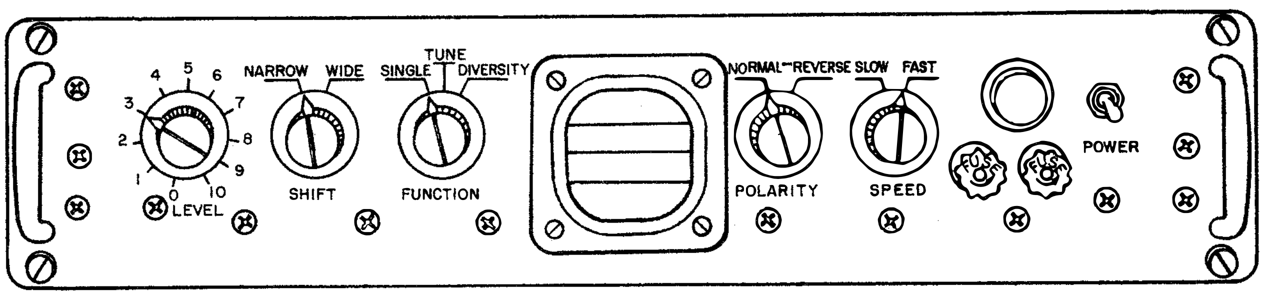

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Figure 10-4.—AN/URA-17 frequency shift converter.

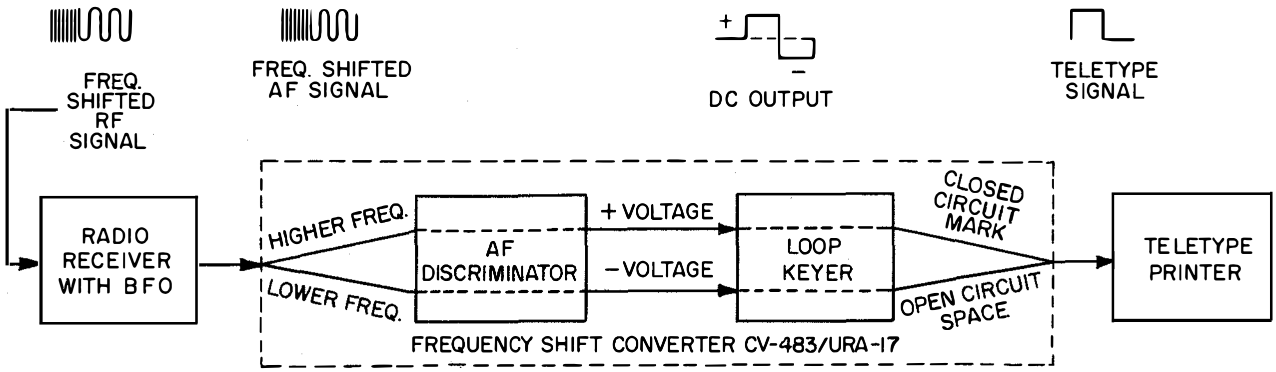

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Figure 10-5.—Frequency shift receiving system, simplified block diagram.

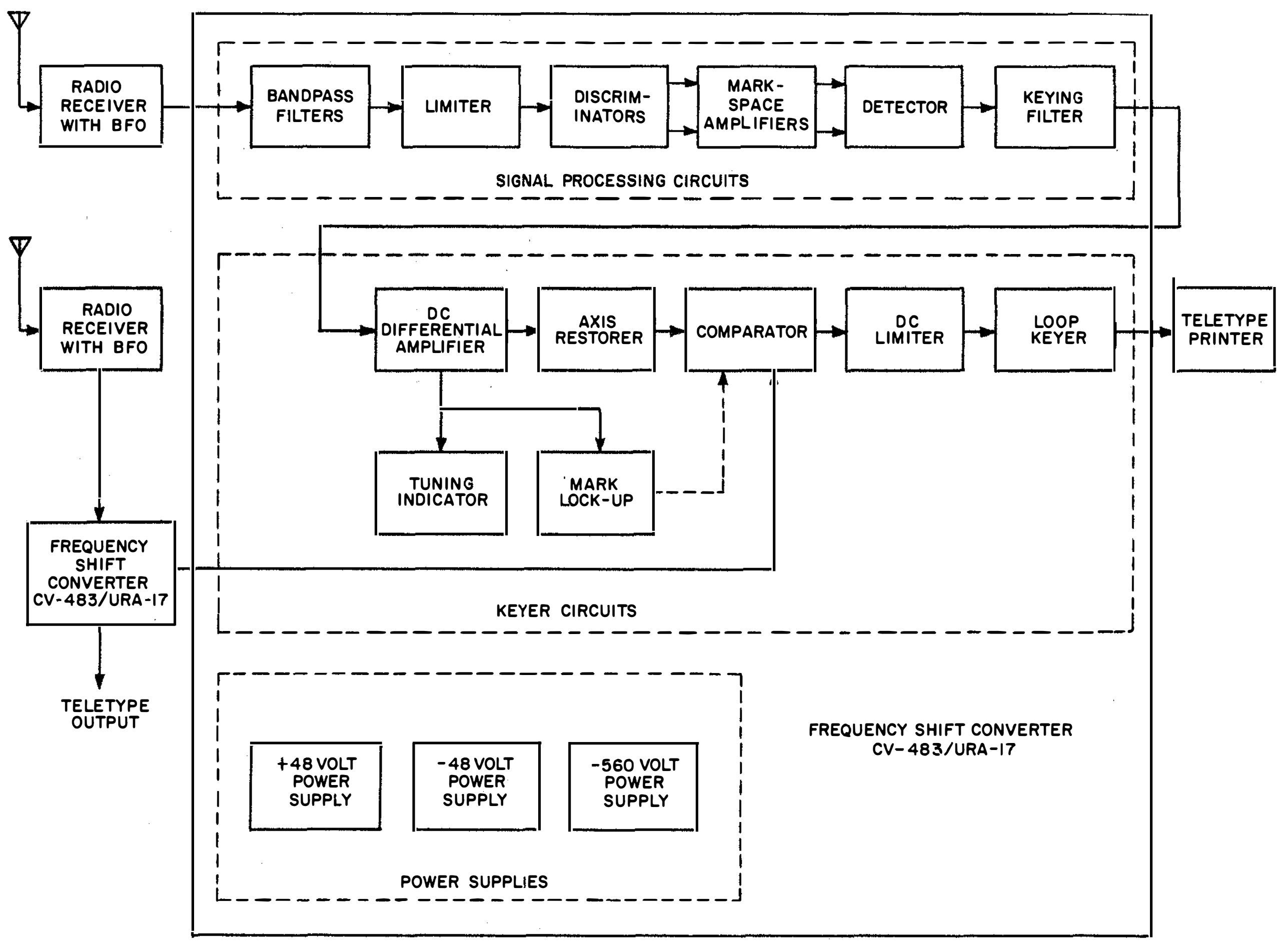

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Figure 10-6.—Comparator-converter group AN/URA-17, functional block diagram.

around the sides of printed circuit boards. In the following topics, the converter is covered as three functional sections: (1) signal processing circuits, (2) keyer circuits, and (3) power supplies. Refer to figure 10-6.

Signal Processing Circuits

The input signal from the receiver is applied to the audio input connector at the rear of the converter. The input transformer matches the 8000-ohm impedance of the bandpass filter to the 600-ohm line from the receiver. A center tap is provided for accommodation of balanced inputs. The input transformer is encased with the bandpass filter.

BANDPASS FILTERS.—High-frequency noise pulses are attenuated by bandpass filters, and both extremes of the shifted audio signal are passed to the limiter. The shift switch selects the correct filter for the shift width of the input signal. The narrow filter is used when the center frequency of the input signal is 1000 cps, with shifts of 5 to 100 cps each side of center. The wide filter is used when the center frequency of the input signal is 2550 cps, with shifts of 100 to 500 cps each side of center.

LIMITER.—The detector output level is held to within 2 db by the limiter, with input signals of from 60 μw to 60 mw. Both diodes have a high forward resistance to signals below approximately 0.6 volt in amplitude. Their resistance to signals of greater amplitude is low. Strong noise pulses are removed from the input signal, and the signal to the discriminator is held at a constant level with fading input signals. The signal level is maintained at approximately 0.6 volt. The output from the limiter is amplified by a common emitter amplifier that uses the level control as the collector load. The level control is used for adjusting the signal level to the discriminators. During reception of a narrow-shift signal, the level must be higher than when receiving a wide-shift signal. The amplified signal is applied to the discriminator through the shift switch.

DISCRIMINATORS.—Discriminators determine the frequency versus amplitude slope of mark and space signals. Each discriminator is a frequency-selective network, consisting of two resonant networks with overlapping frequency response patterns.

The narrow-shift discriminator is used for signals with shift widths of 10 to 200 cps. At one terminal of the narrow-shift discriminator, voltage output increases with frequency to maximum at approximately 1200 cps. At the other terminal, voltage output increases as frequency decreases to a maximum of approximately 800 cps. The crossover point, at which voltages from the two output terminals are equal, is 1000 cps ±15 cps.

The wide-shift discriminator is used for input signals, with shift widths between 200 and 1000 cps. Crossover frequency of the two resonant networks is 2550 cps ±40 cps. One of the outputs increases with frequency to maximum at about 3400 cps. The other output increases as frequency decreases to a maximum at approximately 1700 cps.

The output from one terminal of the discriminator is applied to the base of the first mark amplifier. Output from the other terminal is applied to the base of the first space amplifier.

MARK-SPACE AMPLIFIERS.—The first mark amplifier is a common emitter with fixed base biasing. The mark gain control in the collector circuit provides adjustment of signal gain by controlling degeneration in the emitter circuit. The mark signal is coupled by a capacitor from the collector of the first mark amplifier to the base of the second mark amplifier. Space amplifiers are identical to mark amplifiers. The space gain control is in the collector circuit of the first space amplifier. Two transformers couple the output of mark and space amplifiers to the detector circuit. One transformer is for the mark output, the other for the space output.

DETECTOR.—The detector rectifies and combines outputs of the discriminator transformers into a pulsating d-c signal containing mark-space intelligence. Mark and space signals at the secondary are full-wave-rectified by crystal diodes, then are combined across two resistors, and are applied to the polarity switch.

In conventional frequency shift keying, the high-frequency portion of the shifted signal corresponds to teletype mark pulses; the low-frequency portion corresponds to space pulses. At times, the mark-space relationship may be reversed. Garbled copy results if these reversed characters are applied to a teletype printer. The polarity switch is for the purpose of inverting the mark-space relationship when required.

KEYING FILTER.—Noise pulses and the carrier are removed by the low-pass keying filter. This keying filter consists of two sections. Selection of these sections is made by the speed switch. When the switch is in the slow position, the keying filter section passes keying signals up to 100 wpm. This section attenuates all frequencies above 45 cps. When the switch is moved to the fast position, the other section of the filter is used. This section passes keying signals up to 400 wpm. In the fast position, the equipment can be used with four-channel, time division multiplex up to 100 wpm per channel. All frequencies above 180 cps are attenuated when the switch is in the fast position.

Keyer Circuits

Pulsating d-c signals from the keying filter are converted by keyer circuits into on-off pulses for operating the teletype printer relay.

D-C DIFFERENTIAL AMPLIFIER.—The d-c differential amplifier amplifies the mark-space signals before they are applied to the d-c limiter. This differential amplifier contains five transistors, four of which form two emitter-coupled amplifiers. The fifth transistor is the output and feedback transistor.

The input signal from the keying filter is applied to the base of one of the transistors in the first emitter-coupled amplifier. Input to the base of the other transistor in this amplifier is from the collector of the fifth transistor in the output circuit of the d-c differential amplifier. The feedback signal from the output stabilizes the gain of the d-c differential amplifier.

Both the input signal and feedback signal amplified by the other emitter-coupled amplifier. This amplifier also mixes these two signals and applies them to the output transistor.

The vertical center control, in the emitter of the first transistor, adjusts the vertical centering of the tuning indicator display. Zero balance of the amplifier is established by means of this adjustment.

The linearity control, in the base circuit of the output transistor, is for the purpose of adjusting the bias of this transistor. Thus, the most linear signal possible is provided.

AXIS RESTORER.—The axis restorer maintains the signal axis at ground potential and restores signal symmetry when the transmitter or receiver frequency drifts during operation. Mark-space signals are clamped to ground by different circuits within the axis restorer, and are combined at the output. By clamping both signals separately, then recombining them, the signal axis automatically is placed at ground potential. The signal is coupled to the converter through the function switch.

COMPARATOR.—The main function of the comparator is to compare the strength of signals from the two receivers during diversity operation. Signal strength comparison allows only the stronger signal to be applied to the d-c limiter. The comparator consists of CR14, CR15, CR16, CR17, R54, and R55. (See fig. 10-7.) In diversity operation, two converters are used with two receivers to operate a single teletype printer. Signals are compared at the comparator in each converter. Both converters must have their function switch placed at diversity. The teletype printer may be connected to either converter.

In figure 10-7, peak amplitudes of both input signals are equal, but the signal from converter A contains noise. The signal from converter B, which has a constant peak value of 20 volts,

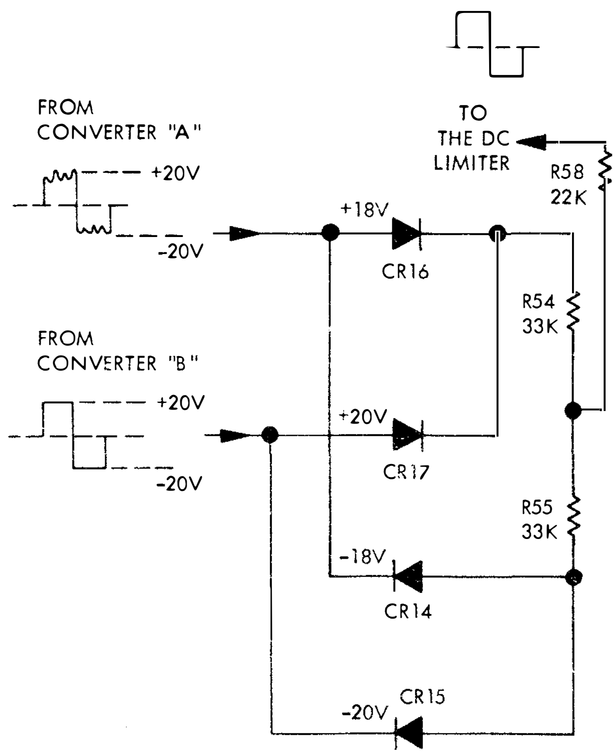

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Figure 10-7.—Comparator circuit, simplified schematic diagram.

will develop a greater voltage across R54 and R55. This action places a reverse bias of 2 volts on CR14 and CR16, preventing converter A from actuating the d-c limiter.

Besides diversity setting, the function switch has two other positions—single and tune. In single, positive mark pulses cause CR16 to conduct; negative space pulses cause CR14 to conduct. In the tune position, the signal input to the d-c limiter is removed while the receiver is being tuned.

D-C LIMITER.—The d-c limiter is a class B push-pull circuit. This circuit supplies about 20 db of post-detection limiting, and aids in proper operation during reception of signals containing strong noise pulses.

The signal from the comparator is applied simultaneously to the base of two transistors. A positive mark signal causes the mark transistor (an n-p-n transistor) to conduct, but cuts off the space transistor. The signal is phase-shifted 180° and is fed to a p-n-p transistor, causing it to give a strong negative signal at the output. A negative space signal causes the space transistor (a p-n-p transistor) to conduct and at the same time cuts off the mark transistor. This signal is shifted 180° and delivered to an n-p-n transistor, causing a strong negative signal at the output. Mark and space signals then are combined and are fed to the loop keyer. Switching action of the loop keyer is controlled by the d-c limiter.

LOOP KEYER.—The function of the loop keyer is to operate the teletype printer loop relay. Two transistors are contained in the loop keyer circuit. Depending on the signal applied, the first transistor causes the second to conduct or not conduct. When the second transistor conducts, the teletype printer relay closes, causing a mark signal to be transmitted. When the transistor doesn't conduct, the relay opens, causing a space signal to be transmitted. A positive signal from the d-c limiter activates the loop keyer circuit; a negative signal cuts off the loop keyer circuit.

MARK LOCKUP.—During traffic interruptions, the mark lockup circuit provides a strong, artificial mark signal to the d-c limiter. When a deep fade in the signal occurs, or if the signal-to-noise ratio is low, noise pulses could cancel the small positive bias on the d-c limiter input, allowing garbled copy to be printed. A steady mark signal is transmitted between messages.

TUNING INDICATOR.—The tuning indicator is a cathode ray tube. Controls for horizontal adjustment, centering, focus, intensity, vertical adjustment, vertical center, and linearity are provided on the converter chassis as screwdriver adjustments. When the associated receiver is tuned properly, the CRT pattern is centered vertically. Correct level control adjustment is achieved when horizontal lines of the pattern coincide with those on the bezel.

Power Supplies

Three d-c power supplies furnish all operating voltages and operating current required by the converter. Tapped primaries on the two power transformers allow operation on line voltages of 105, 115, or 125 volts.

Both the positive and negative 48-volt supplies consist of a full-wave bridge rectifier and a series regulator circuit. Each circuit has a voltage adjust control, enabling voltage to be maintained at a constant level.

The negative 560-volt supply uses two diodes connected as a half-wave rectifier. A voltage divider provides the high voltages required by the cathode ray tube.

FREQUENCY SHIFT CONVERTER-COMPARATOR AN/URA-8B

The frequency shift converter-comparator AN/URA-8B, shown in figure 10-8, comprises two frequency shift converters (top and bottom units), and one comparator (middle unit). It provides an important link at the receiving end of the frequency shift radioteletypewriter system.

Any standard Navy receiver may be used to translate the frequency-shifted r-f signals from the transmitter into audio tones by means of its beat frequency oscillator. From this process, the r-f carrier shift becomes an audiofrequency shift that is patched into the converter unit of the AN/URA-8B. The converter changes these frequency-shifted audio signals into d-c mark-space pulses for operation of the teletypewriter. This method of communication utilizes the noise-reduction advantages of frequency modulation for long-distance RATT reception.

Either converter unit of the AN/URA-8B can be operated in a single-receiver FSK receiving system or can be used together, in combination with two receivers and a single teletypewriter, to provide a diversity receiving system. The diversity system makes use of the principles of

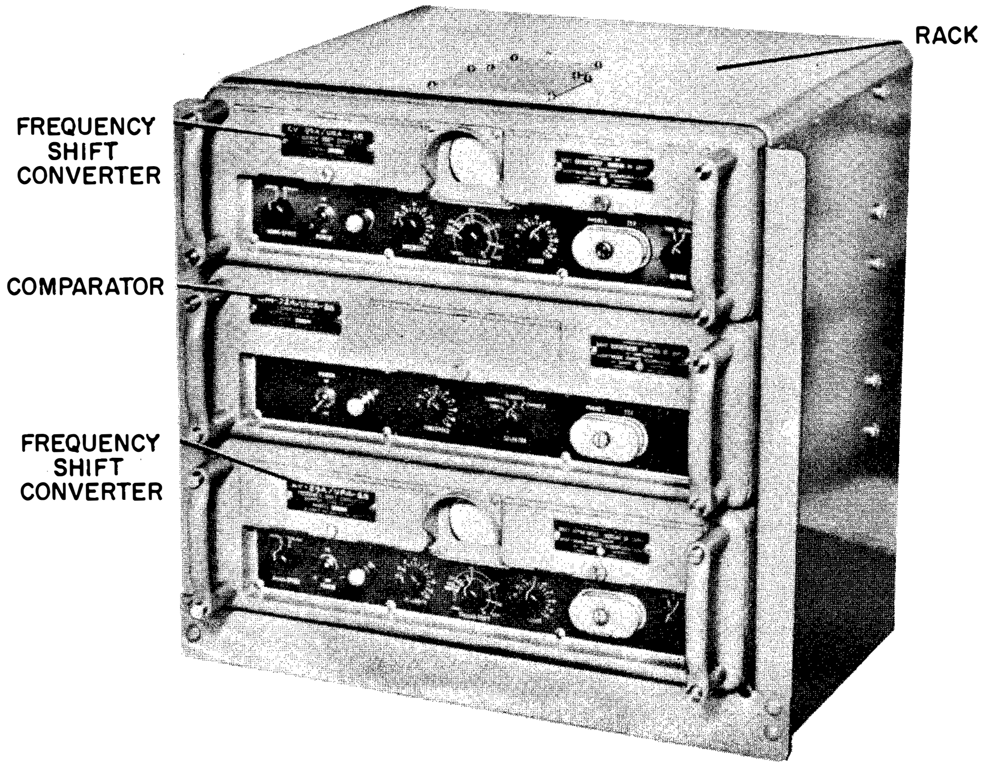

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Figure 10-8.—Frequency shift converter-comparator group AN/URA-8B.

space diversity or frequency diversity reception to eliminate severe signal fading over long transmission distances.

In space diversity operation, two receivers are tuned to the same r-f carrier frequency, but their receiving antennas are spaced several wavelengths apart. The advantage of this method of reception is that maximum fading of a given carrier frequency usually does not coincide in time at points so separated. The audio output of each receiver is applied to a separate converter. The requirement for antenna separation limits space diversity to shore station use.

In frequency diversity operation, two receivers are tuned to different r-f carrier frequencies from two transmitters keyed simultaneously with the same mark-space modulation. The audio output of each receiver is applied to a separate converter. The advantage of this method of reception is that maximum fading of two different carrier frequencies seldom occurs at the same time in a given location. This method is common aboard ship, where space limitations do not allow sufficient antenna separation for effective space diversity reception.

In either method of diversity reception, audio outputs of two radio receivers are patched to the two converters. The d-c signals from discriminator circuits of the two converters are compared in the mark-space selector of the comparator unit, which automatically selects the better mark and the better space pulse for each character. The output of the comparator is patched to the teletypewriter.

The frequency shift employed in the converters may be as little as 10 cps or as much as 1000 cps frequency separation between mark and space signals. This scope of frequency shifts is divided into two ranges called narrow shift (10 to 200 cps) and wide shift (200 to 1000 cps). A frequency shift of 850 cycles is commonly used in Navy radioteletypewriter channels.

BLOCK DIAGRAM

An input filter at the input of the frequency shift converter (fig. 10-9) eliminates the possibility of false keying by spontaneous noise signals outside the frequency shift range of the converter. The input filter comprises both a high-pass and a bandpass filter.

The limiter amplifier is designed to apply a constant voltage to the input circuit of the discriminator. Variations at its input may swing from 60 μv to 60 mv. Amplitude-limiting of both positive and negative peaks is accomplished in the circuit. The limiter output is coupled to the input of the discriminator circuit.

The discriminator circuit is essentially a double-slope detector consisting of three sections: discriminator input network, discriminator rectifier, and discriminator buffer amplifier. The purpose of the discriminator circuit is to convert frequency shift changes into corresponding d-c changes.

Two separate discriminator input networks are employed. One provides for narrow frequency shift operation, and the other passes the wide frequency-shift signals. The output of the two discriminator networks is applied to the buffer amplifier.

The fast-slow filter consists of two separate low-pass filters corresponding to a slow-speed filter and a high-speed filter, respectively. These circuits attenuate spurious signals above the frequency of the pulse rate of the circuit, preventing faulty keying action owing to noise or harmonics.

The axis restorer circuit is provided to produce the optimum signal output when the received signal is weighted heavily on one side or the other, either mark or space. It also maintains the optimum axis, or bias, for keying with the weakest portion of a fading signal. The weighting of the signal may be because of the relative mark and space in each character, selective fading conditions, or improper tuning of the receiver. The axis restorer contains a system that "locks up" the teletype circuit (closing the loop circuit) whenever there is a prolonged mark, space, or no-signal condition.

The oscillator-keyer subunit provides necessary circuits for producing the tone output to a tone receptacle and headphones, and for introducing d-c pulses from the discriminator circuit to the teletypewriter printer. The audio oscillator-amplifier produces frequencies tunable to 595, 765, 935, 1105, 1275, 1445, 1615, and 1785 cps.

A phase splitter is included to supply the push-pull input circuit of the tone modulator, which is a conventional push-pull amplifier whose output is keyed from "tone-on" to "tone-off" by a signal from the flip-flop keyer circuit.

In addition to supplying a signal to the tone modulator, the flip-flop keyer circuit introduces mark and space signals from the discriminator circuit to the electronic relay. Signals from the electronic relay circuit open and close the d-c loop of the teletypewriter.

The power supply circuit of the frequency shift converter is a conventional full-wave rectifier with a single pi filter. The B supply voltage supplies by the circuit is approximately 250 volts d-c. A negative bias of 38 volts is provided through the connection of a resistor and filter capacitor between the center tap of the high-voltage secondary and ground. The circuit of the power supply is not shown in this chapter. The complete schematic diagram of the power source can be found in Frequency Shift Converter-Comparator Group AN/URA-8B, NavShips 91490.

During diversity reception, output signals from two frequency shift converters are fed to the mark-space selector circuit of the comparator. This circuit automatically compares the two signals and selects the better mark pulse and better space pulse for each character of the coded message. The remaining circuits of the comparator perform the same function as described for the converter.

RADIOTELETYPEWRITER TERMINAL SET AN/SGC-1A

Radioteletypewriter Terminal Set AN/SGC-1A is a tone shift keyer/converter used for short-range RATT operation. Normally, it is used for communication on VHF/UHF bands, but it can be used with any transmitter designed for voice modulation. The AN/SGC-1A is shown in figure 10-10, with blocks to indicate other equipments necessary for a complete tone shift system.

In tone modulation transmission, d-c pulses of the teletypewriter code are converted into corresponding audio tones, which amplitude-modulate the transmitter. Conversion of audio tones is accomplished by an audio oscillator

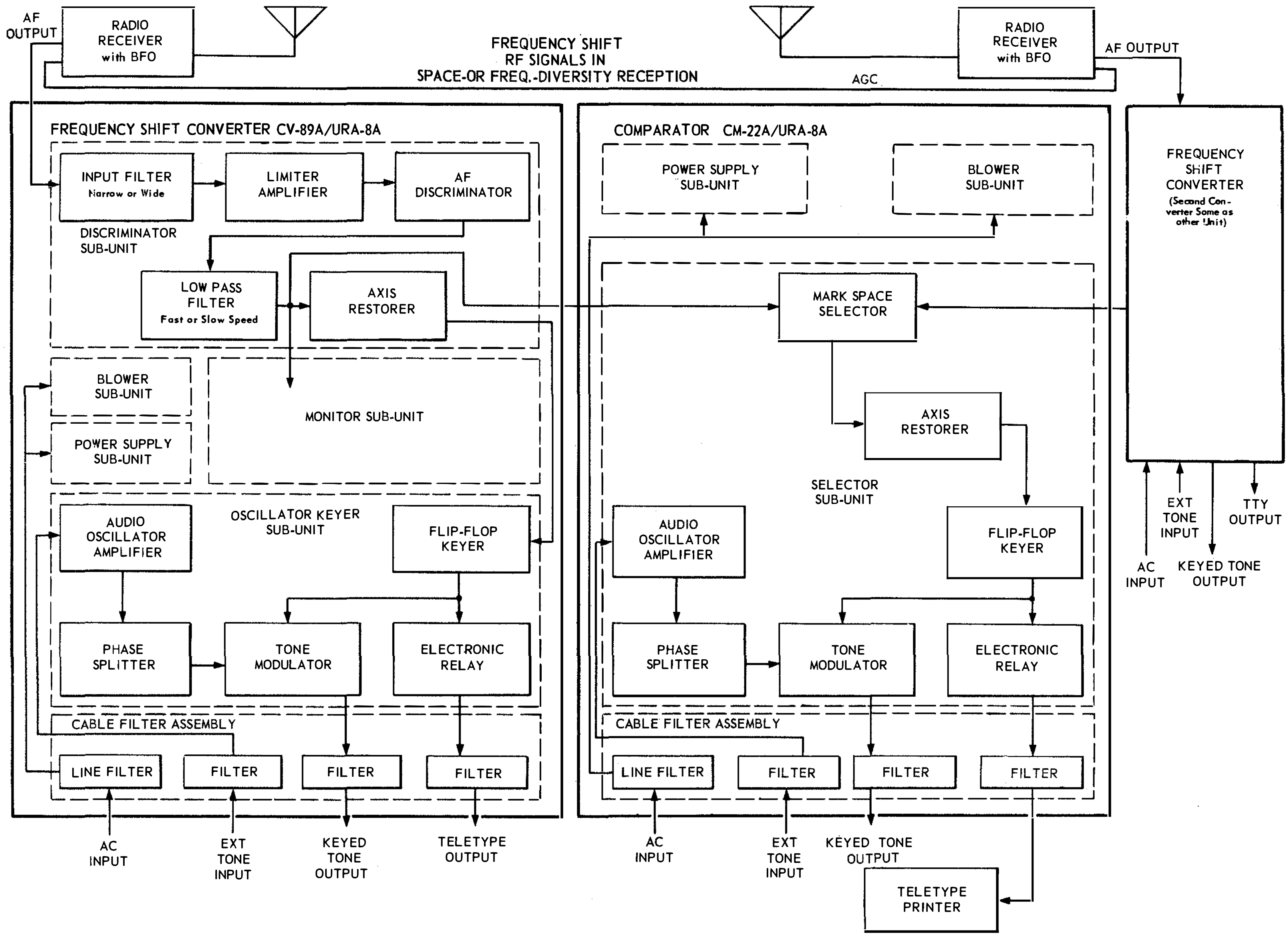

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Figure 10-9.—Frequency shift converter-comparator AN/URA-8B, block diagram.

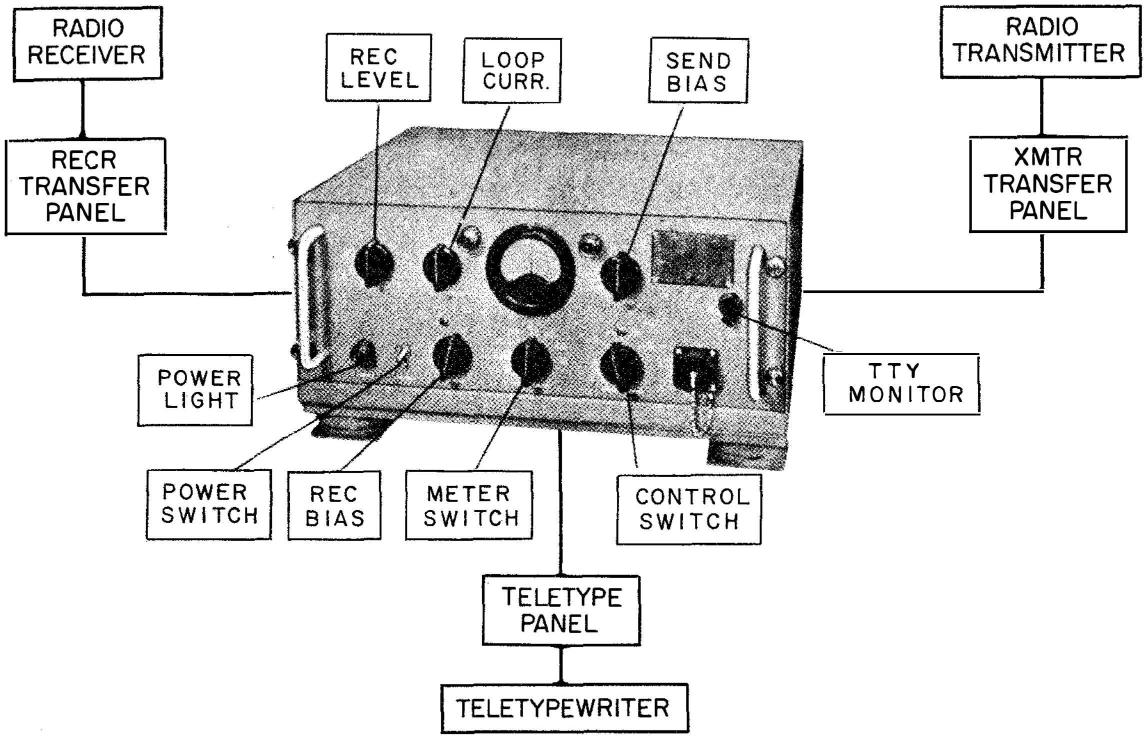

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Figure 10-10.—Tone shift keyer/converter AN/SGC-1A.

in the tone converter, which operates at 700 cycles when the teletypewriter loop is in a closed-circuit (marking) condition, and at 500 cycles when the loop is in an open-circuit (spacing) condition.

An internal relay closes a control line to the radio transmitter, which places the transmitter on the air when the operator begins typing his message. The control line remains closed until after the message is transmitted.

When receiving messages, the tone converter accepts mark and space tones from the radio receiver and converts the intelligence of the tones to make-and-break contacts of a relay connected in the local teletypewriter loop. This action causes the local teletypewriter to print in unison with mark and space signals from the distant teletypewriter.

RECEIVE CIRCUIT BLOCK DIAGRAM

All principal circuits of the AN/SGC-1A are shown in the system block diagram (fig. 10-11). The receive circuits are considered first in this discussion.

At the input of the receive circuit is the attenuator. It permits adjustment of the level of the incoming two-tone signal. A bandpass filter then passes audiofrequencies that fall between 400 and 800 cps, and rejects all other frequencies. After the filter is the amplifier-limiter stage.

The amplifier-limiter circuit provides a constant signal level to remaining circuits of the converter. Its output is coupled to the frequency discriminator filter, which provides separate circuits for selection of mark (700 cps) and space (500 cps) frequencies.

Two germanium rectifiers at the output of the frequency discriminator filter rectify and convert the respective frequencies to a corresponding d-c voltage. This voltage then serves as the input to individual d-c amplifiers. The amplifiers are connected so as to cause the receive relay to close its contacts when the incoming signal is 700 cps, and to open its contacts when the incoming signal is 500 cps.

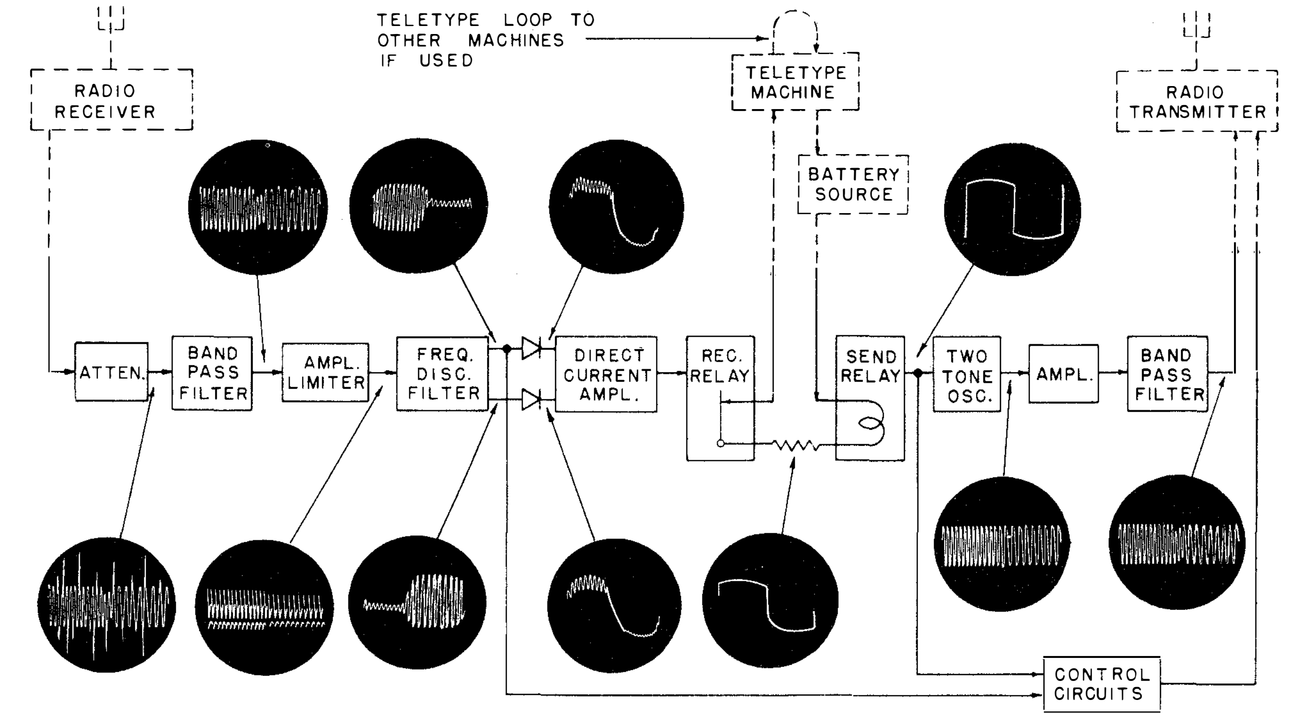

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Figure 10-11.—Tone terminal system, block diagram.

One set of contacts of the receive relay is placed in series with the local teletypewriter loop. Consequently, the receive relay is able to open and close the local teletypewriter loop, thus forming current pulses in the loop identical to those originated at the transmitter.

Because receive and send circuits of the tone converter are discussed separately, the remaining portion of the block diagram (fig. 10-11) is described later in this section. Reference to this diagram is made at the appropriate point in this discussion.

OPERATION OF RECEIVE CIRCUITS

The audio signals (fig. 10-12) of 500 and 700 cps, respectively, are coupled from the receiver (preferably through a 600-ohm line) to the tone converter input by T1. Receive level attenuator E1 allows a 20-step attenuation of 2 db per step, giving a possible maximum attenuation of 40 db for the stronger signals. The degree of attenuation is determined by the setting of the receive level control on the converter front panel (fig. 10-10).

A 6-db pad comprising R1, R2, and R3 provides additional attenuation, and minimizes the effects of mismatch if the output impedance of the associated receiver is not 600 ohms. The signal then passes through control switch S3 in the AUTO or REC STBY positions (contacts 8 and 9) to input filter Z1.

Frequencies from 400 to 800 cps are attenuated no more than 2 db by the input filter. Frequencies above or below this range are attenuated as much as 40 db. The Z1 output is applied to the T2 primary.

Amplifier-Limiter

The signal from the T2 secondary is applied through grid limiting resistor R4 to the first amplifier-limiter (V1A) control grid. Upon reception of weak signals, the stage functions as a conventional amplifier, applying its output through C3 and R10 to the second amplifier-limiter V1B. The signal subsequently is coupled (in the same manner) to V2A and V2B control grids. The operation of all stages is identical, except V2B, which is discussed later.

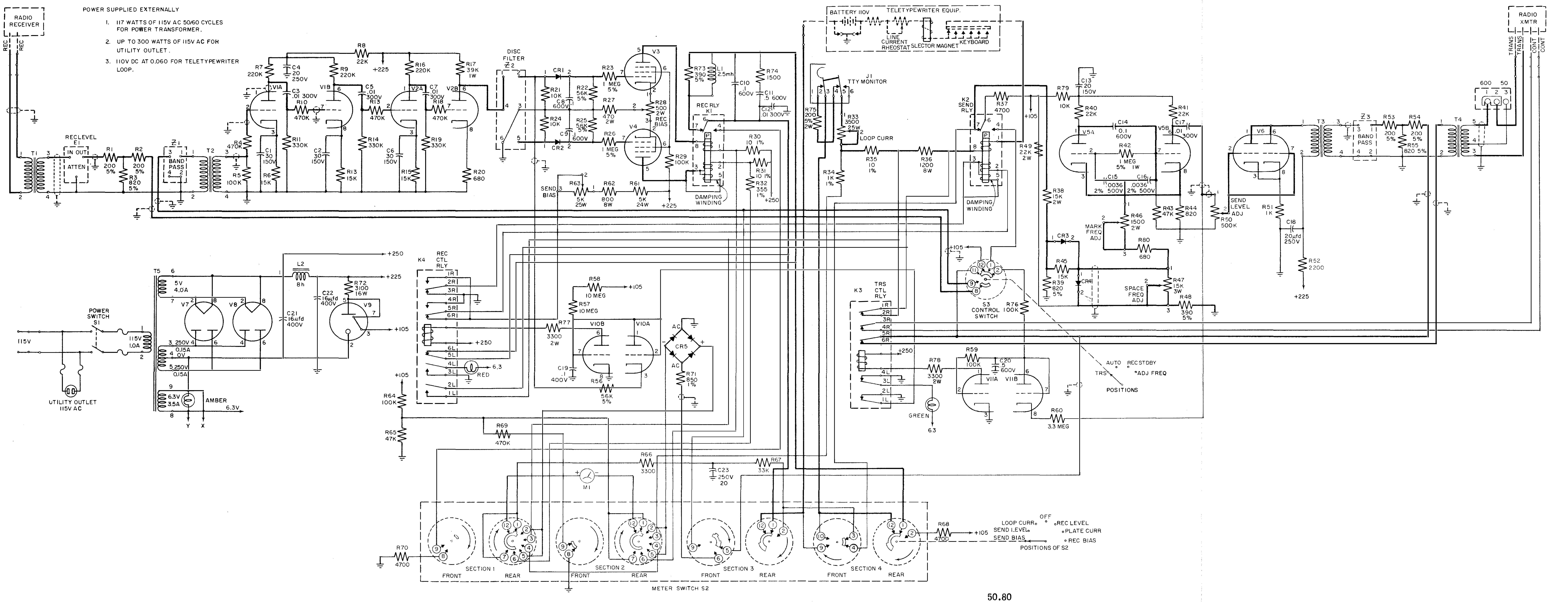

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Figure 10-12.—Tone terminal system, schematic diagram.

The plate load resistors of the respective stages (R7, R9, R16, and R17) are made large to facilitate grid limiting. On strong, positive peaks, grids of the tubes draw a current through their grid resistors (R4, R10, R13, and R18, respectively). The voltage drop developed across these resistors is such that the potential at the grid (negative) opposes the positive going input, and grid limiting occurs on this portion of the positive alteration. Strong negative input signals drive the grids to cut off, which limits the negative alternations. The cathode resistors are made large so that they operate the tubes in the midportion of their characteristic curves.

The fourth stage, V2B, utilizes different circuit constants in its plate and cathode to provide proper impedance matching for the discriminator filter circuit. To correct for possible discrepancies in positive and negative halves of the amplified (or limited) signal, degenerative action is accomplished across R20 in the V2B cathode.

Frequency Discriminator Filter Circuit

The frequency discriminator filter circuit Z2 consists of two complementary bandpass filters in one container. Terminals 1, 2, and 3 connect to the section that passes 700 cps and a narrow band of frequencies above and below that center frequency. Terminals 3, 4, and 5 connect to the section that passes a similar band centering on 500 cps. Terminals 3 and 6 are connected together and grounded.

The input terminals of the two sections (terminals 1 and 4) are tied together and connected to the plate of the last amplifier-limiter, V2B. The internal capacitors of the filters (not shown) eliminate the need of a coupling capacitor.

The two incoming signals from the receiver may be at different amplitude levels. However, the action of the amplifier-limiter causes signals to arrive at the discriminator filter circuit at a constant level. The output of the filter is either 500 or 700 cps with respect to the time of the mark and space signal input. The two frequencies do not appear at the filter output simultaneously. A small amount of leakage exists between the two filters, but not in sufficient amount to cause any appreciable harmful effect.

The mark tone, 700 cps, appears across terminating resistor R21, and the space tone, 500 cps, appears across R24. During the time the mark tone is applied across R21, germanium diode CR1 conducts to charge C8 (on positive half cycles) to approximately 15 volts. During negative half cycles of this input, C8 loses some of its charge through R22. Because discharge resistor R22 is about six times as large as the charging resistance of CR1, the majority of the accumulated charge is retained by C8 until the end of the mark tone. At this time C8 discharges to zero potential.

During the time the space tone is received, the signal charges C9 through CR2 and R24. Capacitor C9 likewise discharges on negative half cycles through R25. As a result of the discharge of C8 and C9 during mark and space intervals, d-c voltage developed across R22 and R25 is applied to individual control grids of V3 and V4.

D-C Amplifier

The cathodes of d-c amplifier pentodes V3 and V4 are connected to opposite ends of receive bias control R28. The arm of the control is connected to common cathode resistor R27 so that it, too, is common to both tubes. Bias control R28 tends to equalize the two cathode currents, as discussed later. The screen voltage of both tubes is maintained at the same value by action of R29, which tends to provide equal plate currents from V3 and V4.

Mark impulses through R23 to the grid of V3 cause plate current to increase from approximately 2 ma to 22 ma. Space impulses applied through R26 to the grid of V4 cause a similar increase in plate current of V4. The receive bias potentiometer R28 permits changing relative amplitude of these impulses by varying the magnitude of pentode plate currents.

When the receive bias control is rotated in one direction, it increases resistance in one cathode circuit while decreasing resistance in the other. This action causes cathode voltage of the first pentode to increase and causes cathode voltage of the second pentode to decrease. Because plate current of the pentodes is controlled by grid-to-cathode voltage, a change in cathode voltage by varying the receive bias potentiometer is effective in changing plate current of the two pentodes.

Receive Relay Circuit

Relay K1 is a polar relay containing a permanent magnet and three controlling coils.

The plate current of V3 and V4 is caused to pass through separate windings of the relay. The movable arm of K1 (contact 6) is operated under the influence of coils to contact 7 for a mark input from the d-c amplifier, and to contact 4 for the spacing signal.

Current from V3 passes through the K1 coil (pins 8 and 1) and meter shunt R30 to the B supply. The current through the 8 and 1 coil of K1 causes the arm of K1 (contact 6) to make with contact 7 during mark. This action completes the teletypewriter loop from contact 7 of K1, through the keying filter comprising R73 and L1, through contacts 1 and 12 of S2 (section 4 rear), through J1 contacts 3 and 2 and R75 (compensating resistor), through contacts 4 and 5 of J1 and the loop current adjust R33, through meter shunt R35 and 2 L and 1 L of receive control relay K4, through coil 8 and 1 of send relay K2 (fig. 10-12), through the local teletypewriter keyboard and selector magnet, through the line current rheostat and power supply, through contacts 12 and 1 of S2 rear (section 3), to return to contact 6 of relay K1, thus completing the loop. Note again that the received signal passes through both the receive and send relays (fig. 10-12).

The spacing current from V4 passes through coil 3 and 2 of K1 to move contact 6 of the relay to make with contact 4. In this condition, the teletypewriter loop is open.

Components L1, R73, C10, C11, R74, and C12 collectively form a spark suppression and waveshaping network. The network compensates for the inductive reaction peculiarity associated with some models of teletypewriters.

The third winding of receive relay K1 consists of only a few turns, which are shorted at socket connections. During the time that 8-1 and 3-2 coils produce collapsing fields, the shorted coil builds a field, which counteracts the changing flux. This action damps the coils to prevent possible oscillations. The damping permits high-speed keying without contact bounce.

Resistors R30 and R31 are used for measuring plate current of V3 and V4. The voltage developed across these resistors is proportional to the plate currents. It is applied to the meter M1 through R32 and S2 (contacts 6 and 12 of section 1 rear) when the meter switch is in plate current position.

Operation of Receive Bias Adjustment

All impulses from the teletypewriter keyboard, with the exception of the stopping impulse, should have the same duration. In the 7.42-unit transmission pattern, duration of the impulses in machines geared for 60 wpm is 22 ms for the starting space, 22 ms for each portion of the 5-coded characters, and 31 ms (42 percent longer) for the stopping mark. The teletypewriter code and the 7.42-unit transmission pattern are explained in detail in chapter 12.

In the process of converting intelligence from d-c pulses to tone, or any of the various methods used for communications, a distortion known as bias is often introduced. This distortion results in mark and space impulses being elongated or shortened with respect to their normal length. The length of time for a teletypewriter letter is fixed by mechanical gearing of the machine and cannot be altered or distorted. Individual mark impulses can be lengthened, however, and space impulses are shortened simultaneously, or vice versa. If marking impulses are longer than normal, the condition is known as marking bias. If spacing impulses are too long, the condition is known as spacing bias.

A teletypewriter can operate with a considerable amount of bias in its signal. Exactly how much bias it can stand without misprinting is determined, for example, by adjustment of its mechanism or the speed of its motor.

To compensate for bias, the receive bias control must be adjusted properly. As considered earlier, operation of this control caused plate current of V3 and V4 to vary accordingly. Figure 10-13, part A shows shape of the mark and space impulses when incoming tones are evenly spaced groups of 700-cps and 500-cps signals. For purpose of explanation, space impulses are shown upside down to indicate opposing action of the two plate currents upon the resultant flux in the receive relay. The ripples in waveforms result from the discharge of C8 and C9. They present no appreciable effect on operation of the relay.

The ripples show that the space tone starts as soon as the mark tone ends, and vice versa. The space-to-mark transition (S-M) closely follows the starting time of the mark tone. Likewise, the mark-to-space transition (M-S) closely follows the starting time of the space tone. These transitions take place immediately after the two plate currents of V3 and V4 are equal.

Figure 10-13, part B shows the effect when one plate current, V3, is increased and the other plate current, V4, is decreased by operation of the receive bias control. The ripples show that timing of incoming tones is unchanged. The S-M and the M-S transitions still take place when the two plate currents are equal, but it should be noted that relative spacing on the timing axis has changed. Because of increase in time from the S-M to the M-S transition, the relay armature would be operated to, and held against, the mark contact longer than normal, and the d-c signals to the teletypewriter would have marking bias. Rotation of the receive bias control in the opposite direction would cause these conditions to change conversely, and signals to the teletypewriter would have spacing bias.

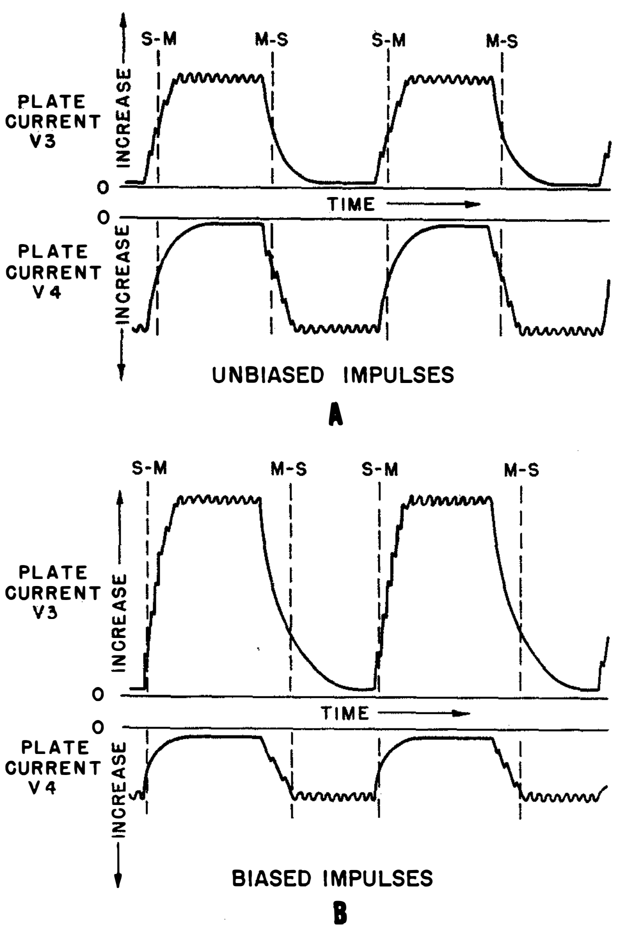

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Figure 10-13.—Biased and unbiased teletypewriter impulses.

Under actual conditions, it would be undesirable to introduce either marking or spacing bias. This explanation is intended only to illustrate how the receive bias control can compensate for a bias distortion introduced into the signal either internally or externally. Where timing of tone groups is distorted, or amplitude of the rectified mark and space impulses is incorrect, the receive bias control usually permits sufficient compensation to correct the signal.

TRANSMIT CIRCUIT BLOCK DIAGRAM

The send relay circuit (fig. 10-11) energizes transmit circuits when a message is to be transmitted. In the receive condition, the send relay is deactivated.

A single two-tone oscillator (multivibrator) provides the two tones of 500 and 700 cycles. A mark and space signal is represented at the oscillator output in the diagram.

Signals from the two-tone oscillator are amplified and applied through a bandpass filter to the associated transmitter. The filter passes frequencies from 400 to 800 cps with little attenuation. Frequencies outside the filter range receive a correspondingly greater amount of attenuation with an increase in frequency on either side of the bandpass of the filter.

Signals from the frequency discriminator filter and the two-tone oscillator are applied to control circuits, which include a transmit and receive control relay and their associated amplifier tubes (discussed later). These control circuits exert a direct influence on transmit and receive circuits to provide the automatic switching action of the tone terminal.

OPERATION OF TRANSMIT CIRCUITS

For the following explanation of transmit circuits of the AN/SGC-1A teletypewriter terminal, refer to the schematic diagram, figure 10-12.

Send Relay Circuit

The send relay K2 (fig. 10-12) is also a polar type relay with three coils. The current in the 8-1 winding (connected in the teletypewriter loop) is 60 ma in mark condition and 0 ma in space condition. In standby condition (neither receiving nor transmitting) current in the 8-1 winding is reduced to 36 ma. Though this action is described in detail later, note that R36 (in series with the teletypewriter loop) causes current to rise or fall from 60 to 36 ma, as determined by the shorted or open condition of the 1R-2R contacts of K3.

A current flowing through the 3-2 winding and voltage dividers R63, R62, and R61 is steady at 30 ma. The send bias control R63 provides a method of adjusting this bias between 20 and 40 ma. The second winding (3-2) is hereafter referred to as the space winding.

In standby condition, the 30-ma current in the space winding (3-2) produces a magnetic flux that is weaker and made opposite to flux produced by the 36-ma closed teletypewriter loop current in the 8-1 winding. The resultant flux holds the send relay armature (6) against the mark contact (7). The third winding produces a damping action in the same manner as presented in the discussion of receive relay K1.

Although the preceding discussion is relative to the standby condition, the same action of the coils is repeated during the marking condition, except that loop current is increased to 60 ma. For space, teletypewriter loop current drops to 0, and unopposed flux produced by the space winding (30 ma) moves the relay armature (6) to the space contact (4). When a message is typed, loop current is changed rapidly and repeatedly from 0 to 60 ma and back to 0 again. The resultant flux is reversed continually, and the relay armature is switched continually from mark (pin 7) to space (pin 4) and back again. In the receive condition, the 30-ma current in the space winding is reversed by action of receive control relay K4, which operates to make 4R-5R and 2R-1R contacts. Thus, flux of the space winding is reversed so that it now aids the flux produced by teletypewriter loop current. Regardless of loop current, therefore, resultant flux of the send relay is always in the same direction. The reversal of the space winding current constitutes the interlocking feature that prevents the send relay from operating when receiving a message.

Receive Control Relay

Twin triode V10 (fig. 10-12) has one of its sections, V10A, connected as a diode. One end of the receive control relay is tied to the 250-volt B supply, and the other end is connected through current limiting resistor R77 to the plate (pin 6) of the V10B triode. The relay is energized when plate current flows. The plate current is controlled by bias voltage on grid 7 of V10B. In general, two factors determine the bias applied at this grid. The grounded or ungrounded condition of the transmit control relay (contact 1L and 2L) is the first determining factor, and the presence or absence of an incoming signal at the V10A cathode is the second.

In standby, no signal is received, and the transmit control relay (contacts 1L and 2L) connected to the grid of the triode is open. Under these conditions, C19 assumes a positive charge from the +105-volt supply. In the voltage divider comprising R58, R57, and the grid-to-cathode resistance of V10B, the resistors assume more than 99 percent of the voltage drop. This drop limits cathode-to-grid positive voltage to less than 1 volt. With this grid potential, V10B conducts heavily through R77 and the solenoid of K4 to operate its contacts.

Now, suppose that the receive circuit begins to receive a signal. The mark frequency taken from the frequency discriminator filter output is applied through R56 to the V10A cathode. Negative half cycles of the input cause V10A to conduct. The circuit containing R56, V10A, and C19 forms a much shorter time constant (when V10A conducts) to charge C19 negative than does the circuit comprising C19, R57, and R58, which tries to charge C19 positive. As a result, higher current in the lower time constant circuit (when V10A conducts) charges C19 negative with respect to ground. The charge is cumulative on alternate half cycles of the signal until C19 assumes a sufficient charge to cut off V10B. This action deenergizes K4 to place it in receive condition. A short time after the last mark cycle (ending the receive condition), C19 completely discharges and assumes a positive charge. Tube section V10B again conducts to energize receive control relay K4. The time of discharge of C19 is determined by the time constant of C19, R57, and R58. This circuit forms a long time constant discharge path.

In the transmit condition the transmit control relay K3 is energized. (This topic is discussed later.) Energized K3 shorts the grid-to-ground potential developed by C19. The cathode and grid of V10B are therefore at ground potential, allowing plate current to flow through the K4 solenoid. Thus, the receive control relay is energized during transmission. Because transmit control relay K3 keeps both ends of C19 at ground potential, any incoming signal from the frequency discriminator filter cannot charge C19 in an attempt to deenergize the receive control relay.

Only in the receive condition will contacts 1R-2R and 4R-5R of K4 be closed. The 1L-2L contacts of transmit control relay K3 are open at this time. This action causes the send relay space winding current to be reversed. Thus, contacts 7 and 6 of send relay K2 are constantly held closed throughout the receive condition. Note that receive control relay K4 is always energized except when the terminal is in the receive condition.

Contacts 5L and 6L of K4 are closed during transmit and standby (as shown), shorting pins 6 and 7 of receive relay K1, so that the teletypewriter loop is closed at this point. Contacts 3L and 4L supply 6.3 volts to the receive indicator lamp when in the receive condition. Contacts 1L and 2L short R36 (in the teletypewriter loop) in the receive condition, allowing the loop current to rise from 36 to 60 ma through the K1 solenoid during mark.

Transmit Control Relay

Twin triode V11 (fig. 10-12) functions in much the same manner as V10 to control action of the transmit control relay K3. Plate current passes through the K3 solenoid when V11A is conducting. The grid bias of V11B is determined by the position of control switch S3 and send relay K2.

The cathode of the diode section of V11B is connected through R60 to the output of audio oscillator V5. The oscillator functions continuously upon application of B supply voltage, and a continuous audio voltage is applied to the V11B diode.

In the transmit position of control switch S3 (as shown), mark and space signals in the teletypewriter loop pass through the solenoid of send relay K2. A positive 105 volts from voltage regulator V9 charges C20 positive with respect to ground through R76 and S3 contacts. The positive potential of C20 is applied to the control grid (pin 2) of V11A, allowing the tube to pass an energizing current through the solenoid of K3.

The 1R-2R contacts of K3 short R36 in the teletypewriter loop to allow the 60-ma mark current. Contacts 3R and 4R close the control line to the transmitter during transmit condition, which places the transmitter on the air. Contacts 5R and 6R close the output circuit during transmit condition so that outgoing signal tones may be applied across the T4 primary.

The 3L-4L contacts complete the circuit to the transmit indicator lamp, and contacts 1L-2L ground the grid of V10B, which causes it to operate the receive control relay.

With control switch S3 in automatic position, an incoming signal causes the terminal to change from standby condition to receive. Keying the local teletypewriter causes the terminal to change from standby condition to transmit.

In standby and receive condition, send relay K2 connects its armature (6) to the mark contact (7) so that the space contact (4) is open. In this condition, the only voltage applied to the V11B diode is the oscillator a-c voltage. On negative half cycles of this input, V11B conducts to charge C20 negative with respect to ground. This negative voltage is applied through grid limiting resistor R59 to the V11A grid. This section of the tube cuts off, thus preventing the flow of plate current through the solenoid of K3. This relay is therefore deenergized during standby and receive conditions.

Because K3 is not energized, contacts 1L and 2L are open. The incoming signal at the V10A cathode cuts off V10B and deenergizes receive control relay K4. Thus, contacts 4R and 5R complete the space winding circuit of K2 so that its current is reversed, and the armature of the send relay is held in mark or receive condition.

When a message is typed locally (S3 in automatic), the armature of the send relay intermittently applies positive 105 volts to the space contact (4). This voltage charges C20 through R76 and contacts 1 and 2 of S3. The positive voltage thus developed across C20 is applied through R59 to the V11A triode, and K3 is energized. Contacts 1L and 2L of K3 are now closed, and V10B conducts to energize K4. The current through the send relay changes back to its original direction because the 1R-2R contacts of K4 are closed again. This action allows the armature to move between pins 7 and 4 under the influence of the teletypewriter characters.

In the adjust frequency position of control switch S3, all contacts are open except contacts 9 and 11. These two contacts connect the output circuit of the terminal to the input so that mark and space tones produced by the oscillator are fed into the receive circuit. The receive circuit separates mark and space tones and applies rectified signals to the d-c amplifier in the manner discussed. When each tone is at its correct frequency, it receives a minimum of attenuation in passing through the discriminator input filter. When the signal is rectified, therefore, it produces a maximum voltage at its corresponding frequency. With maximum voltage applied to the d-c amplifier, the circuit produces a maximum of plate current. With the circuit connected in this manner, mark and space frequency adjust controls can be set for optimum operation.

Two-Tone Oscillator

The circuit of V5 is designed to produce 700- and 500-cps mark and space frequencies used to modulate the frequency of the associated r-f transmitter. Both mark and space frequency adjust controls are provided to exact the respective frequencies.

Disregarding the circuit comprising R42, C15, and C16, and completing the V5A grid circuit, the oscillator can be described as a conventional cathode-coupled multivibrator. If we assume V5A to be conducting, C14 discharges through R43 the common cathode resistor R44 and the conducting resistance of V5A, to return to C14. The negative voltage across R43 toward the V5B grid cuts off this section of the tube until after the complete discharge of C14. At this time, with plate voltage of V5B at the B supply value and zero voltage across R43, V5B begins slight conduction.

Because conduction of V5A has developed a large fixed bias voltage across R44, current through R41 is small at the beginning of V5B conduction. However, the small conduction of V5B is sufficient to raise the R44 bias voltage, which, in turn, moves the operating point of V5A down on its characteristic curve. The rise in plate voltage of V5A charges C14 through R43, aiding the V5B conduction. The latter tube section then moves almost instantaneously up its characteristic curve to the saturation point. The circuit remains in this condition until a positive trigger pulse is applied to the V5A grid.

The null network comprising R42, C15, and C16 couples all but one of the harmonic frequencies from the V5A plate through C14 to the V5A grid. In effect, the circuit cancels one frequency or presents a null to the V5A grid at this frequency.

All frequencies passed by the network appear at the grid, and the same signal simultaneously appear at the cathode as a result of plate current flow. Signals applied to the grid and cathode at the same time and 180° out of phase do not affect plate current of the tube. These frequencies are therefore degenerated. Because null frequency is applied only at the cathode (caused by plate current through R44), it has effect on plate current. The null signal voltage across R44 acts as the trigger input for V5A. Grid leak components C14 and R43 have very little effect on the frequency of the oscillator.

Send relay K2 changes oscillator frequency by shorting R47 in the following manner. A potential of approximately 2 volts positive is developed across R48 as a result of a current flow through R48 and R40 to the +105-volt supply. This action establishes a +2-volt potential at the bottom end of diode CR4. When K2 is in mark condition (contact 7), another current flows from ground through R39, R38, send relay contacts (7 and 6) and R37, to the +105-volt supply. Approximately +4 volts is developed across R39 and is applied to the arrow of CR3. The two diodes, CR3 and CR4, therefore conduct during mark condition to short R47. Thus, null network resistance is decreased, and oscillator frequency rises to 700 cps. With R46, R80, and R48 in the circuit, mark frequency can be adjusted to exactly 700 cps by mark frequency adjust control R46.

During space condition, armature 6 of K2 is disconnected from the +105 volts at its contact 7. The two diodes (CR3 and CR4) do not conduct as a result of the +2 volts still applied to the bottom end of CR4. In effect, then, the diodes are not in the circuit, and the full resistance of R47 is placed again in the null network circuit. Likewise, oscillator frequency decreases to 500 cps. The proper setting of space frequency adjust R47 at this time corrects the space frequency output.

Tone Amplifier

Mark and space tones from the oscillator at the V5B plate are coupled by C17 to tone amplifier V6. (Refer to fig. 10-12.) This amplifier comprises a single-stage twin triode with the two sections of the triode parallel-connected to provide low plate resistance. The input level of the tones is adjustable by means of send level potentiometer R50 in the grid circuit. Resistor R52 and capacitor C18 decouple the plate of V6 from the B supply. Degeneration, because of unbypassed cathode resistor R51, aids in maintaining the two frequencies at approximately the same level. The amplified tones are coupled to the output circuit through plate transformer T3.

Output Curcuit

The signal at the T3 secondary (fig. 10-12) is applied to bandpass filter Z3. The filter passes frequencies from 400 to 800 cps with an attenuation no greater than 2 db. Frequencies outside this range receive greater amounts of attenuation, depending on its harmonic frequency.

The filter output is applied to a 6-db pad comprising R53, R54, and R55. This circuit is identical to the 6-db input pad, and functions to minimize effects of a possible mismatch between the terminal and radio transmitter.

Before the signal can reach impedance matching transformer T4, it must pass through the 5R-6R contacts of transmit control relay K3. These contacts are closed when a message is transmitted. The secondary of T4 is tapped for matching to either a 600- or 50-ohm output impedance.

METERING CIRCUITS

Meter M1 is a d-c (zero center) milliammeter requiring a current of 1 ma for full-scale deflection. The 100-0-100 and -10 to +5 dbm scales are shown on the meter. The meter is switched into the circuit by meter switch S2 (fig. 10-12).

In the send bias position of S2, send bias control R63 may be adjusted so that the meter reads zero, indicating proper length of mark and space tones being transmitted. Switch contacts 8 and 9 of S2 (section 2 front) are closed in the send bias position to parallel R69 and R65. This connection places a positive potential (of a predetermined value) at the negative side of meter M1. The positive side of the meter is connected through a current limiting resistor R66 and a filter section comprising C23 and R67. The filter section is connected to the mark contact (pin 7) on send relay K2.

The third impulse of a spacing signal represents a current in the loop. The first, second, fourth, and fifth impulses are no-current signals. If the space bar on the teletypewriter keyboard is held down, the send relay armature moves back and forth between its mark and space contacts. A positive 105 volts is applied to the mark contact (7) from the B supply when the armature is in mark condition. This positive voltage is applied to the metering circuit. When the armature is on the space contact (4), positive voltage is not applied to the metering circuit.

On mark impulses, C23 acquires a charge from ground through R67 and R37. During spacing impulses, C23 may discharge through R65 and R69 (in parallel), through the meter, and R66 to the positive side of C23. Because of fast movement of the send relay armature, voltage on C23 stabilizes at a value that depends on relative length of the mark and space impulses. If the space impulse is too long, voltage on C23 has more time to leak off, and voltage applied to the meter from C23 is low. Conversely, if the space impulse is too short, voltage applied to the meter is too high. The result is that when mark and space impulses are of proper relative length, the C23 voltage and the positive voltage applied to the negative side of the meter are the same. In this condition, the meter reading will be zero.

In the send level position of S2 (one clockwise rotation of all sections), send level potentiometer R50 may be adjusted so that the meter indicates the proper level of the signals fed to the transmitter. Potentiometer R50 controls the level of the signal applied to tone amplifier V6.

With S2 in the send level position, the output of bandpass filter Z3 (passing through the output 6-db pad) is applied through section 3 front of S2 (contacts 5 and 6) through R71 to a bridge rectifier CR5. The rectifier changes the signal to d-c pulses, which are applied through section 2 rear of S2 (contacts 2 and 12) to meter M1. The circuit path is completed through contacts 12 and 2 of section 1 rear, bridge circuit CR5, and ground, to return to the filter Z3.

The loop current position of S2 switches the proper components for metering and adjusting loop current. With the switch in this position, the R34-R35 junction is connected by S2 to the negative side of M1 through contacts 3 and 12 of section 2 rear. Section 1 rear (contacts 12 and 3) connects the positive side of M1 to the R35-R36 junction. In this manner, the meter and multiplier resistor R34 are placed across R35.

The voltage developed by R35 is proportional to the current flowing in the teletypewriter loop circuit. Loop current rheostat R33 now can be adjusted so that the meter reads 60 on its upper scale when the terminal is in transmit condition.

In the off position of S2, contacts 4 and 12 of section 2 rear and contacts 4 and 12 of section 1 rear short meter M1. If vibration causes the meter pointer to move, the meter coil develops a back voltage, which dampens its movement.

The receive level position of S2 connects a circuit similar to that already discussed for the send level position. In this position, the output of the receive level attenuator (passing through the input 6-db pad) is applied from R2 to contact 9 of section 3 front. Because contacts 9 and 6 are shorted in this position, the input signal is passed from contact 3, through a section of the bridge rectifier CR5, contacts 5 and 12 of section 2 rear, to the negative side of M1. Direct current (rectified by CR5) leaves the positive side of the meter and passes through contacts 12 and 5, another section of CR5 to ground, to return to E1. In this condition, the receive level attenuator may be adjusted until the meter reads 0 dbm.

In the plate current position of S2, switch contacts 12 and 6 of section 2 rear and 12 and 6 of section 1 rear connect meter M1 across d-c amplifier metering resistors R30 and R31. The current through these resistors is in opposite directions, so the voltage applied to the meter is equal to the difference of the potentials across R30 and R31.

In effect, the meter reads the differential plate current. The differential current for mark signals causes the meter to read to the right, and space signals cause a deflection to the left. The current reading of the meter represents the current effective in producing magnetic flux in the receive relay.

The meter connection in the receive bias position is similar to that already discussed for the send bias position. Resistor R65 again applies a positive potential to the negative terminal of M1. Resistor R65 is not paralleled by R69 as in the send bias position of S2. The positive terminal of the meter connects through contacts 12 and 7 of section 1 rear, through R66 to C23. Resistor R67 is now connected through contacts 1 and 2 of section 3 rear to the armature 6 of receive relay K1. When the armature is in the mark position, a positive voltage from the +105-volt supply charges C23 through R67, R73, contacts 1 and 2 of section 4 rear, and R68. When the receive bias control is adjusted properly, the positive potential on both sides of the meter will be equal, permitting it to indicate a zero reading.

MULTIPLEX SYSTEMS

The number of communication networks in operation per unit of time throughout any given area is increasing constantly. In the past, each network was required to operate on a different frequency. As a result, all areas of the radiofrequency spectrum have become highly congested.

The maximum permissible number of intelligible transmissions taking place in the radio spectrum per unit of time can be increased through the use of multiplexing. The primary purpose of a multiplex system is to increase the message-handling capacity of teletypewriter channels and transmitters and receivers associated with them. This increased capacity is accomplished by simultaneous transmission of several messages over a common channel.

Multiplexing can be accomplished by either of two methods. Frequency division multiplexing, for example, employs a number of tone channels slightly displaced in frequency. Each tone channel carries signals from a separate teletypewriter circuit and modulates a common carrier frequency. Time division multiplexing, on the other hand, divides the time duration of a standard start-stop signal into a number of equal intervals and allots each interval to a separate teletypewriter circuit. Thus, start-stop signals are, in effect, compressed in time for transmission. Receiving equipment at a distant station accepts multiplex signals, converts them to start-stop signals (in effect, expands them in time), and distributes them in proper order to a corresponding number of circuits.

TRANSISTOR MULTIPLEX SET AN/UGC-1

Model AN/UGC-1 transistor multiplex set consists of three function equipment groups: transmitting group, receiving group, and power supply group. They are illustrated, top to bottom, in figure 10-14.

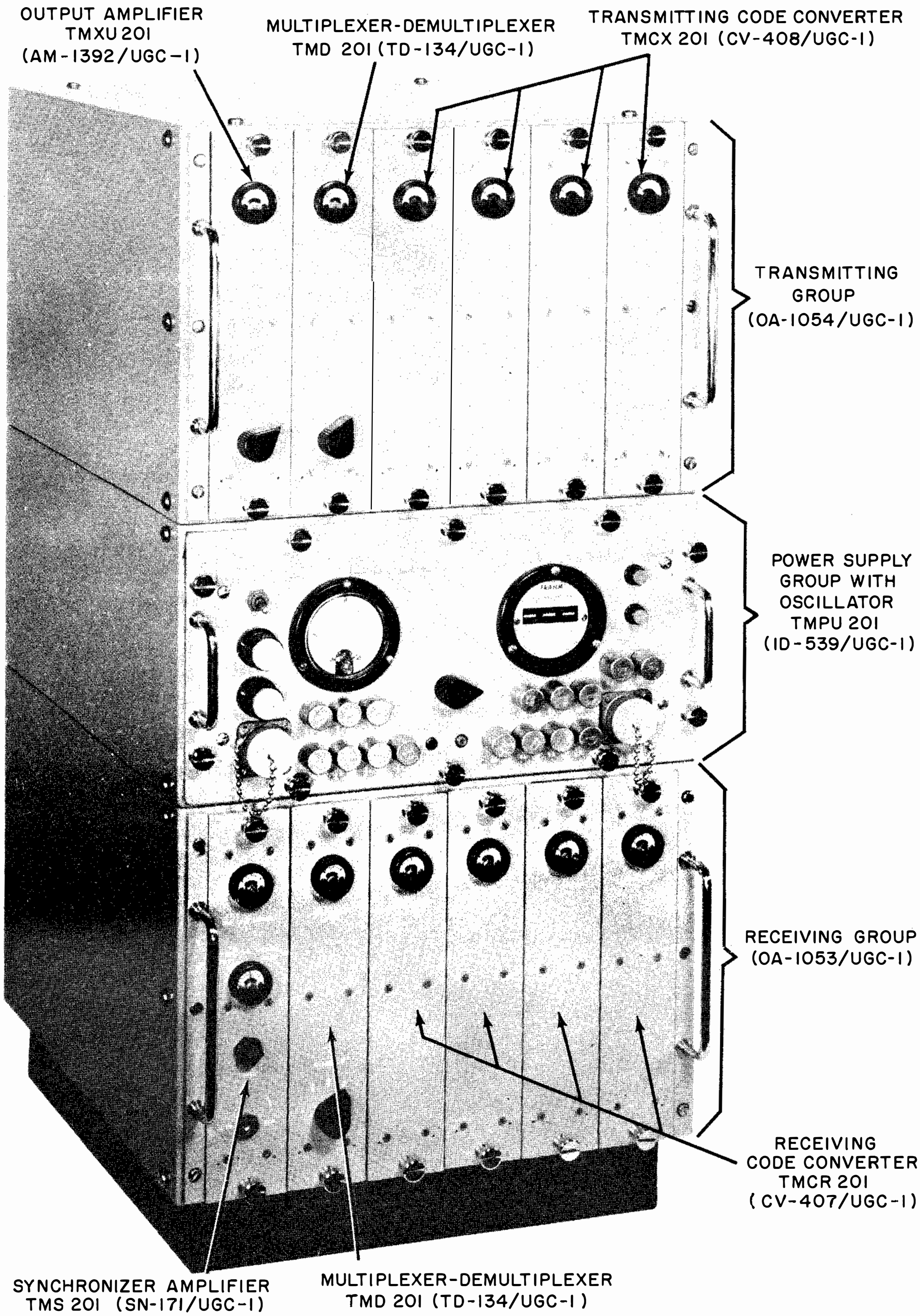

Figure 10-14.—Transistor multiplex set AN/UGC-1.

The transmitting group accepts teletypewriter signals from two, three, or four separate circuits and assembles them in sequential order for multiplex transmission over a single radio circuit.

The receiving group accepts multiplex signals from the distant station, converts them to start-stop form, and distributes them to two, three, or four separate teletypewriter circuits.

The power supply group provides necessary voltages and a frequency standard for both the transmitting and receiving groups.

Overall Operation

A schematic representation of a multiplex send-receive installation is shown in figure 10-15. The frequency shift transmitter, keyer, radio receiver, demodulator (converter), patch panels, and teletypewriter equipments are included to show the complete send-receive system.

At the send side of the multiplex station, four teletypewriter tape transmitters simultaneously send four messages to respective transmitting code converters (identified in fig. 10-14) in the transmitting group. The code converters translate these signals, which are in sequential form, into 6-wire parallel form. The start and stop elements of the signals are discarded, and a sixth element is added. The multiplexer-demultiplexer unit of the transmitting group sweeps over outputs of code converters, channel by channel, and picks up, in turn, a complete signal character from each converter. By varying the pulse-division ratio, equipment can be switched to operate with two, three, or four teletypewriter circuits (designated channels A, B, C, and D in figure 10-15). The teletypewriter equipment can be operating at speeds of 60, 75, or 100 wpm, but speed must be the same for each channel. The output of the transmitting group is fed through the patch panel and keyed to the radio transmitter, where the frequency-shifted multiplex signals is placed on the air.

At the receiving station, the multiplex signals from the radio receiver are patched to the synchronizer-amplifier in the receiving group of the AN/UGC-1. This unit amplifies the signals and sends inverted and normal versions to the multiplexer-demultiplexer. The latter unit performs functions complementary to multiplexing in the transmitting group. It separates multiplex signals into 6-wire parallel signals and, as it sweeps over the input wiring of receiving code converters, it applies, channel by channel, proper signals to proper converters. The sixth pulse of the parallel signals, which is used only to recognize the presence of bona fide blank transmission, is dropped. The start and stop elements are added, and d-c teletypewriter code signals are sent at the proper speed to the four receiving teletypewriters.

TRANSISTOR MULTIPLEX SET AN/UCC-1

The AN/UCC-1 transistor multiplex set is a modular terminal for frequency shift carrier telegraph communication. It employs a frequency division multiplex system over single sideband radio circuits, voice frequency wirelines, microwave circuits, or other transmission systems. Within the nominal frequency band of 300 to 3300 cps, the equipment provides a total of 16 narrowband channels, or 8 narrowband and 4 wideband channels. For space diversity operation, 16 transmitter channels and 32 receiver channels are available. A multiplexer-demultiplexer furnishes translation of a composite signal between the 300 to 3300-cps band and the nominal frequency band of 3300 to 6300 cps, so that 32 narrowband channels or 16 narrowband and 9 wideband channels are available for communication over a 6-kc single sideband radio circuit. The terminal is all solid state design, with plug-in modules. (See figs. 10-16 and 10-17.)

Functional Description

Functions that can be performed by the AN/UCC-1 telegraph terminal are shown in figure 10-18. The terminal provides up to 16 different narrowband voice frequency tone channels, each passing a different band of frequencies. (See table 10-1.)

Associated with each channel is an oscillator, which, keyed by a telegraph loop, generates one frequency representing a mark and another representing a space (frequency shift keying). These two frequencies are symmetrical with respect to the center of the channel passband. The output from any set of different channels can be combined on a single line for transmission over a single 3-kc bandwidth communication link.

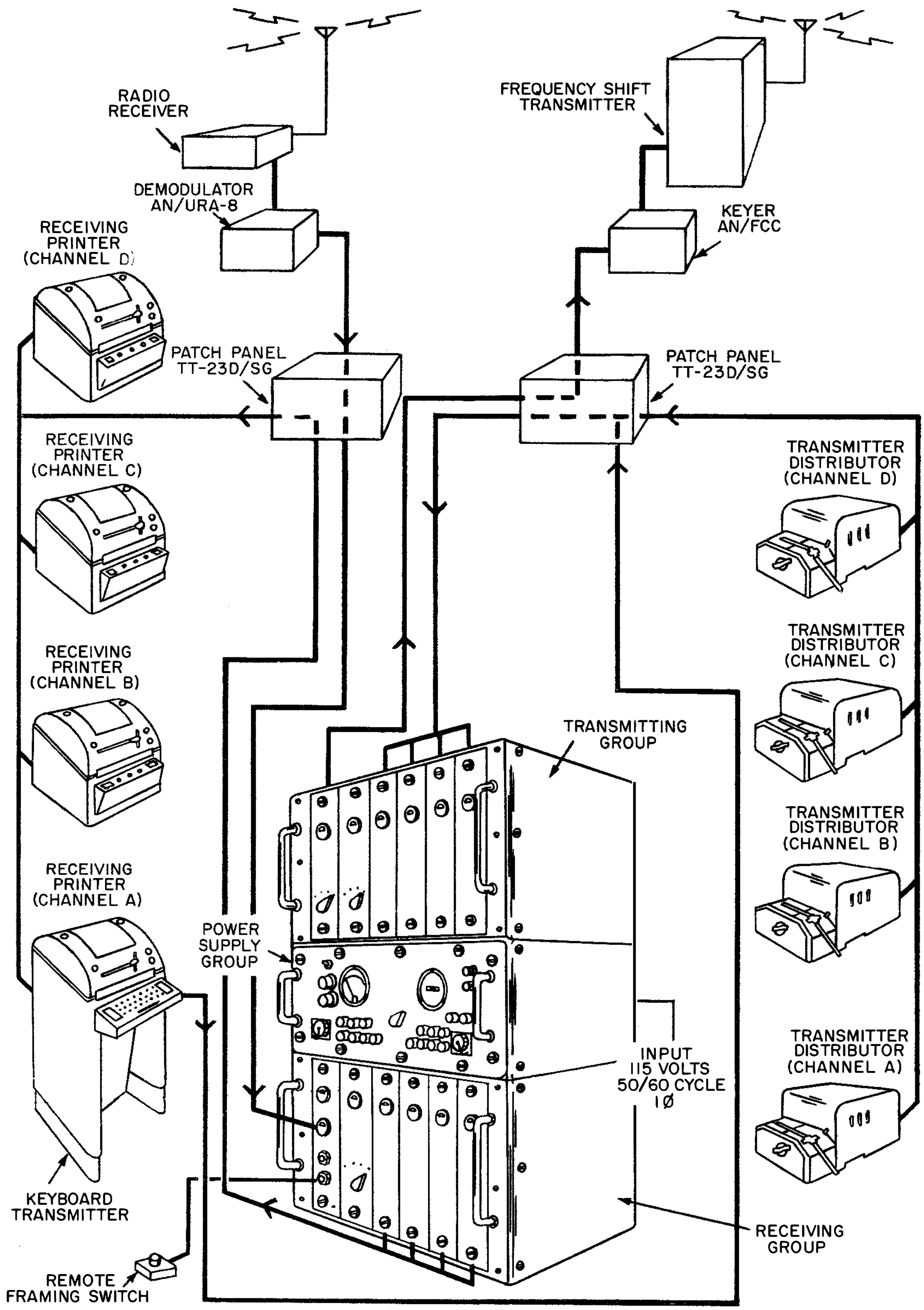

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Figure 10-15.—Typical multiplex send-receive station.

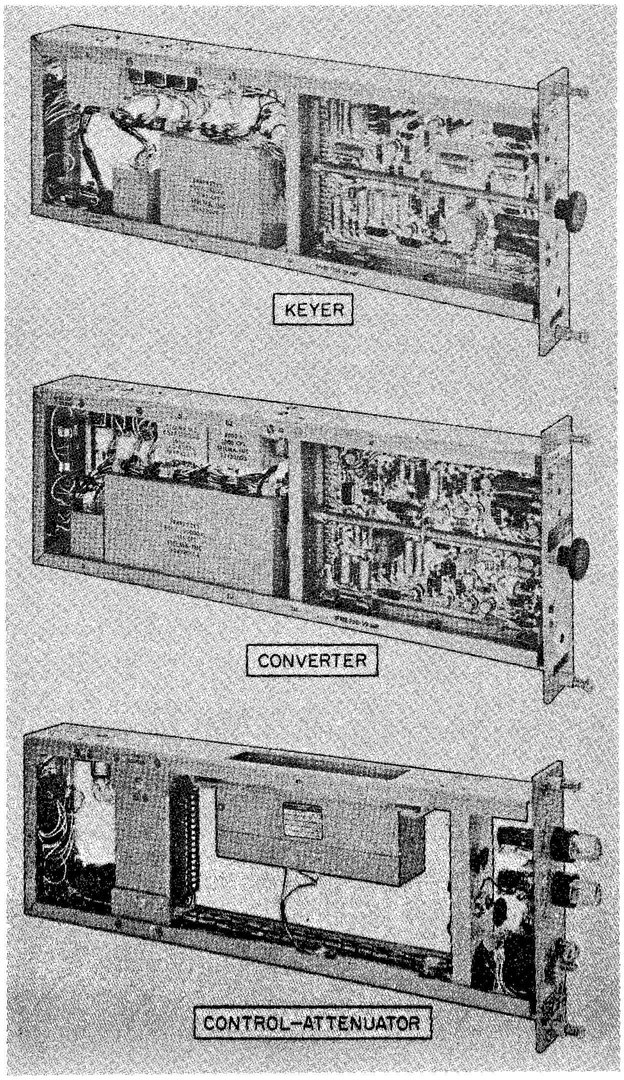

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Figure 10-16.—Keyer frequency shift KY-490(P)/UCC-1(V); converter frequency shift CV-1522(P)/UCC-1(V); and control-attenuator C-4702/UCC-1(V).

Two 3-kc bandwidth voice frequency signals can be accommodated by the telegraph terminal for transmission over a single 6-kc bandwidth communication link. These two 3-kc signals may contain 16 telegraph tone channels in each 3-kc bandwidth (total of 32) or 16 telegraph tone channels in one 3-kc signal and speech in the other 3-kc signal.

Each frequency shift keyer provides one channel that accepts d-c telegraph signals from an external loop, supplying the appropriate voice frequency mark-space frequency shift output signal. Each frequency shift converter has one channel that accepts a particular frequency shift voice frequency signal, and produces an electronic keying signal for operation of a d-c telegraph loop.

For 32-channel operation, the multiplexer unit shifts the composite output of one set of 16 narrowband channels from the 375- to 3025-cps band to a 3265- to 5915-cps band, combining the shifted output with the unshifted output of the second set of 16 channels for transmission over a 6-kc bandwidth communication link.

At the other end of the link the demultiplexer returns the shifted signal to the original band, placing it on a separate output line from the unshifted signal. Each channel accepts one voice frequency signal, which it converts into an electronic keying signal for a receiving telegraph loop.

When the telegraph terminal is used in a 3-kc bandwidth communication link, no multiplexer-demultiplexer units are required. The reason is because the AN/UCC-1(V) channels occupy separate frequencies in the audio spectrum. (No two channels occupy the same spectrum.)

Converter Diversity Combinations

Two factors determine converter diversity connections: switch settings on individual converters, and cabinet positions (stations) occupied by the converters. Cabinet wiring for the first four stations is identical to that for the last four stations, hence figure 10-19 illustrates only one four-station group. Each channel, regardless of the station into which it is plugged, can be connected to an associated individual input transformer or to either one of two composite input line transformers (designated as RCV A and RCV B). The two composite input lines are used in the frequency diversity/space diversity system. In this system, two converter modules are assigned to each channel. One group of four converters (for the eight channels) processes signals from radio receiver A, which appears on the RCV A input line. The other group of four converters processes signals from radio receiver B, on the RCV B input line. With the tone input switches set as shown, the converters in stations A1 and A3 are connected to parallel A, and those in stations A2 and A4 are connected to parallel B. Converters

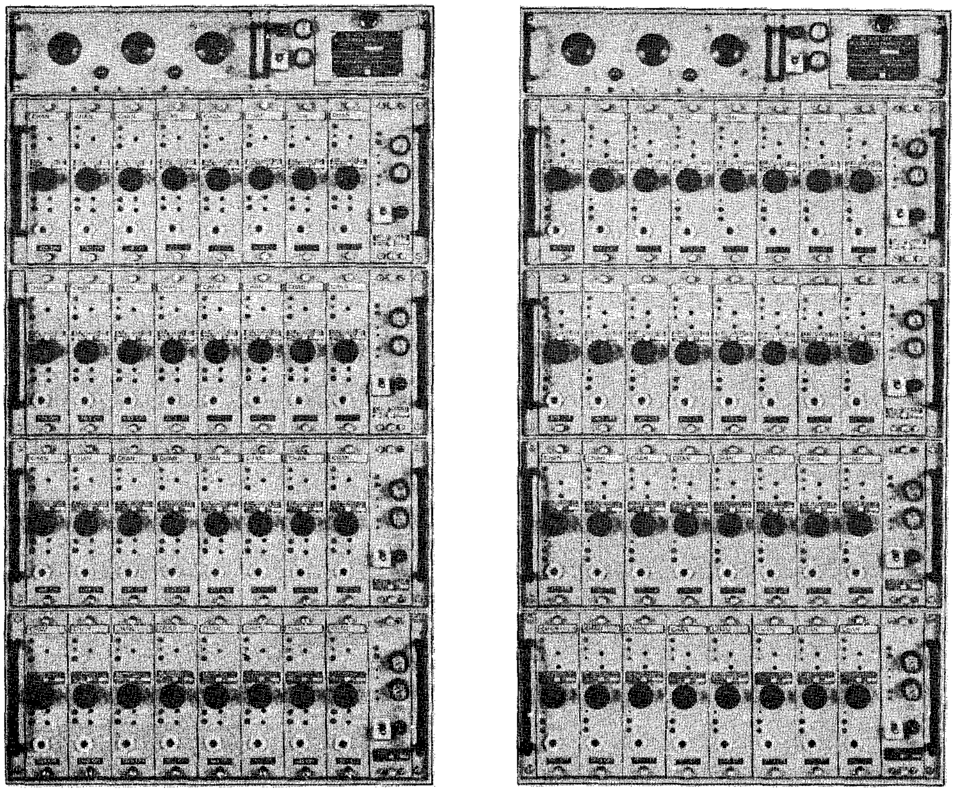

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Figure 10-17.—16-channel frequency-diversity terminal (utilizes 6-kc bandwidth).

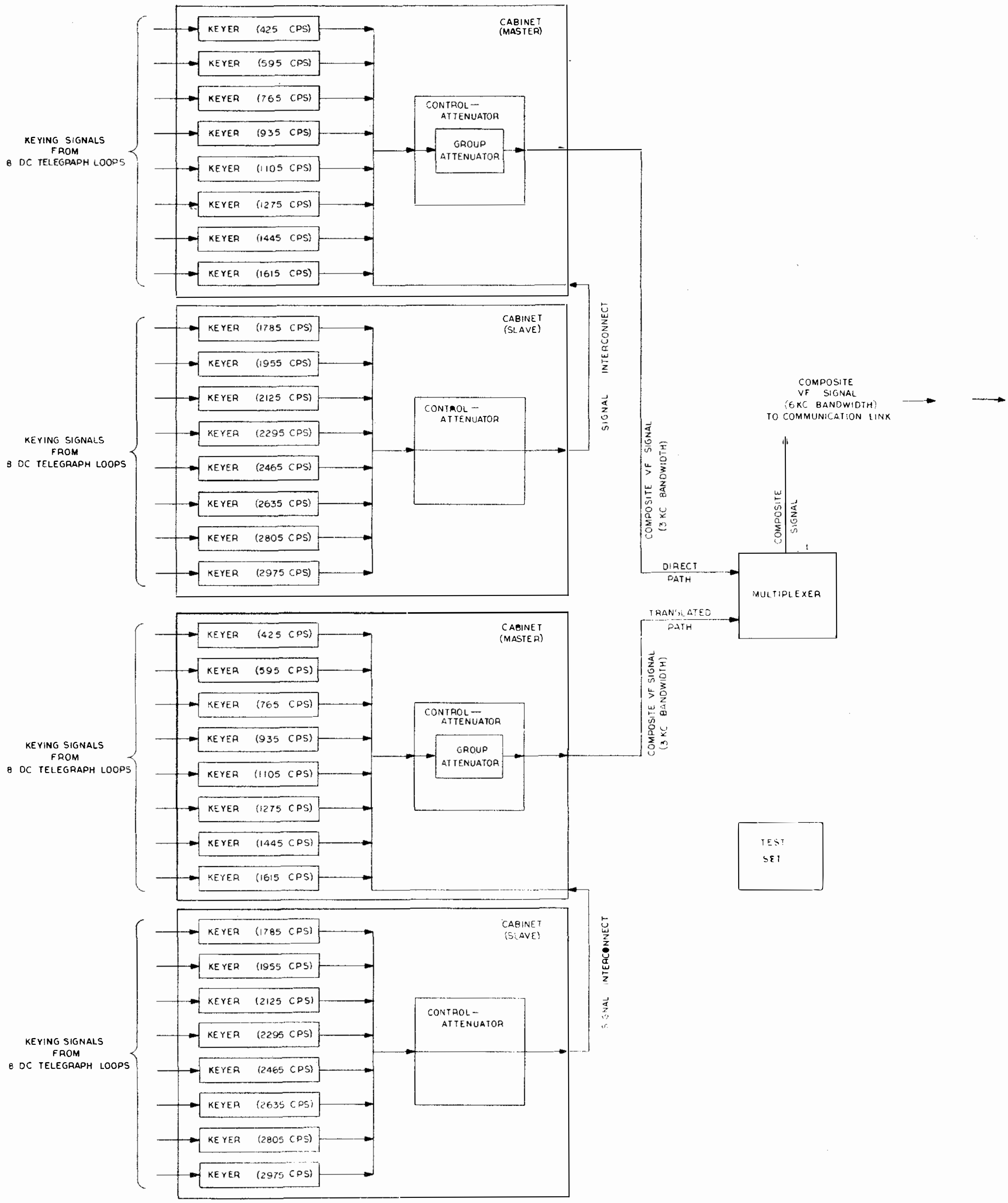
in stations A1 and A3 and those in A2 and A4 function as frequency diversity pairs. Converters in A1 and A2 and those in A3 and A4 function as space diversity pairs. By way of illustration, converters in the first two stations might be 425-cps channels; those in A3 and A4 would be 1785-cps channels, thereby forming a narrowband frequency diversity/space diversity combination. (See table 10-2.) In this combination, outputs of the four channel discriminators are added in series and are applied between the bias network on the station A1 converter and the input to the keyer circuit of the station A1 converter. To combine the outputs of all four channels, the four channel circuit grounds must be tied together. This function is performed by one bank of diversity CHS switches through the associated cabinet wiring.

To use the converters in stations A1 through A4 as two frequency diversity pairs, the diversity CHS switch on each converter is set to 2 and the converters must be rearranged. (See fig. 10-19.) Converters used in stations A1 through A4, for example, might be 425-, 1785-, 595-, and 2125-cps channels, the first two and the last two functioning as narrowband diversity pairs. With the diversity CHS switches on the four converters set to 2, discriminator outputs on station A1 and A2 modules are placed in series between the bias network and the input to the output circuits on the station A1 converter.

Outputs of discriminators on station A3 and A4 converters are placed in series between the bias network and the output circuits on the station A3 converter. Grounds on station A1 and A2 converters are tied together, as are those on station A3 and A4 converters.

Inasmuch as no space diversity pairs are involved, all four tone input switches are set to the same position so that all four converters are connected to the same composite tone line.

As shown in figure 10-19, the composite input transformers are connected to the cabinet's mode switches, and the composite tone lines are


KEYER (425 CPS)
KEYER (595 CPS)
KEYER (765 CPS)
KEYER (935 CPS)
KEYER (1105 CPS)
KEYER (1275 CPS)
KEYER (1445 CPS)
KEYER (1615 CPS)
CABINET (MASTER)
CONTROL — ATTENUATOR
GROUP ATTENUATOR
KEYING SIGNALS FROM 8 DC TELEGRAPH LOOPS
KEYER (1785 CPS)
KEYER (1955 CPS)
KEYER (2125 CPS)
KEYER (2295 CPS)
KEYER (2465 CPS)
KEYER (2635 CPS)
KEYER (2805 CPS)
KEYER (2975 CPS)
CABINET (SLAVE)
CONTROL — ATTENUATOR
SIGNAL INTERCONNECT
COMPOSITE VF SIGNAL (3 KC BANDWIDTH)
COMPOSITE VF SIGNAL (6 KC BANDWIDTH) TO COMMUNICATION LINK
COMPOSITE SIGNAL
DIRECT PATH
TRANSLATED PATH
MULTIPLEXER
TEST SET

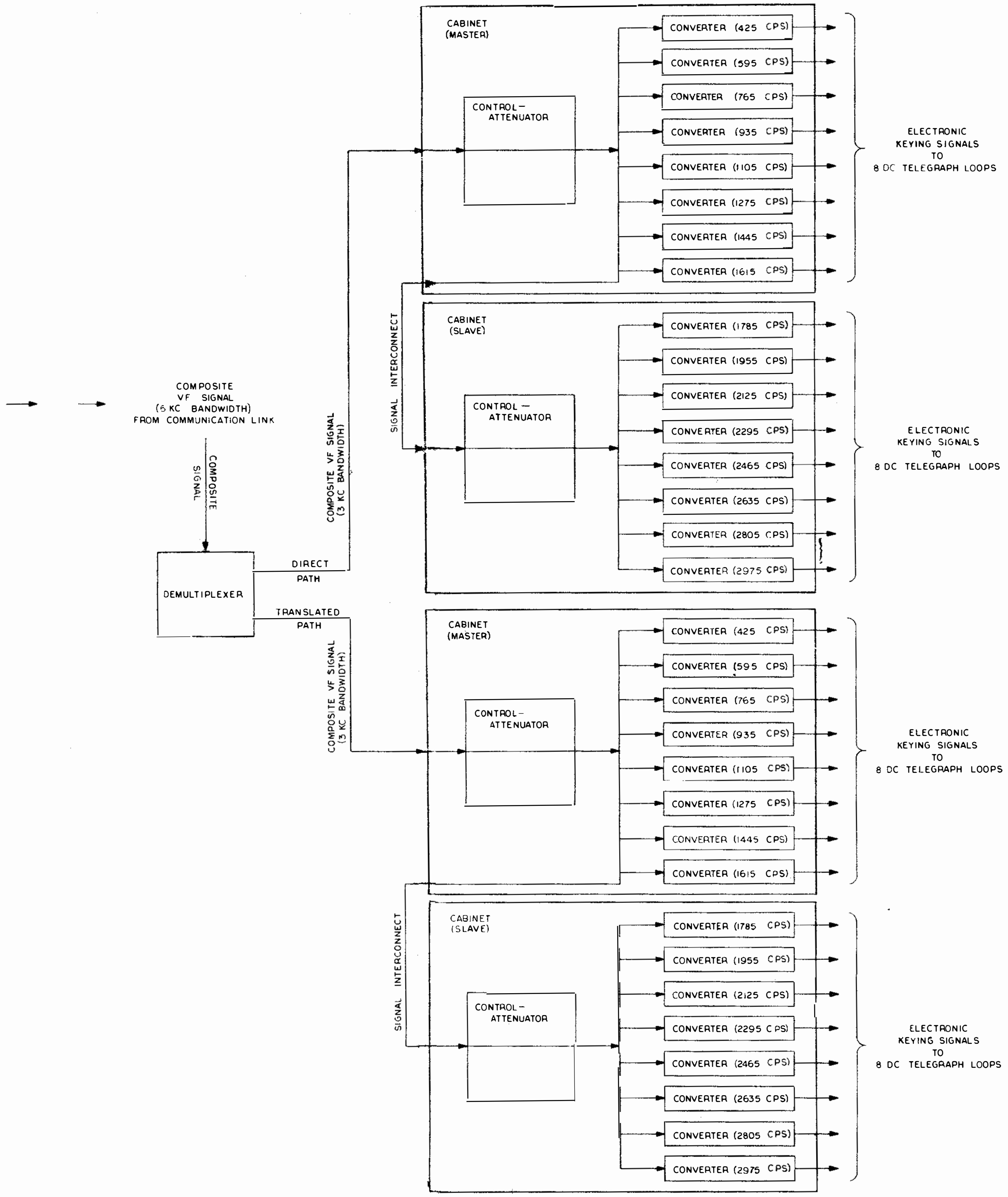


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Figure 10-18.—Telegraph terminal AN/UCC-1(V), overall functional block diagram.

Table 10-1.—Channel Frequencies*

Center frequency (cps)	Mark frequency (cps)	Space frequency (cps)
425	467.5	382.5
595	637.5	552.5
765	807.5	722.5
935	977.5	892.5
1105	1147.5	1062.5
1275	1317.5	1232.5
1445	1487.5	1402.5
1615	1657.5	1572.5
1785	1827.5	1742.5
1955	1997.5	1912.5
2125	2167.5	2082.5
2295	2337.5	2252.5
2465	2507.5	2422.5
2635	2677.5	2592.5
2805	2847.5	2762.5
2975	3017.5	2932.5
**1955	2040	1870
**2380	2465	2295
**2805	2890	2720
**3230	3315	3145

*Signal sense switch in NORMAL position. With signal sense switch in REVERSE position, interchange mark and space frequencies.

**Wideband channels (±85 cps).

connected to interconnect A and interconnect B connectors.

When more than one cabinet is used, composite tone lines are connected to the corresponding lines in other cabinets. In this case, the mode switch is set to master in one of the cabinets, and to slave in each of the other cabinets. The number ONE inputs are then received through the input transformers in that cabinet where the mode switch is in the master position. In the 8-channel frequency diversity/space diversity system, for example, which employs four cabinets containing converters, input transformers of the top cabinet and of the third cabinet from the top are used.

Each converter can operate its own keyer by placing the diversity CHS switch on the module to the number ONE position. Each converter can be connected to an individual input line by setting the unit's tone input switch to individual position.

When a group of converters is used in a diversity combination, inputs to the AGC control amplifiers (not shown) for all modules in the group are connected together. This common connection is on the anode of a diode (on each converter) whose cathode is connected to the output of the AGC detector for that channel. The converter receiving the largest signal input produces the most negative detector output, which back-biases the diodes on other converters of the group, effectively disconnecting them from the common AGC control amplifier input point. Thus, AGC control amplifiers on all converters of the converter receive the largest input signal. The AGC attenuation depends upon the level of the AGC control amplifier output with respect to a -12-volt reference level developed by a Zener diode on each converter.

When station A1 and A2 converters are connected as a frequency diversity pair (diversity CHS switches set to 2), the Zener diode of station A1 converter serves as the reference for both converters. Similarly, if converters are used as diversity pairs in stations A3 and A4, A5 and A6, or A7 and A8, reference voltage is supplied by the Zener diodes on converters in stations A3, A5, and A7, respectively.

When converters in stations A1 through A4 (or A5 through A8) form a frequency diversity/space diversity combination (diversity CHS switches set to position 4), the reference level is supplied by the Zener diode of station A1 (or station A5) converter.

Table 10-2.—Frequency Diversity Combinations

Narrow band (cps)	Narrow width band (cps)
425 -1784	425 -1105
595 -2125	595 -1445
765 -1955	765 -1275
935 -2295	935 -1615
1105-2465	1955-2805
1275-2805	2380-3230
1445-2635	
1615-2975	

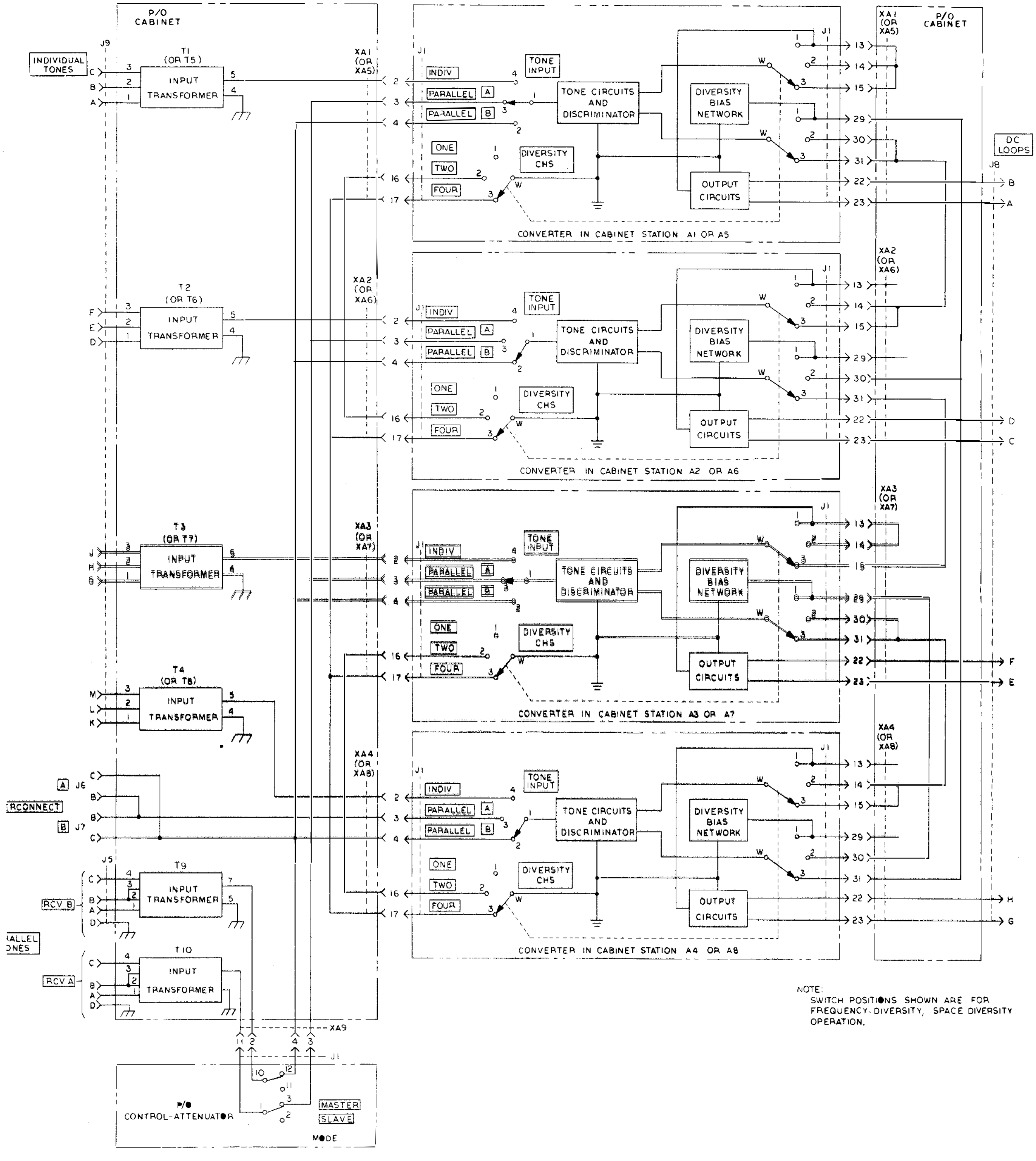

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Figure 10-19.—Converter, diversity combination, block diagram.

CHAPTER 11

SINGLE-SIDEBAND COMMUNICATION EQUIPMENT

Although a brief discussion of single sideband (SSB) is included in the effective edition of Radioman 3 & 2, NavPers 10228, the subject is treated in greater detail in this chapter. Because single sideband is becoming increasingly important in naval communications, it is necessary for Radiomen to understand the basic principles of its operation. If you understand the principles of operation, you will experience little difficulty in utilizing the equipment technical manuals in maintenance work.

It is, of course, impossible in one chapter of reasonable length to include everything that has been written on the subject of single sideband. Some valuable articles appear from time to time in the Electronics Information Bulletin and the Naval Ship Systems Command Technical News. You should make every effort to keep abreast of advances in this field.

The purpose of this chapter is to list, first of all, the advantages of single sideband and to point out the differences between SSB and the conventional system of amplitude modulation, which utilizes both sidebands and the carrier. Next, some of the more important problems in SSB communications are discussed.

In order to approach the subject of equipment operation in the most logical manner, a description of a functional block diagram of a single-sideband transceiver (model AN/URC-32), widely used aboard ship, is given first. This delineation is accompanied by a discussion of the functions performed in each of the blocks, followed by circuit diagrams.

Also included in this chapter is a brief description of model AN/WRT-2, the newest high-frequency SSB transmitter in the fleet.

ADVANTAGES OF SINGLE-SIDEBAND COMMUNICATIONS

Figure 11-1 shows a simplified block diagram of an SSB transmitter. In the SSB system the desired audio, CW, or FSK tones (intelligence) are used to modulate or heterodyne the intermediate frequency (300 kc), sometimes called the carrier frequency. These audio, CW, or FSK signals are fed into the balanced modulator along with the 300 kc from the carrier oscillator and are heterodyned. The balanced modulator is a circuit designed for obtaining the sideband components of modulation. If no modulation is present, the output is zero. The output of the balanced modulator is then fed into selected filters in the upper or lower sideband sections. If a 1-kc tone is used, the USB is 301 kc and the LSB is 299 kc. In this instance a switch selects the upper or lower sideband. Filters pass the desired sideband (in this example, the USB 301 kc) to the HF modulator. This frequency is sometimes called the intermediate frequency. The intermediate frequency (301 kc) is heterodyned in the HF modulator with the frequency from the HF oscillator (4.7 mc) to give the desired output. This frequency (5001 kc) or band of frequencies is selected by tuned circuits and amplified to the required output power. Thus, all of the transmitted power is used for the intelligence, although in some instances the carrier frequency may be inserted at reduced level for tuning purposes and for automatic frequency control at the receiver end. In voice or CW operation, there is no radiated power when intelligence is not sent if the carrier frequency isn't inserted. In FSK operation, either the mark or space tone is transmitted.

A comparison of the frequency and power relationships between single-sideband transmission and conventional a-m transmission is illustrated in figure 11-2. The SSB system is shown in part A of the diagram. Although the lower sideband is transmitted (in the illustration), the upper sideband could have been transmitted just as easily. In the AN/URC-32

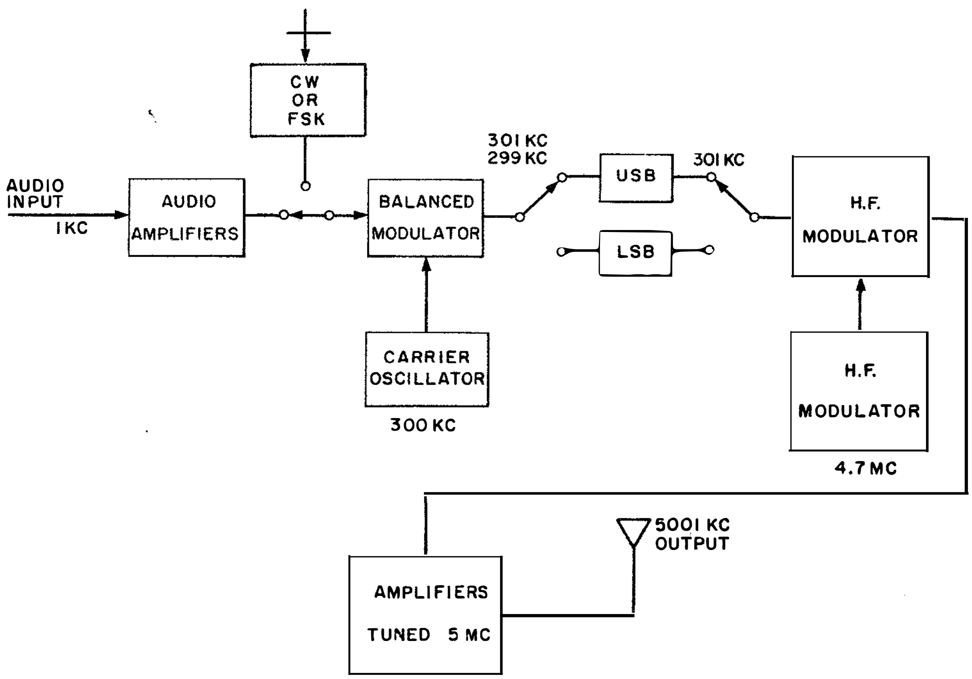

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Figure 11-1.—SSB simplified block diagram.

and AN/WRT-2 transmitters, both sidebands may be utilized independently.

In the familiar a-m system of communication (fig. 11-2, part B), the radiated signal includes the carrier and an upper- and a lower-sideband frequency for each frequency in the modulating signal. For example, if a 1-mc carrier is modulated by a 1-kc tone, the radiated signal includes the 1-mc carrier, the lower sideband frequency (1-mc—1 kc = 999 kc), and the upper sideband frequency (1 mc + 1 kc = 1001 kc). If the modulating signal contains many frequencies, there are, of course, many frequencies in the sidebands. In this system of transmission, none of the transmitted intelligence is contained in the carrier, and therefore the power put into the carrier is wasted insofar as transmitting intelligence is concerned. Likewise, because duplicate information is contained in each of the two sidebands, the intelligence content of the transmitted signal could be recovered from one sideband only.

In a conventional a-m system, where both sidebands and the carrier are transmitted, the power in the sidebands depends on the amount of modulation. For 100 percent modulation, the power in the sidebands is equal to one-half

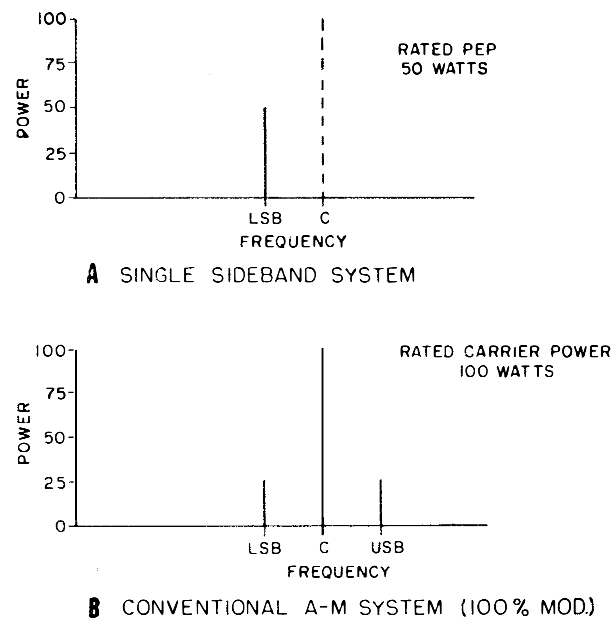

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Figure 11-2.—Comparison of amplitude modulation and SSB.

that in the carrier. Thus, a conventional a-m transmitter with 100-watt carrier power has 50 watts in the sidebands (25 watts in the upper sideband and 25 watts in the lower sideband) at 100 percent modulation, making the total power transmitted 150 watts. (Refer to fig. 11-2.) It can be seen, then, that two-thirds of the total radiated power in a conventional a-m system (assuming 100 percent modulation) is in the carrier and is therefore not useful in conveying intelligence.

When the r-f signal is demodulated in the conventional a-m receiving system, the audio output is a combination of the upper and lower sidebands. In this conventional type of detection, the audio output is proportional to the power contained in the two sidebands.

In a single-sideband system, only one sideband is transmitted, hence the audio output of the SSB receiver is proportional to the power contained in the one sideband.

It therefore becomes apparent that an SSB transmitter and an a-m transmitter perform equally (from signal-to-noise ratio) under ideal propagating conditions, if the total sideband power of the two transmitters is equal. Considering the relationship between sideband power and carrier power in a conventional a-m system, it is evident that an SSB transmitter performs as well as an a-m transmitter of twice the power rating under ideal propagating conditions. Thus, a single-sideband transmitter rated at 50 watts produces the same signal intelligence level at a receiver as a conventional a-m transmitter rated at 100 watts.

As propagating conditions become less than ideal, the SSB system shows an even greater advantage over an a-m system. Under poor propagation conditions, a-m transmission is subject to distortion. The reason for this condition is that all three components of the transmitted signal (the upper sideband, the lower sideband, and the carrier) must be received in the exact amplitude and phase relationship as transmitted to realize perfect reception. Because there is only one component in the transmitted signal for an SSB system, it is not so affected by poor propagating conditions. Studies show that reception in the SSB system improves from 0 to 9 db under various conditions of propagation when the total sideband power in SSB is equal to that in amplitude modulation (fig. 11-3).

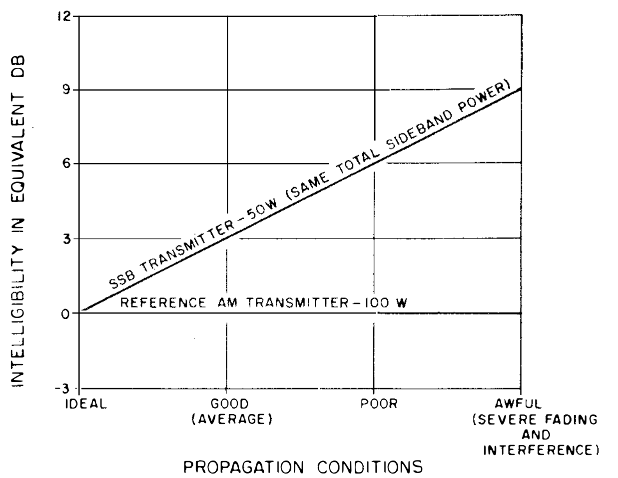

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Figure 11-3.—Comparison of amplitude modulation and SSB under varying propagation conditions.

Note that under the average conditions (good), the SSB system shows about a fourfold advantage over the a-m system. In other words, in normal use, an SSB transmitter rated at 100 watts (peak envelope power) gives equal performance with an a-m transmitter rated at 400-watt carrier power.

As far as bandwidth is concerned (assuming one sideband only), the SSB system requires only about one-half the frequency spectrum as does the conventional a-m system.

The advantages of SSB over the conventional a-m system may be summarized as follows:

1. The SSB transmitter performs as well as an a-m transmitter of twice the power rating under ideal propagating conditions. Under average conditions there is also an additional 3-db advantage of an SSB system over an a-m system having the same sideband power.
2. If only one sideband is used, the SSB system requires about one-half as much r-f spectrum as the a-m system.
3. The SSB transmitting system uses smaller units than comparable a-m units because less power is required.
4. By virtue of less power in the antenna, lower voltages are obtained, with attendant reduction of potential breakdown.
5. The SSB system is subject to less noise interference because the bandpass is narrower.

PROBLEMS IN SINGLE-SIDEBAND COMMUNICATIONS

The advantages of SSB cannot be realized without the use of specially designed components and circuitry. First of all, there is the problem of frequency stability, especially when the carrier is totally suppressed. Frequency stabilization means that the oscillators in the transmitter and in the receiver must not drift more than 30 cycles. Actually, the permissible frequency variation for SSB systems is 1/100th of that for an a-m system.

In one type of independent sideband generation, filters of extreme selectivity are needed. Linear power amplifiers, which are difficult to design, are also needed.

Another problem, when SSB equipment is used on high-speed aircraft, is doppler shift. This shift is especially noticeable at the higher radiated frequencies.

SSB TRANSCEIVER AN/URC-32

One of the Navy's most versatile modern communication equipments is the AN/URC-32 (fig. 11-4). It is a transceiver operating in the 2- to 30-mc high-frequency range, with a transmitter peak envelope power (PEP) of 500 watts.

A transceiver, as you know, uses part of the same electronic circuitry for both transmitting and receiving. For this reason, it cannot transmit and receive simultaneously.

The AN/URC-32 is designed chiefly for single-sideband transmission and for reception on either the upper or lower sidebands, or on both sidebands simultaneously, with separate audio and i-f channels for each sideband. In addition to single-sideband operation, provisions are included for a-m (carrier reinserted), CW, or FSK operation.

The frequency range of 2 to 30 mc is covered in four bands. The desired operating frequency is selected in 1-kc increments on a direct-reading frequency counter. Frequency accuracy and stability are controlled by a self-contained frequency standard.

AN/URC-32 BLOCK DIAGRAM

The transmitter of the AN/URC-32 (fig. 11-5) produces voice, CW, or FSK modulated signals on a single-sideband r-f carrier or on a compatible amplitude modulated r-f carrier.

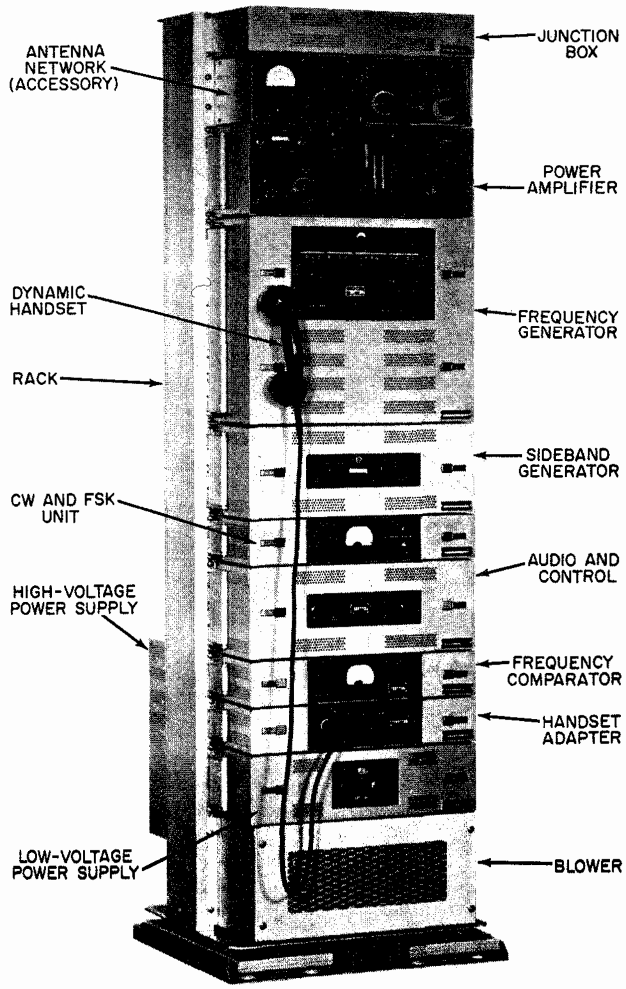

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Figure 11-4.—Single-sideband transceiver AN/URC-32.

Voice input signals from the dynamic handset are fed to the handset adapter. Input signals from a remote control unit also are applied to the handset adapter, permitting the operator to select either the local or remote audio input. Teletypewriter signals are applied directly to the CW and FSK unit, which provides separate audio tones for the mark and space conditions. These frequencies are later converted to the required frequency shift signals for FSK transmission.

The output from the handset adapter is amplified in the audio and control unit. Two separate audio input paths to the audio and control unit

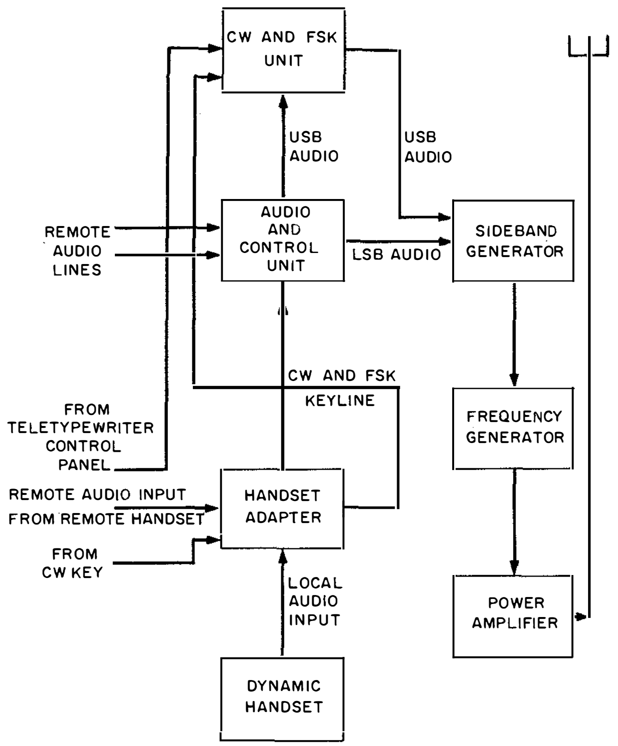

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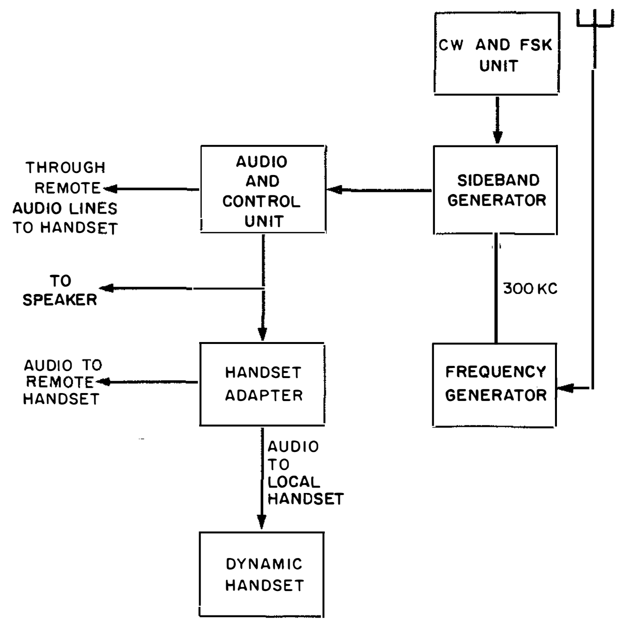
Figure 11-5.—AN/URC-32, transmit function, block diagram.



32.137
Figure 11-6.—AN/URC-32, receive function, block diagram.

are provided through the 600-ohm remote audio lines.

The audio and control unit amplifies the audio signal and feeds it to the sideband generator. During single-sideband voice operation, the audio and control unit output is fed through a selector switch in the CW and FSK unit. For CW or FSK operation, the CW and FSK unit supplies audio tones to the sideband generator.

The sideband generator converts the audio input to the selected sideband of a 300-kc intermediate frequency. The modulated 300-kc output is fed to the frequency generator. This unit provides the necessary number of heterodyning processes (while preserving the signal intelligence) to produce the selected nominal carrier frequency in the 2- to 30-mc range. The output signal is amplified in the power amplifier to the required peak envelope power of 500 watts and is fed to the antenna.

During receive operation (fig. 11-6) the antenna input signal in the range from 2 to 30 mc is heterodyned in the frequency generator so that the output will be a modulated 300-kc signal. This signal is detected and amplified in the sideband generator, is further amplified in the audio and control unit, and is fed to the speaker.

During FSK reception, the CW and FSK unit supplies a 300, 550-kc signal to the sideband generator as a beat frequency for the received signal. The beat frequency can be changed over a range of ±1 kc.

DYNAMIC HANDSET

The dynamic handset (fig. 11-7) consists of a noise-canceling dynamic microphone incorporating a transistor amplifier, a dynamic receiver, and a push-to-talk switch. The dynamic handset has the same plug-in connections, output impedance, and output level as the Navy 51007A carbon handset, which makes these two units interchangeable. The dynamic handset, however, provides improved audio quality over a carbon handset.

Both the transmitter and receiver are sealed plug-in units. The transmitter contains the

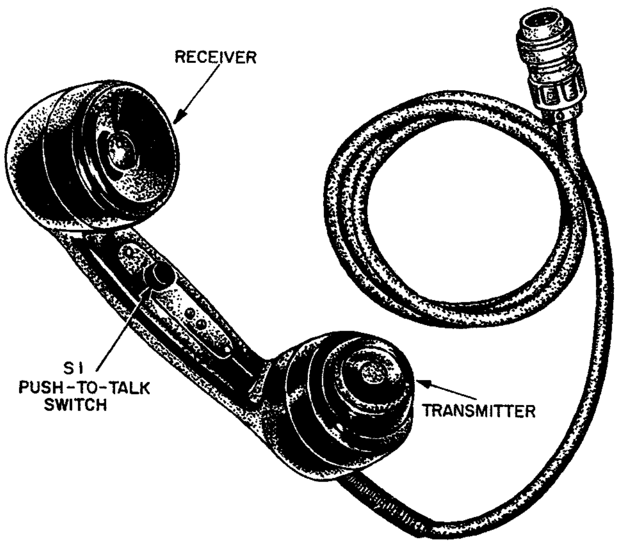


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Figure 11-7.—Dynamic handset.

noise-canceling dynamic microphone and the transistor amplifier. The receiver is a standard 600-ohm dynamic telephone receiver.

HANDSET ADAPTER

The handset adapter (fig. 11-8), permits local operation of the transmitter-receiver, using the dynamic handset just described, or remote operation using a C-1138/UR radio set control and the AN/URC-32 dynamic handset. Local or remote operation is selected by the handset control on the front panel. A connector on the front panel is provided for the handset.

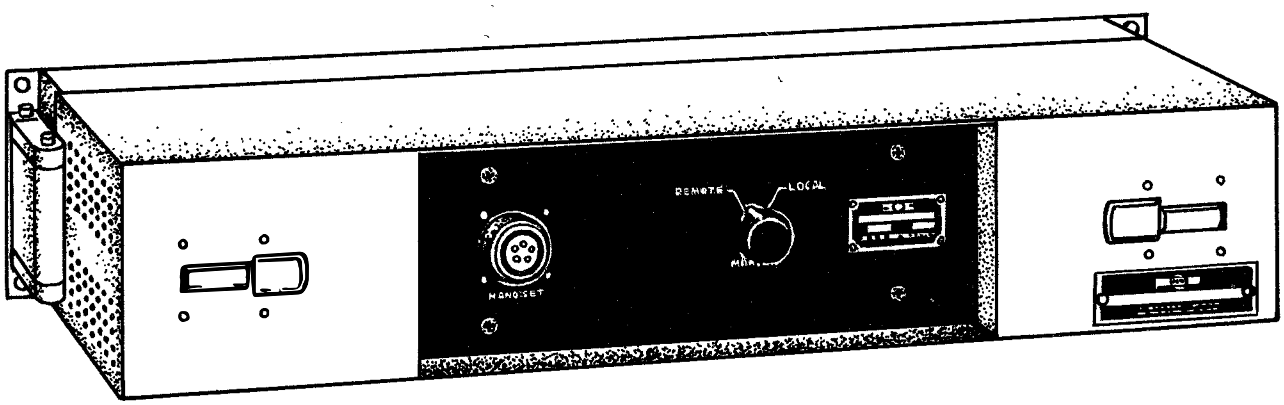
In the LOCAL position, handset switch S1 (fig. 11-9) connects the audio output from the receiver (terminals 5 and 6) to the handset (terminals A and B), and connects the audio output from the handset transmitter to the system transmitter. Also, in local operation, the key line is connected to contact 4 of relay K1. Contacts 4 and 3 of K1 are open (as shown) for receive operation. When the handset push-to-talk button is depressed, relay K1 energizes, and contacts 4 and 3 close to apply a ground to the key line. In turn, this action operates the various control circuits of the transmitter.

A 12-volt power soucce supplies power for K1 and the handset microphone. This supply uses transformer T1 and rectifiers CR1-CR4 in a full-wave dry-disk bridge rectifier circuit.

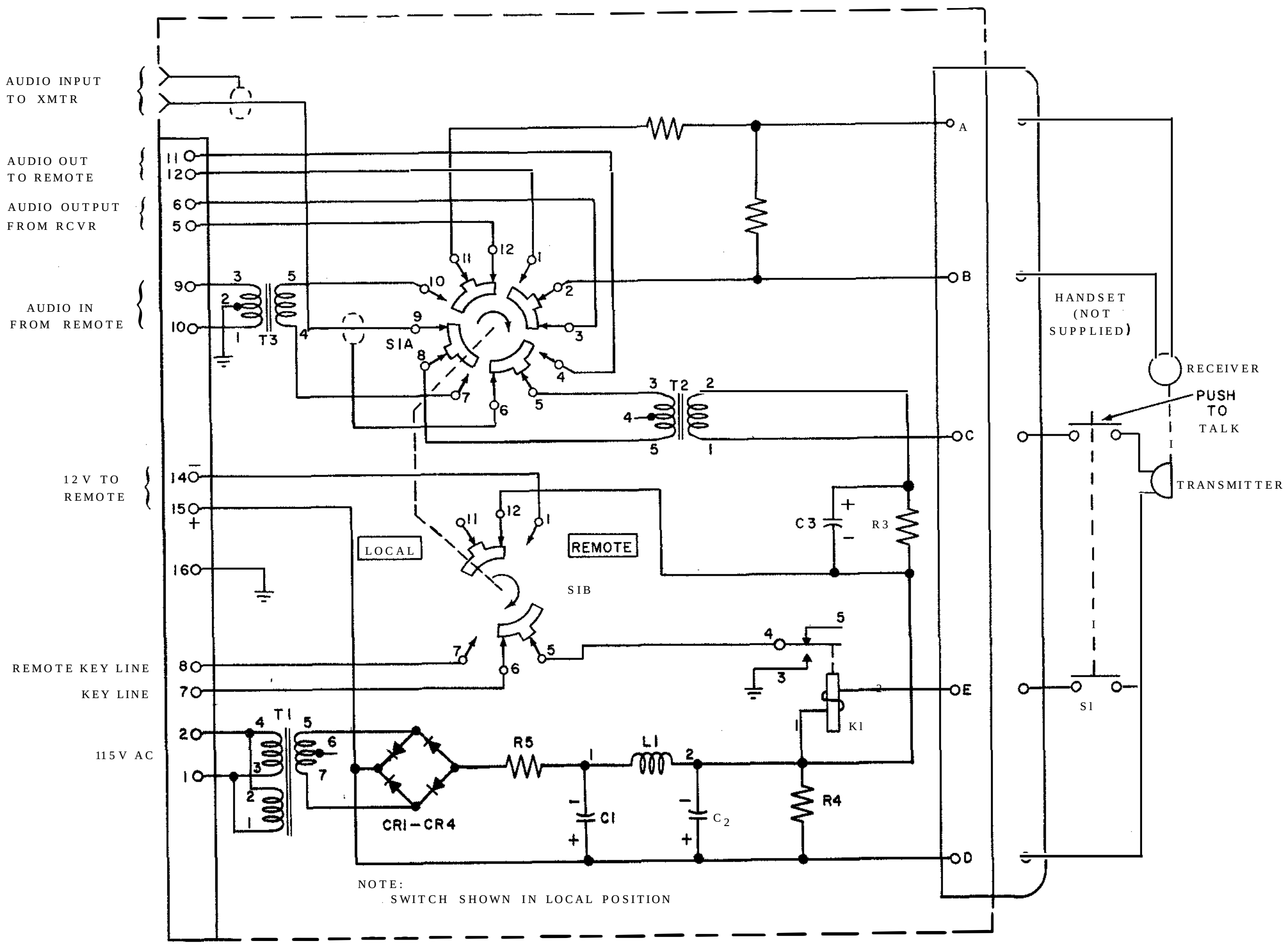
In the REMOTE position, handset switch S1 connects the audio output from the receiver to the remote control circuits, and also connects the audio output from the remote control circuit to the transmitter. In remote operation, the key line and 12 volts from the handset adapter power supply are connected to the remote controls.

AUDIO AND CONTROL UNIT

The audio and control unit (fig. 11-10) is a dual-channel amplifier. It can provide audio



32.140
Figure 11-8.—Handset adapter.



32.141

Figure 11-9.—Handset adapter, schematic diagram.

inputs from two 600-ohm balanced lines, a 600-ohm unbalanced line, or a high-impedance microphone. In the normal AN/URC-32 installation, the 600-ohm balanced lines and the dynamic microphone input are not used.

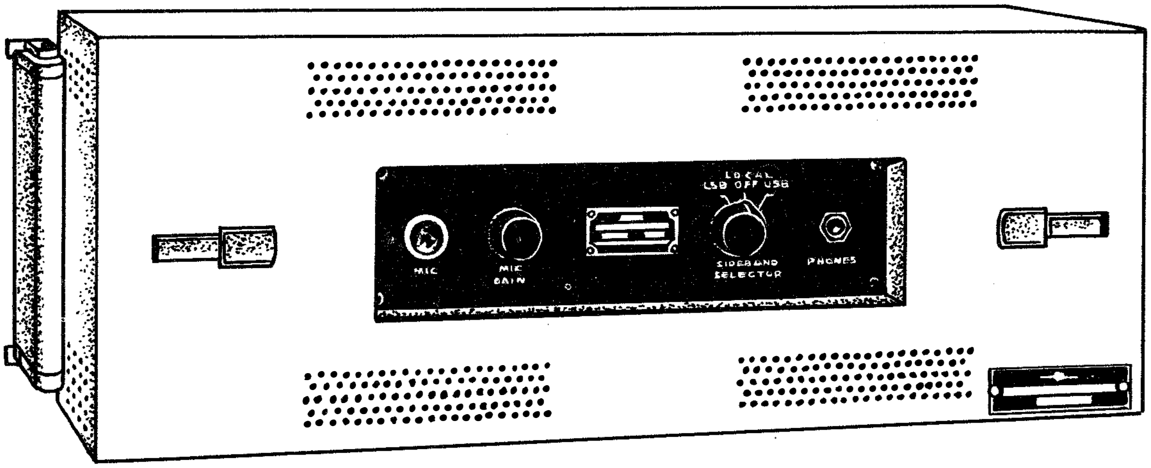
Block Diagram

On transmit, when using the 600-ohm unbalanced input, the audio signal from the handset adapter is fed to the audio and control unit via audio transformer T6 (fig. 11-11). This input, after amplification, can be applied to the upper sideband line amplifier or to the lower sideband line amplifier in the audio and control unit.

The sideband selector switch controls the signal transmission and reception. With the switch in the OFF position, the microphone amplifier circuits and the remote audio input are disconnected from the line amplifiers. This action also connects the upper and lower sideband 600-ohm audio line inputs to the line amplifiers.

With the sideband selector switch in the UPPER position, the microphone audio or remote audio is fed into the upper sideband line amplifier. This also selects the upper sideband audio output from the sideband generator and applies it to the speaker amplifier circuits.

The reverse of this action happens when the sideband selector is placed in the LOWER position. When earphones (not shown) are plugged into the phone jack on the front panel (fig. 11-10), the audio output normally fed to the speaker is removed.



32.142

Figure 11-10.—Audio and control unit.

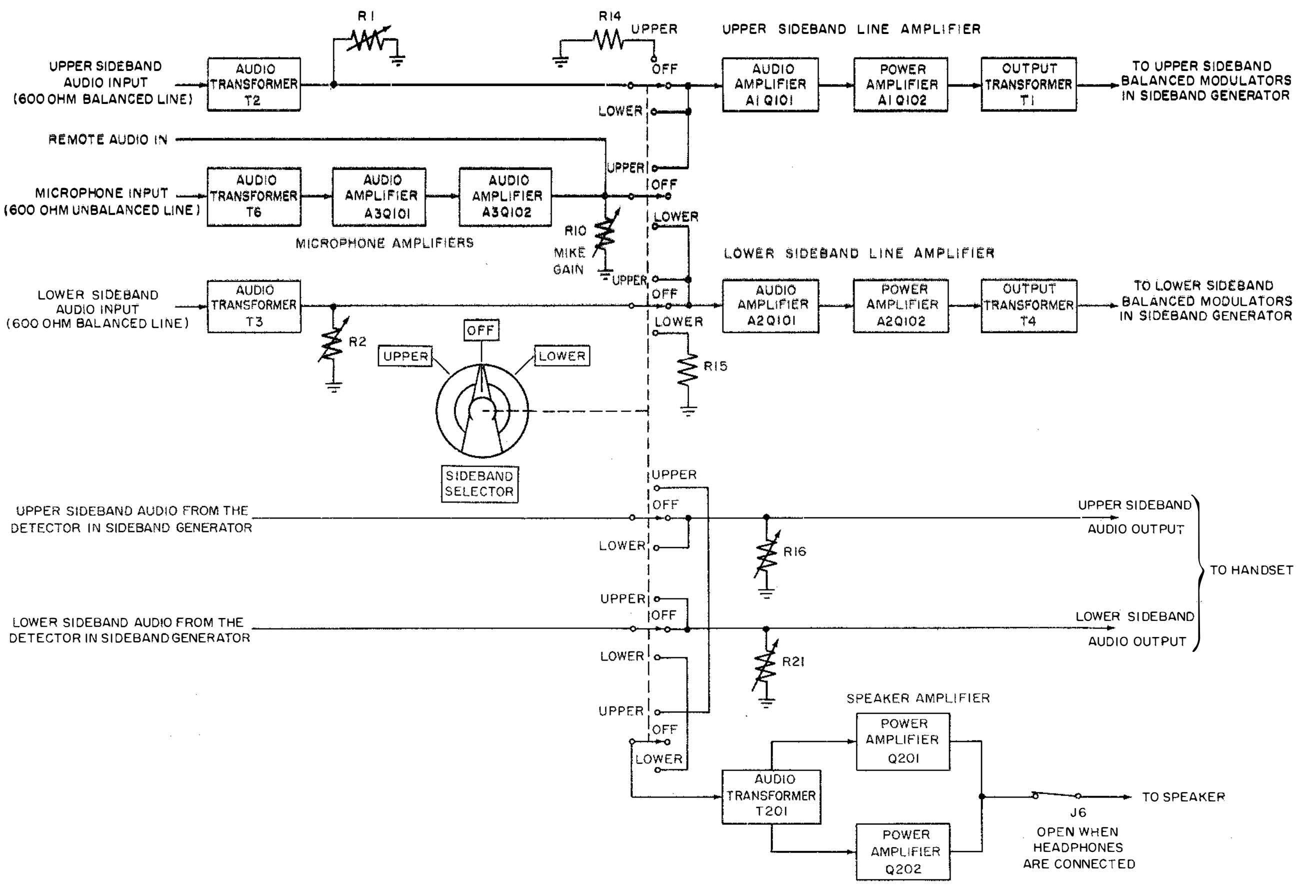


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Figure 11-11.—Audio and control unit, block diagram.

The upper and lower sideband line amplifiers (fig. 11-11) are controlled by the upper and lower sideband audio inputs. With the sideband selector switch in the OFF position, the two sideband amplifiers can be used either individually or simultaneously.

Assume the audio input is on the upper sideband. This input is coupled by audio transformer T2 and the sideband selector switch (in the OFF position) to the first upper sideband line amplifier A1Q101 for amplification. The amplified output of A1Q101 is coupled to the power amplifier A1Q102 for further amplification. The output is fed via T1 to the upper sideband balanced modulator in the sideband generator. The gain of the sideband line amplifier is controlled by attenuator R1. Operation is the same for both the upper and lower sideband line amplifiers.

When the sideband selector switch is in the UPPER position, the upper sideband audio is removed from the audio amplifier A1Q101 and is terminated by R14. Either the microphone amplifier circuit or the remote audio is then connected to the audioamplifier A1Q101.

With the sideband selector switch in the LOWER position, the lower sideband audio is removed from A2Q101 and is correctly terminated by R15. The microphone amplifier circuits are then connected to the audioamplifier A2Q101.

SIDEBAND GENERATOR

The sideband generator (fig. 11-12) translates audiofrequencies to intermediate frequencies during transmit condition, and intermediate frequencies to audiofrequencies during receive condition.

Transmit Function

The block diagram of the sideband generator is shown in figure 11-13. The balanced modulator, carrier generator, and transmitter gain control (TGC) operate during transmit condition. The audio input to the sideband generator is taken from the audio and control unit (fig. 11-11) and applied to the sideband generator via T3 and T4. Audio input transformers T3 and T4 (fig. 11-13) couple the upper sideband and lower sideband audio inputs to the balanced modulators.

The balanced modulators modulate a 300-kc carrier to produce separate and distinct upper and lower sideband signals with the carrier suppressed. The 300-kc carrier is produced in the carrier generator by tripling the 100-kc reference oscillator signal from the frequency generator (discussed later).

The balanced modulator contains two 300-kc balanced modulators. Because of a frequency inversion in the r-f tuner, the lower sideband balanced modulator is followed with an upper

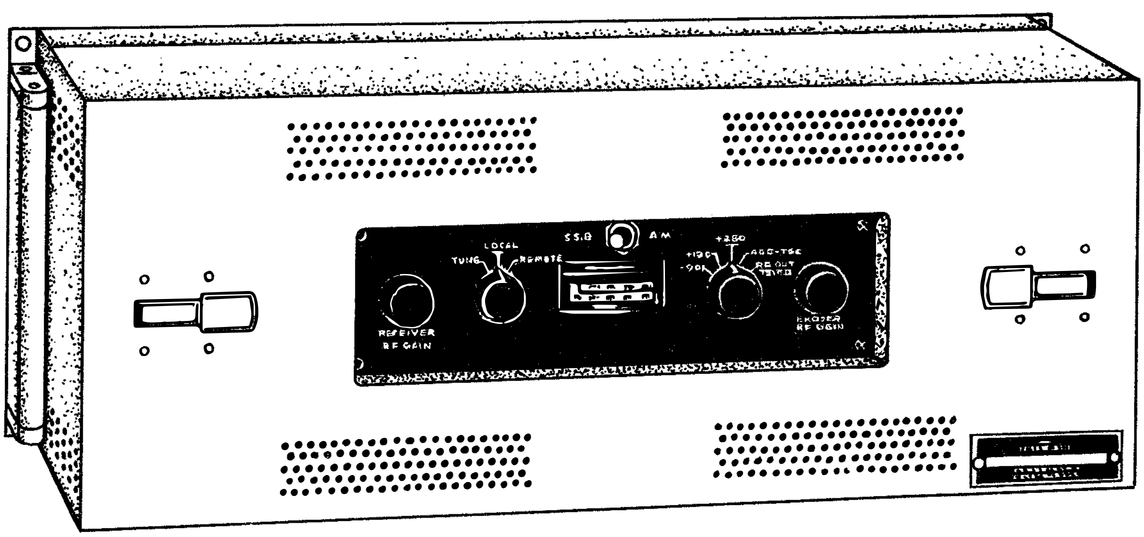

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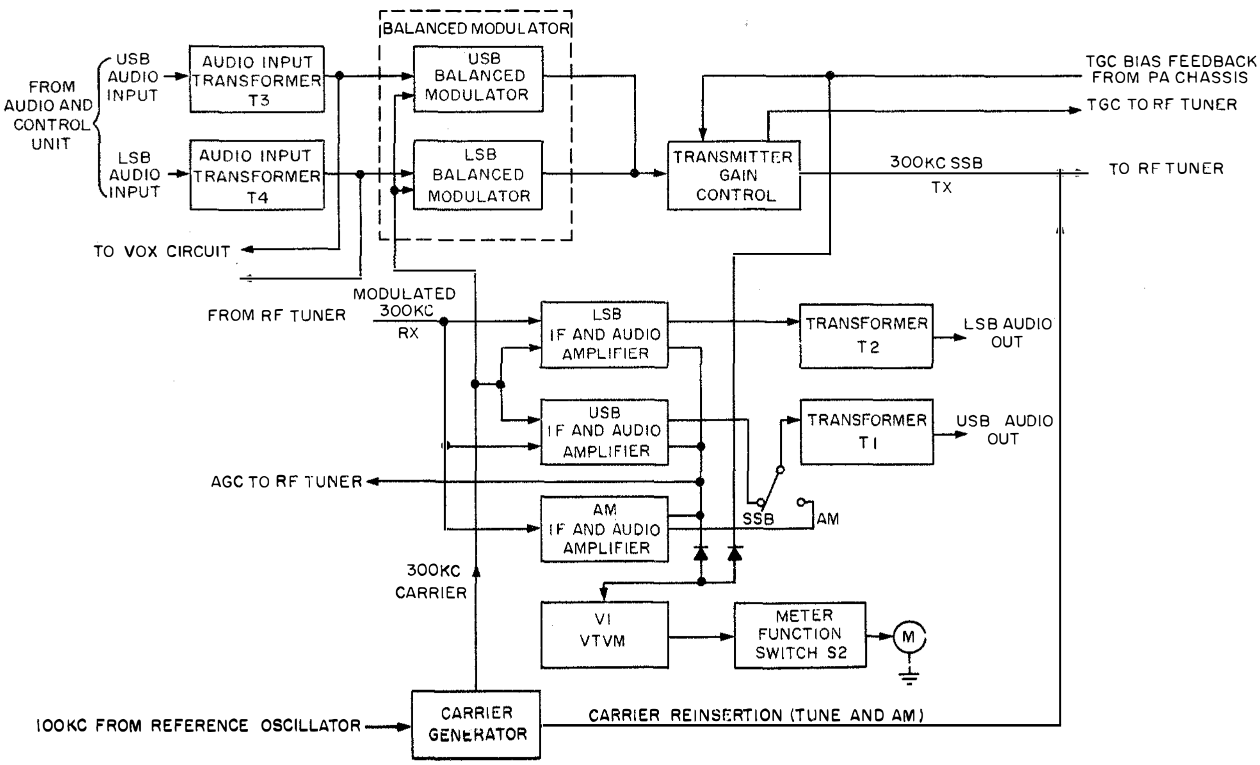
Figure 11-12.—Sideband generator.



32.146

Figure 11-13.—Sideband generator, block diagram

sideband filter, and the upper sideband balanced modulator is followed with a lower sideband filter. The inversion process which takes place in the r-f tuner is explained later.

The outputs of the balanced modulator are connected in parallel and fed to the transmitter gain control. The TGC circuit is controlled by a TGC voltage received from the power amplifier unit. This circuit maintains the 300-kc i-f output voltage at a sufficiently low level to prevent overdriving any of the subsequent stages.

The 300-kc SSB signals are fed via line TX to the r-f tuner and power amplifier (described later). During tune and a-m transmit conditions only, the unmodulated 300-kc carrier generator output is reinserted in the upper sideband signal at the inputs of V1A in the r-f tuner. Reinsertion of the carrier at the transmitter eliminates reinsertion at the receiver and the necessity for special equipment to receive the transmitted signal. The absence of the lower sideband does not affect the quality of the received signal. Only one sideband plus carrier is transmitted, however, and the received signal is considerably stronger than it would be for double-sideband a-m operation.

Receive Function

The i-f and audioamplifiers (lower sideband, upper sideband, and a-m) operate only during the receive condition to amplify the modulated 300-kc i-f signal from the r-f tuner (via line RX). These units also demodulate the signal and amplify the detected audio. A 300-kc carrier is reinserted into the lower sideband and upper sideband i-f/a-f amplifiers from the carrier generator.

When the front panel SSB a-m switch is in the a-m position, the LSB and USB i-f/a-f amplifiers are disabled. The carrier generator (a-m receive only) also is disabled, as will be shown later. The audio output from the am i-f/a-f amplifier is fed through the SSB a-m switch in the a-m position to the upper sideband audio output lines via transformer T1. The a-m i-f/a-f amplifier is disabled when the SSB a-m switch is in the SSB position.

CW AND FSK UNIT

The CW and FSK unit (fig. 11-14) enables the AN/URC-32 transceiver to be operated in the CW and FSK modes of operation. On FSK transmit operation (tone modulation), the CW and FSK unit converts the keying input from a teletypewriter current loop to audio tones of 1575 cps for space (no loop current) and 2425 cps for mark (loop current). On CW transmit operation the unit provides a keyed audio tone of 1000 cps or 1500 cps as selected by the OSC control switch on the front panel.

During FSK receive operation, the CW and FSK unit provides a bfo (beat frequency oscillator) signal required for FSK reception. This signal is centered on 300.550 kc, and is variable approximately 1 kc above or below this frequency. This variation raises the space and mark tones 550 cps to make the AN/URC-32 compatible with other teletypewriter terminal equipments.

The CW and FSK unit (fig. 11-15) consists of (1) an oscillator-buffer-amplifier (V1A, V1B, and V2A), (2) a bfo (Q1), (3) a CW break-in relay and relay amplifier (V2B), and (4) a monitor circuit (via S2). The monitoring circuit contains a meter M1, which is used for monitoring the receive and transmit audio outputs of the audio and control unit, as well as for monitoring the output of the CW and FSK unit.

The function of the CW and FSK unit is determined by the position of the oscillator control switch S1 located on the front panel. In the OFF position, S1C disables the CW and FSK unit by removing the B+ voltage (+130 v) from the circuits. Also, in this position, S1E connects the upper sideband transmit audio input line from the audio and control unit to the upper sideband transmit audio output line connected to the upper sideband balanced modulators of the sideband generator. Thus, in the OFF position, the CW and FSK unit circuits (fig. 11-15) are deenergized, and the voice input signals from the handset are transmitted.

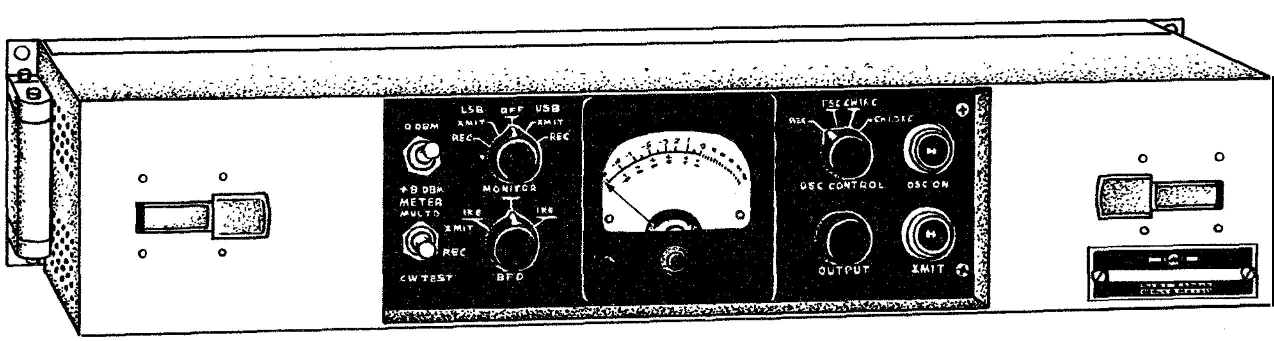
When S1 is moved one position (from the position shown), FSK signals are transmitted. In the final two positions of S1, CW signals are transmitted.

During FSK and CW operation, the upper sideband transmit audio input line from the audio and control unit is disconnected, and the output of the oscillator-buffer-amplifier circuit is connected to the upper sideband transmit audio output line. In the FSK position, the frequency of the oscillator V1A is shifted by the teletypewriter loop input from 1575 cps for space to 2425 cps for mark.

In the CW positions, the oscillator frequency is 1000 cps (corresponding to the 1-kc position) or 1500 cps (corresponding to the 1.5-kc position), depending on the setting of oscillator control switch S1 on the front panel. Buffer stage V1B permits passage of the V1A oscillator output when the CW and FSK key line is completed to ground.

CW and FSK Oscillator

The oscillator V1A frequency is adjusted, as determined by the mode of operation, by



32.154

Figure 11-14.—CW and FSK unit.

changing the components in the grid cathode tank circuit. With S1B in the FSK position, the tuned circuit of oscillator V1A consists of L1, C3, and the capacitors in the FSK circuit. The teletypewriter input signal at pin 1 of J1 determines which capacitors of the FSK keying circuit are inserted in the tuned circuit, and therefore determines the frequency of the oscillator.

The FSK keying input circuit has a relatively high impedance. For this reason, if the CW and FSK unit is to be used with a teletypewriter operating on a standard loop current, an external resistor of approximately 800 ohms or larger should be placed across the signal line to permit the 20-, 30-, or 60-ma loop current to develop a positive voltage pulse of 25 to 50 volts at the input terminal.

With no current in the teletypewriter loop (corresponding to space condition), voltage divider R11 and the teletypewriter terminating resistor in parallel with R12 applies a negative voltage across CR2 and CR3 from the -90 volt bias line. This condition causes CR2 and CR3 to conduct. With CR2 and CR3 conducting, C4 and C5 are placed in the tuned circuit of the oscillator in parallel with C6 and C7. This action produces an oscillator output frequency from V1A of 1575 cps, which represents the space condition FSK output frequency.

When a mark current is present in the teletypewriter loop, a positive voltage is developed across the external resistor in parallel with R12. This voltage exceeds the negative voltage that appears across R12 and the external resistor during the space condition. Also, the direction of current through these resistors changes direction from downward through the resistors to upward.

The resulting positive voltage at the R12-CR2 junction cuts off CR2 and CR3, and effectively removes C4 and C5 from the tuned circuit of the oscillator. As a result of the decrease in capacitance, the oscillator frequency changes to a higher frequency to produce 2425 cps. This frequency corresponds to the mark condition of the FSK output. The oscillator signal is fed through the buffer V1B and the output amplifier V2A, S1E, and S1F, to the upper sideband transmit audio output lines.

In the CW 1-kc position of S1, section S1B removes the capacitors in the FSK keying input circuit and inserts C8 in the oscillator tank. This action tunes the oscillator to 1 kc. In the CW 1.5-kc position, C9 is connected in the oscillator tank circuit to tune the oscillator to 1.5 kc.

Buffer and Output Amplifier

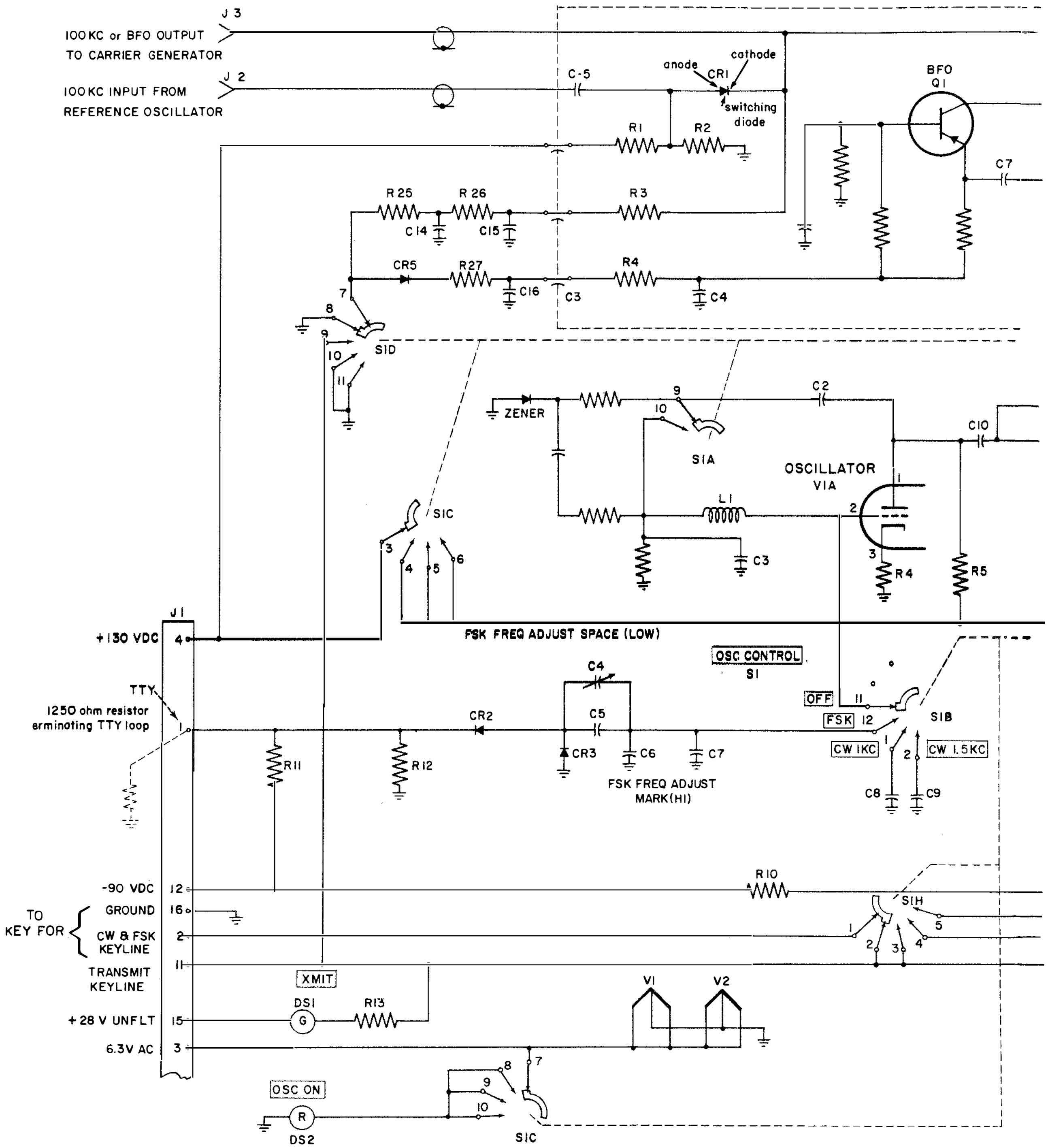
The output of the oscillator V1A is fed to the grid of buffer V1B. In the FSK position (12), S1A applies a ground to grid resistor R8, and the buffer stage functions continuously. In the two CW positions (1 and 2) of S1A, the buffer (V1B) is biased to cutoff. The cutoff voltage is applied to the V1B grid through R8 and R9 from the junction of R10 and R17, which are connected from the -90 volt supply to ground. The buffer is keyed by the CW and FSK line, which applies a ground (when closed) to the junction of R10 and R17 through contacts 1 and 4 (or 5) of S1D. Thus, closing the CW key removes the bias from the buffer stage, and V1B passes the ocillator (V1A) output.

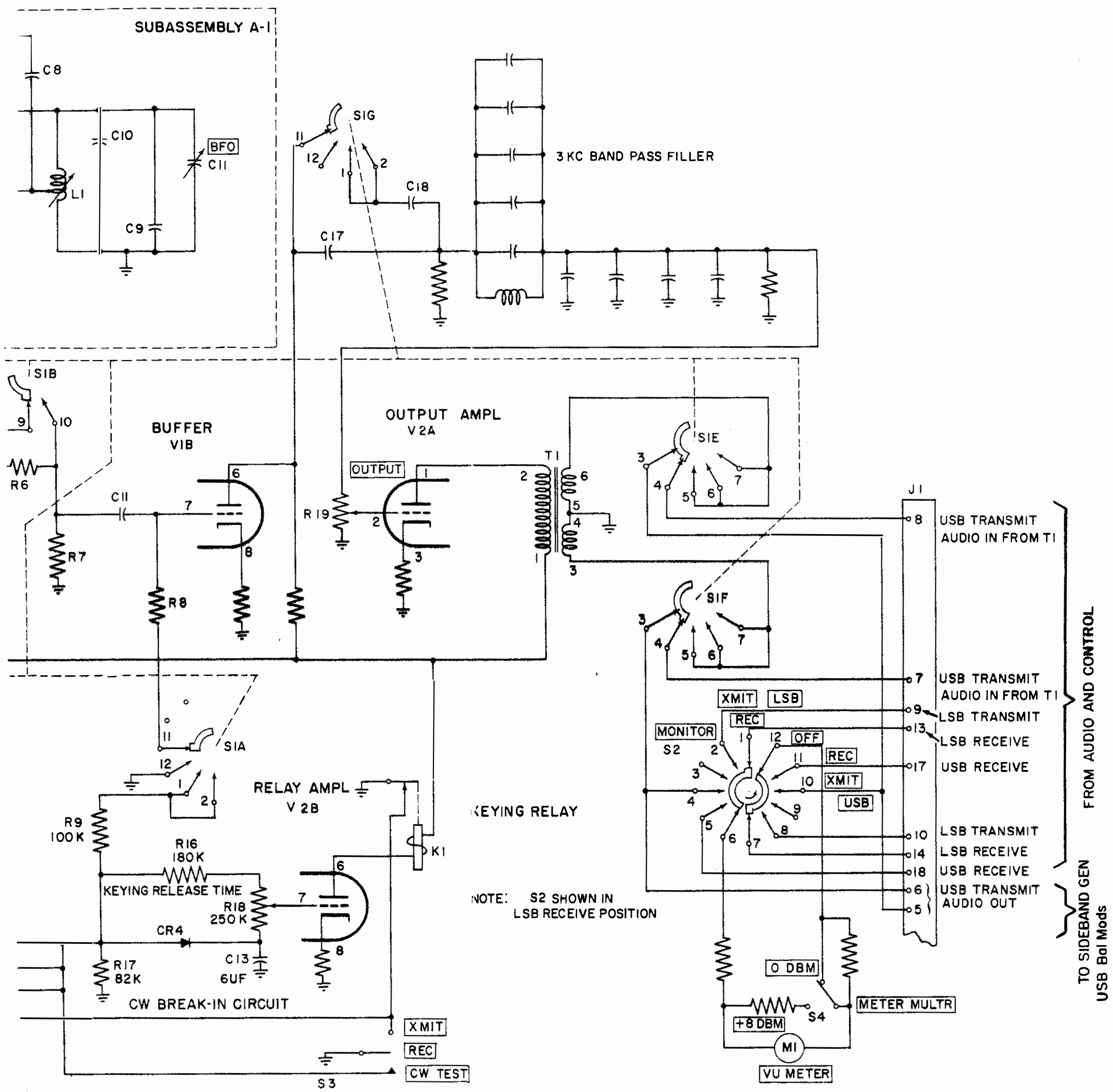
The V1B output is fed through a bandpass filter which rejects 3 kc. On CW operation, C18 is connected in the filter input path by S1G, in parallel with C17, and the filter attenuates the second harmonic of 1.5 kc and the third harmonic of 1 kc. During FSK operation (position 12), S1G removes C18 from the filter input circuit, and the second harmonic of the 1575-cps space frequency is attenuated.

The filtered output from V1B is developed across output control R19. The T1 secondary provides a 600-ohm balanced output (CT grounded) via S1F and S1E (CW and FSK positions 5, 6, and 7) to the upper sideband audio output line. In the OFF position (as shown), S1E connects the upper sideband transmit audio input line directly to the upper sideband transmit audio output line.

CW Break-In Relay Circuit

The CW break-in relay circuit, made up of relay amplifier V2B and keying relay K1, applies a ground to the transmit key line via pin 2 and pin 16 of J1 when the CW key is closed. It maintains this ground via pin 11 of J1 through the normal CW key open intervals of a CW transmission. In the two CW positions, S1H (pins 4 and 5) connects the CW and FSK key line through R16 and R18 to the grid of relay amplifier V2B. The plate circuit relay K1 operates on a fast response and a delayed release principle. This relay action is accomplished by controlling the grid voltage of V2B from two RC circuits, one with a short


J 3
100 KC or BFO OUTPUT TO CARRIER GENERATOR
J 2
100 KC INPUT FROM REFERENCE OSCILLATOR
C-5
anode
cathode
CR1
switching diode
R1
R2
BFO Q1
C7
R 25
R 26
R3
C 14
C15
CR5
R27
R4
C16
C3
C4
S1D
ZENER
C2
S1A
C10
OSCILLATOR V1A
L1
C3
R4
R5
S1C
J1
+130 VDC
FSK FREQ ADJUST SPACE (LOW)
OSC CONTROL S1
TTY
1250 ohm resistor erminating TTY loop
C4
C5
CR2
CR3
C6
C7
OFF
FSK
S1B
CW 1KC
CW 1.5KC
R11
R12
FSK FREQ ADJUST MARK(HI)
C8
C9
-90 VDC
TO KEY FOR
GROUND
CW & FSK KEYLINE
TRANSMIT KEYLINE
R10
S1H
XMIT
DS1
R13
V1
V2
+28 V UNFLT
6.3V AC
OSC ON
DS2
S1C



32.155

Figure 11-15.—CW and FSK unit, schematic diagram.

time constant, and one with a long time constant.

In the initial key-up condition, C13 charges to approximately -20 volts through R10, R16, and R18, from the -90 volt supply. The voltage across C13 maintains V2B in cutoff, and K1 is deenergized.

When the CW key is closed, a ground is applied to the CW and FSK key line, and C13 is discharged through the small forward resistance of CR4, pins 4 or 5 of S1H, the key and ground, or via pins 2 and 16 of J1. This condition represents a short time constant as compared to the charge path through R16 and R18. The discharge of C13 removes the negative bias voltage from the grid of V2B, the tube conducts, and K1 is energized, thereby placing a ground on the transmit key line via pin 11 of J1.

When the CW key is opened, the ground is removed from the CW and FSK key line, and C13 is charged through the high resistance of R16 and R18. When the voltage at the top of R18 reaches the cutoff value of V2B, K1 is deenergized, and ground is removed from the transmit key line.

The long time constant of R10, R16, R18, and C13 provides the time delay necessary to maintain the transceiver in the transmit condition during the normal key-open interval of a CW transmission. When S1D is in the OFF or FSK positions (1, 2, or 3), the CW and FSK key line is connected directly through contacts 1 and 2 (or 3) to the transmit key line. The CW and FSK key line can then be used as a remote transmit key line.

BEAT FREQUENCY OSCILLATOR

The beat frequency oscillator (bfo) circuit consists of transistor oscillator Q1 and a switching diode CR1. On FSK receive operation, the diode disconnects the 100-kc input signal at J2 from the 100-kc output signal jack J3. During all modes of operation except FSK receive, the 100-kc signal input from the reference oscillator at J2 (discussed later) is fed through J3 to the carrier generator. There, it is multiplied to produce the 300-kc i-f signal. Diode CR1 is maintained in a conducting state by a bias voltage obtained from the voltage divider made up of resistors R1 and R2 across the +130 volt supply. In the OFF and CW positions of S1, S1D completes the d-c path through CR1 from ground contacts 8 and 7 of S1D, R25, R26, R3, CR1, and R1 to the +130 volt supply.

Because the peak amplitude of the 100-kc input signal at J2 is smaller than the voltage from the C5-CR1 junction to ground, CR1 remains conducting during the application of the complete 100-kc sine wave signals. The output voltage variations from CR1 are developed across R3, R25, and R26. The 100-kc input from J2 is fed via J3 to the carrier generator for all modes of operation except FSK receive.

During FSK transmit condition, the ground on the CR1 anode is completed through contacts 7 and 9 of S1D when the transmit key line is closed. Thus, during FSK transmit, the 100-kc signal is coupled through CR1 to the carrier generator, and the 300-kc i-f signal is produced in the normal manner.

During FSK receive operation, +28 volts d-c is applied to the transmit key line through indicator lamp DS1, R13, and the relay solenoids connected to the key line in other units. This positive potential is applied through contacts 9 and 7 of S1D, R25, R26, and R3, to the cathode of CR1. Because this potential is more positive than the positive voltage applied to the anode of CR1, the diode cuts off during FSK receive operation, thereby disconnecting J2 from J3.

The positive voltage on the transmit key line is fed to bfo circuit Q1 through CR5 and a filter consisting of R27, C16, R4, and C4. This action energizes the bfo.

The frequency of the bfo circuit is determined by parallel resonant tank circuit L1 and C9, C10, and C11 in the collector circuit. The feedback signal from the L1 tap to ground is coupled through C7 to increase emitter forward bias current when collector current is increasing. When Q1 saturates, the feedback potential from L1 drops momentarily to zero. As forward bias decreases, collector current decreases, and the feedback from the L1 tank decreases the base-emitter current. This action sustains oscillation in the tank circuit. Inducter L1 can be adjusted for a center frequency of 300.550 kc. Capacitor C11 provides a method of varying the frequency approximately 1 kc above or below the center frequency.

The output signal from the bfo is taken from the tap on L1 and fed through C8 to the output jack J3. This signal is amplified in the carrier generator and used as a beat frequency signal with the received FSK signals.

CONTROL CIRCUITS

The AN/URC-32 is keyed to transmit by applying a ground to a transmit key line. The method by which this ground is supplied to the transmit key line depends upon the mode of operation and the position of the handset switch on the handset adapter and OSC control switch on the CW and FSK unit.

During voice operation, the OSC control switch is set to OFF. This position deenergizes the CW and FSK unit circuits and connects the transmit key line to the handset switch. When the handset switch is in the LOCAL position, a ground is applied to the transmit key line by a relay in the handset adapter. The relay (K1 in the handset adapter) is energized when the push-to-talk button on the local handset is depressed. This action closes the K1 contacts to ground the transmit key line.

When the handset switch is in the REMOTE position, the transmit key line is connected to the remote key line. The ground is supplied to the line by a push-to-talk relay in the remote phone unit.

For FSK operation, the OSC control switch (on the CW and FSK unit) is set to the FSK position, and the handset switch is set to REMOTE. This setting energizes the FSK circuits of the CW and FSK unit, and connects the transmit key line to the remote key line. A ground is then applied to the remote key line at the teletypewriter control panel.

For CW operation, the OSC control switch S1 (fig. 11-16) is set to either the CW 1-kc or the CW 1.5-kc position, and the handset switch is set to REMOTE. This action applies B+ to the CW circuits of the CW and FSK unit, and connects the remote key line to the CW key line of the CW and FSK unit. The remote key line becomes a CW key input, and is grounded by the CW key.

When the CW key is open, the grid of buffer stage V1B is blocked by a high negative potential. When the key is closed, the V1B negative grid bias is reduced and the oscillator signal from V1A is allowed to pass. With V2B conducting, the break-in relay K1 is energized to apply a ground to the transmit key line. This action keys the transmitter carrier.

The break-in relay K1 incorporates a delay circuit, which holds the transceiver in transmit operation during normal CW key-open intervals. When K1 in the CW and FSK unit is denergized, the ground for the transmit key line is removed by the K1 contacts.

Grounding the key line energizes the receive transmit relays of the AN/URC-32 and the antenna coupler. When transmitting, K1 in the sideband generator applies the transmit audio signals to the balanced modulator via oscillator control S1 in the OFF position. The relay also closes the contacts that operate an antenna bypass circuit in a remote antenna tuner (such as the AN/BRA-3) when different transmitting and receiving frequencies are utilized (crossband operation). A separate receiver unit must be used during crossband operation.

With the antenna tuner bypass switch in the REMOTE position (not shown), the antenna tuner is bypassed when the relay contacts are open (receive condition). When crossband operation is not being used, the bypass switch in the antenna tuner should be in the TUNER-IN position to decrease the transmit keying time. Transmit keying time increases during crossband operation because the transmit keying circuit is interlocked through the antenna tuner bypass circuit so that the AN/URC-32 is not keyed to transmit until the tuner bypass circuit of the remote antenna tuner switches from the BYPASS to the TUNER-IN position. When CW keying is used in the AN/URC-32, this time lag may result in a partial loss of the first character of the code transmissions.

In the transmit condition, K2 in the frequency generator disables the receiver circuit of the r-f tuner. Disabling is accomplished by applying a cutoff bias voltage to the grids of the receiver stages and by disconnecting the receive r-f input from the antenna to the r-f tuner. Relay K2 in the power amplifier applies voltage to the driver screens and plates and to the power amplifier screens. This relay is interlocked through contacts of relay K3, which prevents the operation of K2 when the power amplifier plate voltage is not applied.

The output level of the power amplifier is controlled by the tune-operate switch S1B. This switch controls the driver plate and screen voltage and the power amplifier screen voltage by inserting a dropping resistor R16 in the 400-volt supply line during the tune or low level condition of the transmitter. For high power operation, this resistor is shorted out through tune-operate switch S1B and the tuner high power interlock (not shown). The antenna tuner high power interlock prevents high power operation when the antenna tuner is not tuned to the operating frequency.

The relay in the antenna coupler switches from the receiver input circuit in the frequency generator to the transmitter output

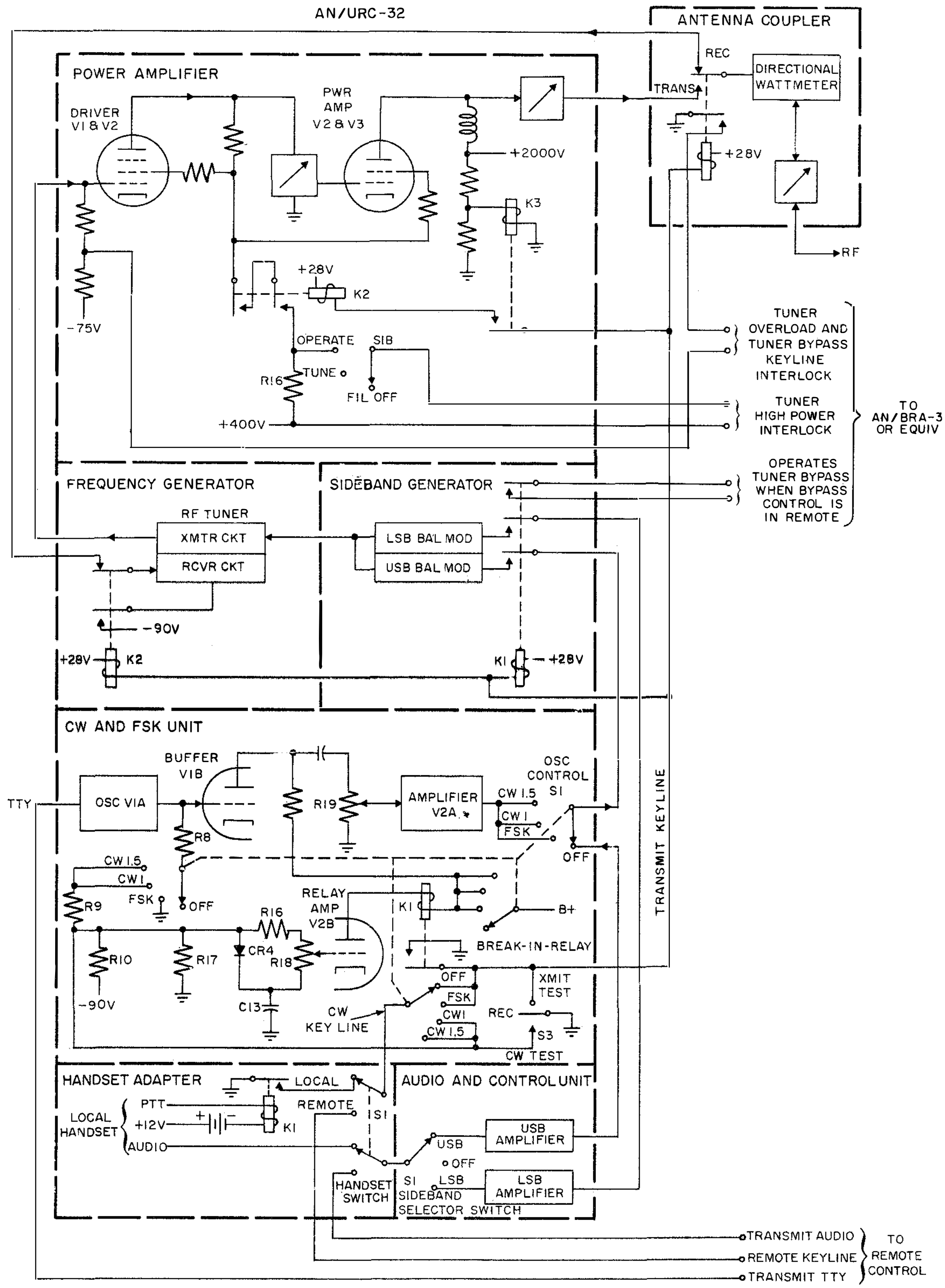


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Figure 11-16.—Transmit control circuit.

circuit of the power amplifier. Auxiliary contacts on the relay apply a ground through an antenna bypass interlock to remove the disabling bias applied to the driver grids of the power amplifier unit during transmission. The antenna bypass interlock prevents r-f drive power from being applied to the power amplifier when the antenna tuner is bypassed.

FREQUENCY GENERATOR

The frequency generator, shown in figure 11-17, is an important part of the AN/URC-32 transceiver. The band change and frequency change controls on the front panel of the frequency generator determine the frequency to which the unit is tuned.

The frequency generator (fig. 11-18) consists of a main chassis and five plug-in units. These units are—

1. R-f tuner;
2. Stabilized master oscillator;
3. Sidestep oscillator;
4. Frequency divider; and
5. Reference oscillator.

All five units are shown in figure 11-19 in greater detail.

R-F Tuner

The r-f tuner of the frequency generator (lower part of fig. 11-19) is an i-f to r-f translator during transmit condition, and an r-f and i-f translator during receive condition. During the transmit condition, the r-f tuner accepts the 300-kc single-sideband signal from the balanced modulators of the sideband generator (fig. 11-13) and translates it to any desired frequency (in 1-kc steps) in the range from 2.0 to 30.0 mc.

During receive condition, the r-f tuner accepts the selected received signal (as indicated on the band dial of fig. 11-17) and translates it to a 300-kc i-f signal. This signal is fed to the i-f/a-f amplifier of the sideband generator (or a-m/i-f amplifier, depending on the type of reception) for demodulation and amplification, as discussed earlier in this chapter.

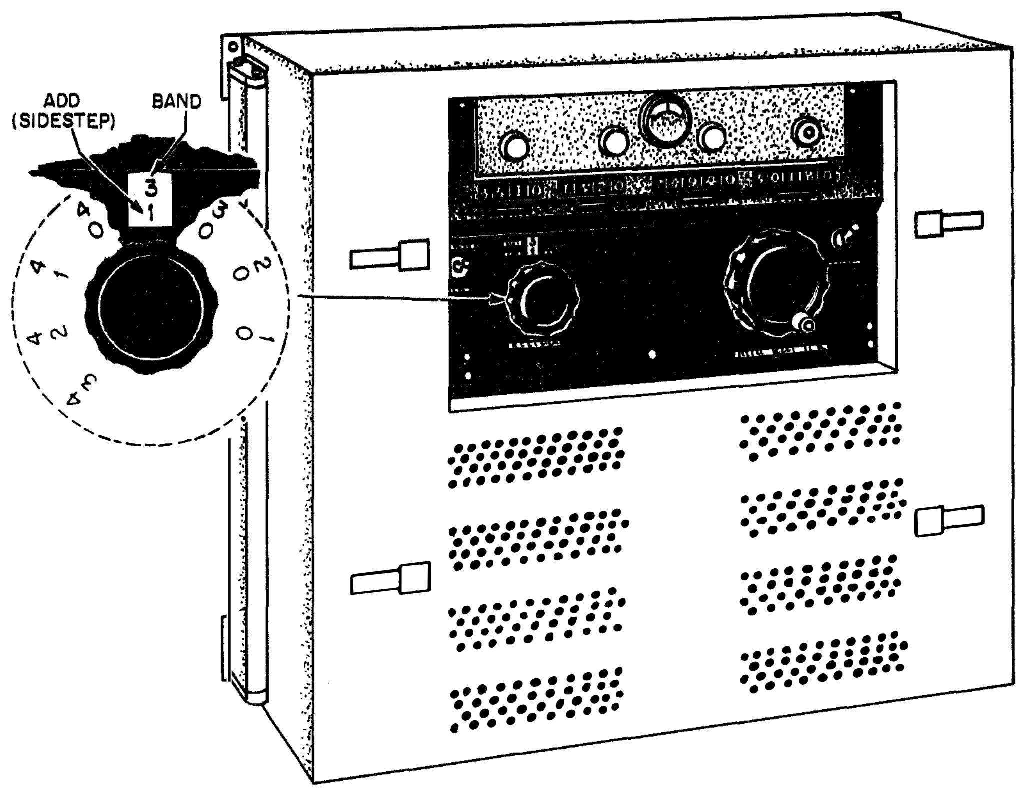

Figure 11-17.—AN/URC-32 frequency generator. 32.157

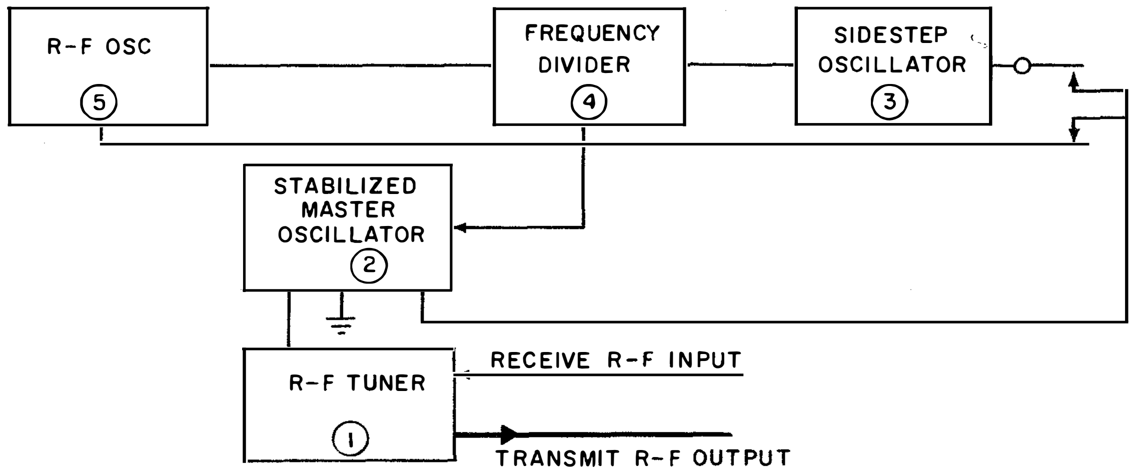

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Figure 11-18.—Frequency generator, simplified block diagram.

The r-f tuner is tunable through its normal operating range (2.0 to 30.0 mc) in four bands. These bands are—

Band 1—1.7 to 3.7 mc;
Band 2—3.7 to 7.7 mc;
Band 3—7.7 to 15.7 mc;
Band 4—15.7 to 31.7 mc.

The r-f tuner can be tuned in 1-kc steps over the entire tuning range.

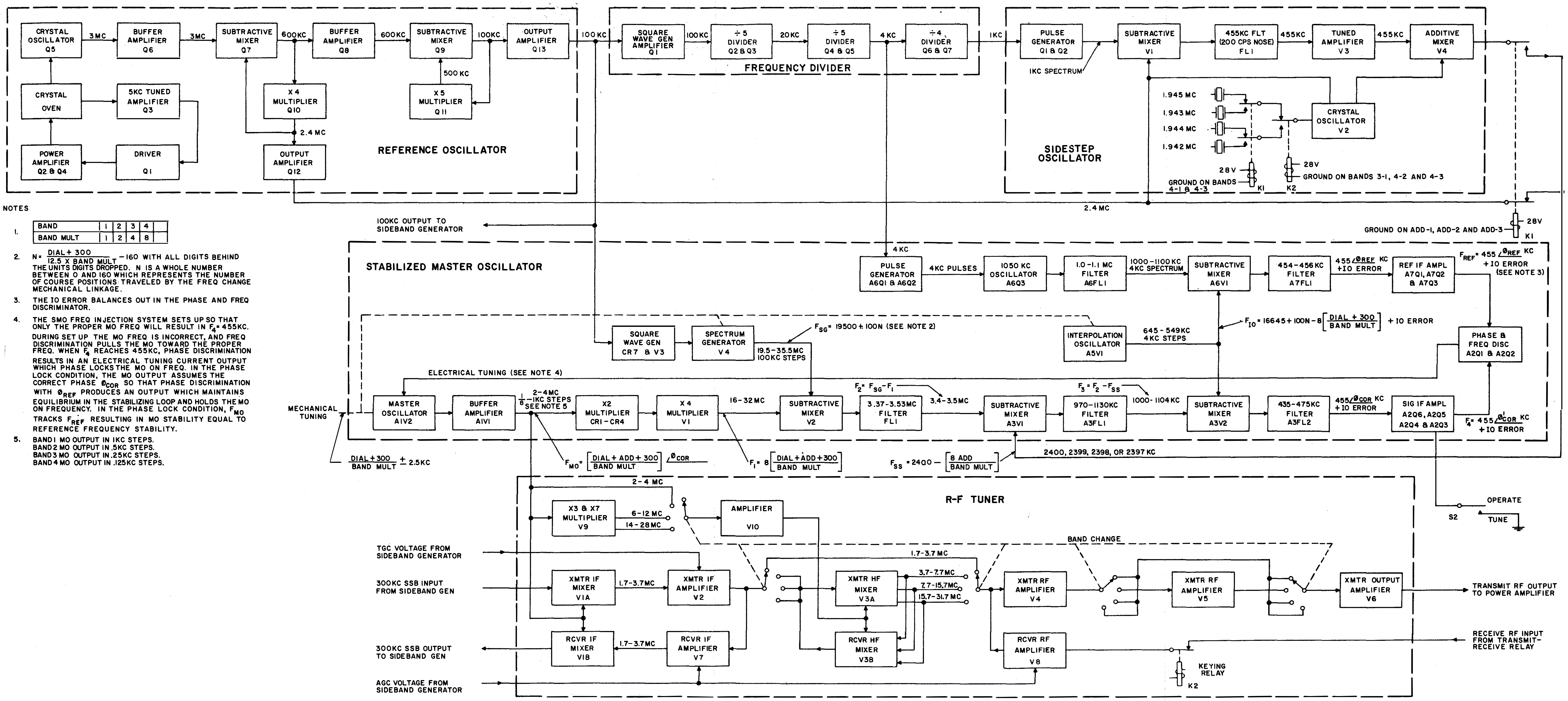
During transmit and receive conditions on band 1, the r-f tuner performs a single frequency conversion. The heterodyning process takes place in V1A (fig. 11-19) for transmit and in V1B for receive. On bands 2, 3, and 4, the r-f tuner performs a double frequency conversion in either V3A or V3B.

On receive operation, the r-f input signal from the transmit-receive relay (at the antenna input) is fed through the keying relay K2 to receiver r-f amplifier V8. (Keying relay K2 permits passage of the received signal during receive condition; break-in relay K1 applies an additional bias to cut off the stages of the receiver during transmit.) On bands 2, 3, and 4, the output of V8 is fed to receive h-f mixer V3B where it is converted to a 1.7- to 3.7-mc variable i-f signal.

On band 1, the output of V8 is in the 1.7- to 3.7-mc range and is fed directly to receive i-f amplifier V7. The 1.7- to 3.7-mc variable i-f signal (during receive operation) is amplified by receive i-f amplifier V7, and is fed to receiver i-f mixer V1B. There it is converted to a 300-kc fixed i-f signal. The V1B output is fed to the i-f/a-f amplifier of the sideband generator (fig. 11-13). An automatic gain control (AGC) voltage from the sideband generator controls the gain of the receiver amplifiers V7 and V8 (fig. 11-19).

On transmit operation, the 300-kc fixed i-f signal from the balanced modulators of the sideband generator is converted to a 1.7- to 3.7-mc variable i-f signal in transmit i-f mixer V1A by mixing with a 2- to 4-mc signal from the stabilized master oscillator. The variable i-f signal is amplified by transmit i-f amplifier V2. The gain of V2 is controlled by a transmit gain control (TGC) voltage from the TGC unit of the sideband generator. On band 1, the output of V2 (fig. 11-19) is fed through the bandchange switch to the transmit r-f amplifier V4.

During transmission on bands 2, 3, and 4, the output of V2 is fed through the band-change switch to the transmit h-f mixer V3A. In V3A it is converted to an r-f signal in the range of 3.7 to 31.7 mc, depending on the band selected. The transmit h-f mixer V3A is followed by three stages of r-f amplification on band 2, and by two stages of amplification on bands 1, 3, and 4. The necessity for greater amplification on band 2 is caused by losses in special tuned circuits used during transmission on this band. The output from V6 is fed to the power amplifier unit.



NOTES

1\.

BAND	1	2	3	4
BAND MULT	1	2	4	8

2\. $N = \frac{DIAL + 300}{12.5 \times BAND\ MULT} - 160$ WITH ALL DIGITS BEHIND THE UNITS DIGITS DROPPED. N IS A WHOLE NUMBER BETWEEN 0 AND 160 WHICH REPRESENTS THE NUMBER OF COURSE POSITIONS TRAVELED BY THE FREQ CHANGE MECHANICAL LINKAGE.

3\. THE 10 ERROR BALANCES OUT IN THE PHASE AND FREQ DISCRIMINATOR.

4\. THE SMO FREQ INJECTION SYSTEM SETS UP SO THAT ONLY THE PROPER MO FREQ WILL RESULT IN $F_4 = 455$KC. DURING SET UP THE MO FREQ IS INCORRECT, AND FREQ DISCRIMINATION PULLS THE MO TOWARD THE PROPER FREQ. WHEN F_4 REACHES 455KC, PHASE DISCRIMINATION RESULTS IN AN ELECTRICAL TUNING CURRENT OUTPUT WHICH PHASE LOCKS THE MO ON FREQ. IN THE PHASE LOCK CONDITION, THE MO OUTPUT ASSUMES THE CORRECT PHASE $Ø_{COR}$ SO THAT PHASE DISCRIMINATION WITH $Ø_{REF}$ PRODUCES AN OUTPUT WHICH MAINTAINS EQUILIBRIUM IN THE STABILIZING LOOP AND HOLDS THE MO ON FREQUENCY. IN THE PHASE LOCK CONDITION, F_{MO} TRACKS F_{REF} RESULTING IN MO STABILITY EQUAL TO REFERENCE FREQUENCY STABILITY.

5\. BAND 1 MO OUTPUT IN 1KC STEPS.
BAND 2 MO OUTPUT IN .5KC STEPS.
BAND 3 MO OUTPUT IN .25KC STEPS.
BAND 4 MO OUTPUT IN .125KC STEPS.

Figure 11-19.—Frequency generator, block diagram.

Stabilized Master Oscillator

In conventional a-m transmitters, the final output is obtained by multiplying the basic oscillator frequency in one or more stages. Special care must be taken to ensure that the multiplier stages operate at an exact harmonic frequency during tuning, and that the stages remain on frequency throughout the transmission.

In single-sideband transmitters, the final output normally is obtained by heterodyning in mixer stages. The sum frequency can be many times the original frequency and contain the same modulation components. To yield the desired output frequency, the injection frequency must be exact, and it may be controlled automatically. This process is used in the transmitter section of the AN/URC-32.

The stabilized master oscillator (center section, fig. 11-19) consists of a master oscillator and a stabilizing loop that provides error correction for the master oscillator. The master oscillator is an inductance-tuned oscillator that can be adjusted mechanically in 0.5-kc increments through the frequency range of 2 to 4 mc. It can be tuned to any 1 of 2000 1-kc r-f tuner channels in band 1. In band 2, it can be tuned to any 1 of 4000 1-kc r-f tuner channels.

Bands 3 and 4 of the r-f tuner, containing 8000 and 16,000 1-kc channels, respectively, require the master oscillator to produce a greater number of injection frequencies than are possible with the mechanical positioning device. Generation of the additional increments is accomplished by positioning the master oscillator mechanically to the nearest lower 0.5-kc increment. Then the stabilizing loop is operated automatically so as to position the master oscillator electronically to the additional required increments.

Electronic tuning of the master oscillator is accomplished by varying the d-c component of current in a saturable reactor located in the tuning circuit of the oscillator. This process is described later. The master oscillator output frequency can be computed by the formula:

$$\text{FMO} = \frac{\text{Dial} + \text{add} + 300}{\text{Band Mult}}$$

Where FMO = the master oscillator frequency in kilocycles;

DIAL = the frequency generator dial frequency;

Add = the ADD KC indication on the band change switch (fig. 11-17);

300 = the 300-kc fixed i-f subtracted in the 5-f tuner i-f mixer;

Band Mult = multiplication of the master oscillator frequency in the r-f tuner;

- Band 1 = 1;
- Band 2 = 2;
- Band 3 = 4;
- Band 4 = 8.

The master oscillator stabilizing loop tunes the master oscillator electronically to the desired frequency and phase-locks it to the reference oscillator. A master oscillator frequency accuracy/stability, equal to that of the reference oscillator, can thus be maintained. This action is accomplished by comparing the master oscillator signal with the reference oscillator signal in a phase and frequency discriminator. The stabilizing loop operates as follows: The 2- to 4-mc output of the master oscillator is multiplied by 8 and is applied to mixer V2. There it is beat with a selected 100-kc signal from the spectrum generator.

The triggering signal for the 100-kc spectrum generator is obtained from the reference oscillator. The output of mixer V2 is filtered in FL1 and is applied to mixer A3V1. In this mixer it is beat with a signal from the sidestep oscillator or the reference oscillator.

The sidestep oscillator injection is used to obtain, electronically, the frequency increments that cannot be obtained by mechanically tuning the master oscillator. The output of mixer A3V1 is filtered to obtain a difference frequency between 970 and 1130 kc and is applied to mixer A3V2. In this mixer it is beat with a signal from the interpolation oscillator. The interpolation oscillator A5V1, which is tuned by a mechanically operated tuning shaft, supplies an injection signal. In turn, the injection signal produces a mixer difference frequency F_4. This frequency is 455 kc plus the master oscillator error and the interpolation oscillator error.

The mixer A3V2 output frequency (F_4) is filtered, amplified, and applied to the phase and frequency discriminator. Here F_4 is compared with a reference frequency (F_{REF}).

The reference frequency (F_{REF}) is generated by converting a 4-kc signal from the frequency divider to a 4-kc spectrum in the 1000- to 1100-kc frequency range and mixing it in A6V1 with the interpolation oscillator output. The reference frequency (F_{REF}) is equal to 455 kc plus the interpolation oscillator error. The interpolation error present in both F_{REF} and F_4 is balanced out in the phase and frequency discriminator.

When F_4 (which contains the oscillator error) is exactly 455 kc, phase discrimination of F_{REF} and F_4 results in a tuning current output from the discriminator (f-m detector), which phase-locks the master oscillator on frequency. In the phaselocked condition, the master oscillator output frequency assumes the correct phase (Φ_{COR}) and, in comparison with the reference phase (Φ_{REF}), produces an output which maintains equilibrium in the stabilizing loop and holds the master oscillator on frequency. Thus, in the phase-locked condition, the master oscillator frequency (F_{MO}) tracks the reference frequency (F_{REF}), resulting in a master oscillator stability equal to the reference frequency stability.

Sidestep Oscillator

The sidestep oscillator (shown also in fig. 11-19) provides the injection frequency for the subtractive mixer A3V1 of the stabilized master oscillator. The term "sidestep" refers to a change from a given frequency by a definite number of kilocycles. The injection frequency is sidestepped by 1, 2, or 3 kc, as required, to obtain the electronic tuning necessary to supplement the mechanical tuning of the master oscillator in the SMO. Sidesteps 1, 2, and 3, are referred to as ADD 1, ADD 2, and ADD 3, respectively, and indicate the number of kilocycles the sidestep oscillator output is displaced from 2400 kc.

The output of the pulse generator (Q1, Q2), the 2.4-mc injection signal, and the crystal oscillator V2 output are mixed in the subtractive mixer V1 to provide a 455-kc output. This signal is mixed with the crystal oscillator output in additive mixer V4 to produce the sidestep oscillator output. The output can be changed in steps of 1 kc by selection of the V2 crystal oscillator frequency, while maintaining a stability on all output frequencies equal to that of the reference oscillator input.

Frequency Divider

The frequency divider (top center, fig. 11-19) supplies a 4-kc signal to the stabilized master oscillator and a 1-kc signal to the sidestep oscillator.

The frequency divider consists of square wave generator-amplifier Q1 and three multivibrator-type frequency dividers. The 100-kc signal from the reference oscillator is amplified in Q1, and divided to 20 kc by one multivibrator (Q2 and Q3). The 20-kc signal is divided to 4 kc by another multivibrator (Q4 and Q5), and the 4-kc signal is divided to 1 kc by a third multivibrator (Q6 and Q7). Because the 4-kc and 1-kc input signals are derived from the 100-kc input signal, their stability is equal to that of the reference oscillator.

Reference Oscillator

The reference oscillator (top left, fig. 11-19) provides the basic reference frequencies of 100 kc and 2.4 mc for the entire equipment. Because the frequency accuracy of the equipment depends on the stability of the 3-mc crystal oscillator, the crystal is enclosed in a temperature-controlled oven.

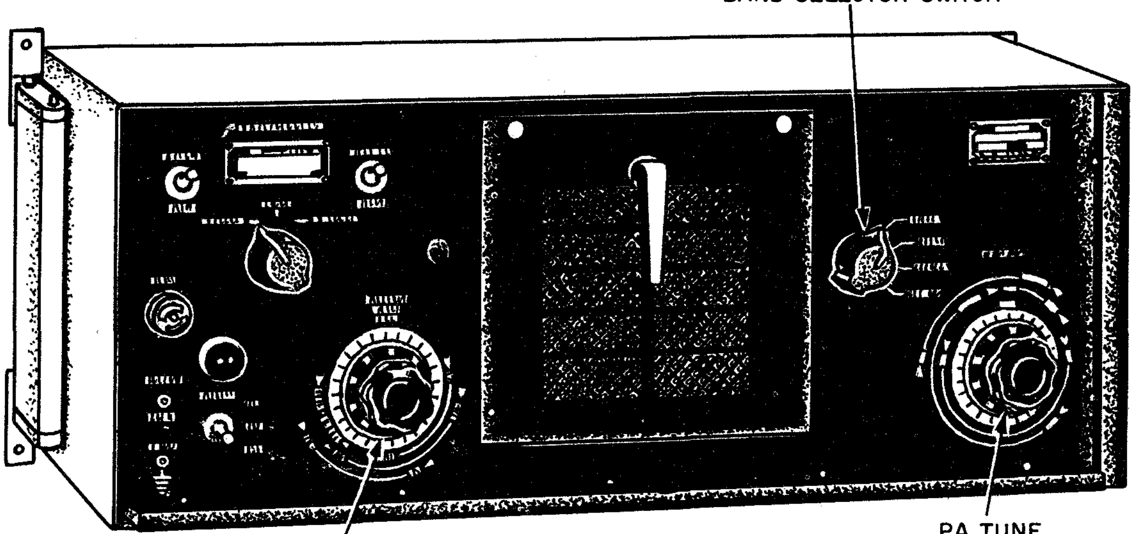
The 3-mc output of the crystal oscillator is fed through buffer amplifier Q6 to a regenerative divider circuit. This circuit consists of subtractive mixer Q7 and times 4 multiplier stage Q10.

The 2.4-mc output of the Q10 multiplier stage is fed through output amplifier Q12 to the sidestep oscillator.

The 600-kc output of the regenerative circuit is fed through buffer amplifier Q8 to another regenerative divider, which consists of subtractive mixer Q9 and times 5 multiplier stage Q11. Buffer Q8 isolates the two regenerative circuits. The 100-kc output of the divider circuit is amplified in Q13, then is fed to the frequency divider, the stabilized master oscillator, and to the sideband generator. The 100-kc output of the reference oscillator represents the frequency standard for the equipment, and has a long-term stability of 1 part 10^8 cycles per day.

POWER AMPLIFIER

The power amplifier (fig. 11-20) is composed of two r-f stages, which amplify the 0.15-watt PEP signal from the frequency generator to a nominal output power of 500 watts PEP. As shown in figure 11-21, it contains a driver stage (V1-V2), a power amplifier stage (V3-V4), a TGC rectifier, a bias and filament



32.160

Figure 11-20.—Power amplifier.

supply, and the necessary control and interlock circuits.

The driver and power amplifier plate circuits are tuned manually in four bands through the frequency range of 1.7 to 31.7 mc. The power amplifier plate circuit uses a tuned pi network to obtain an unbalanced 50-ohm output impedance over the complete range of frequencies.

Driver Stage

The output r-f signal from the r-f tuner is fed through coaxial cable to r-f input jack J1 (fig. 11-22). Resistor R1 terminates the line in its characteristic impedance.

Driver tubes V1 and V2 are connected in parallel to increase the current-carrying capabilities of the stage and to ensure conservative operation of the tubes. Parasitic suppressors Z1 and Z2 reduce the generation of undesired frequencies.

The shunt-fed plate output tuned circuit of V1 and V2 consists of variable inductor L4 and one of the capacitors (C16, C17, or C18) in shunt with the input capacitance between the grid and ground of the power amplifier stage. The driver plate tank is tuned to the desired operating frequency by the driver tune control on the PA front panel (fig. 11-20), which varies the inductance of L4 (fig. 11-22).

Driver-PA band selector switch S2 (section S4A) selects the V1 and V2 driver plate tuning capacitance for operation on any of the four bands. The switch is shown in the band 1 position. On bands 2, 3, and 4, S4A connects one of the resistors (R28, R27, or R26), in parallel with the tuned circuit. This action reduces the Q of the circuit from that obtained on band 1 so that the V3 and V4 power amplifier grid driving voltage remains approximately equal on each of the four bands.

Power Amplifier Stage

The power amplifier stage (V3 and V4) is parallel-connected and uses two 4X250B tetrodes. Parasitic suppressors R38 (in the grid input path) and Z3 and Z4 (in the plate circuits) suppress undesired oscillations.

The driver (V1 and V2) output from the C9-L4 junction is amplified in V3 and V4. On bands 1 and 2, L8 and L9 in series constitute the PA plate load inductance. For operation on

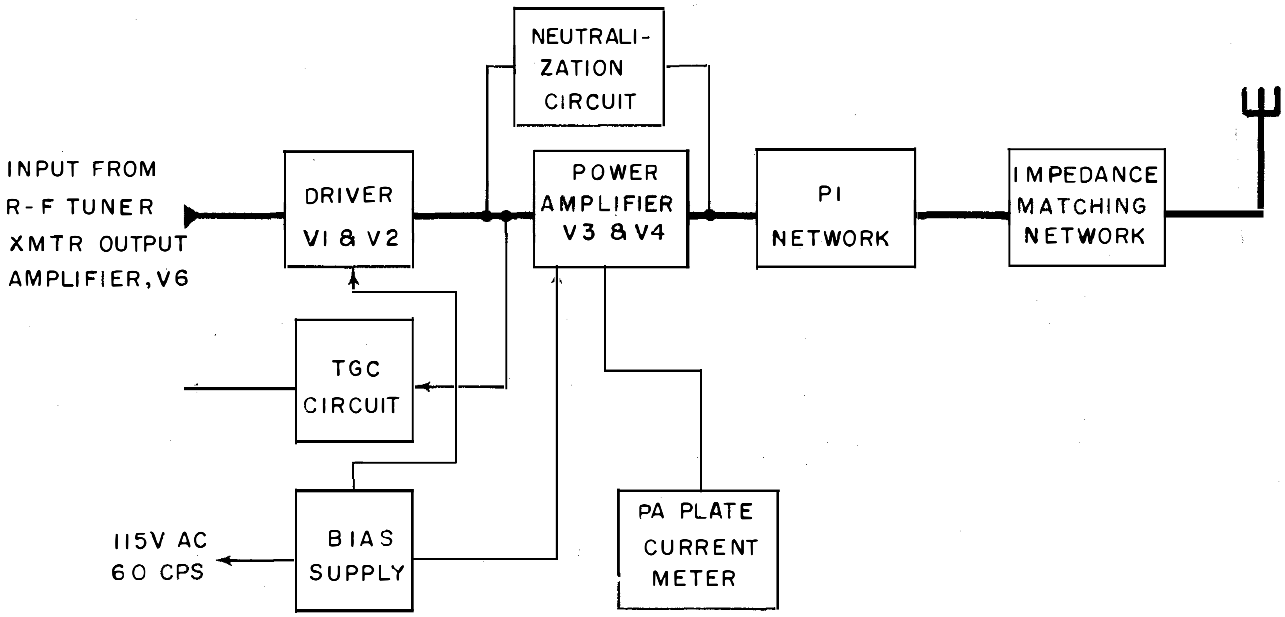


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Figure 11-21.—Power amplifier, block diagram.

bands 3 and 4, S3D closes (opposite the position shown) to short L9.

Capacitor C20 couples the 500-watt PEP output signal from the power amplifier to a pi network (low pass filter) consisting of C33, PA tune control L10, C29, and any of the capacitors C21 through C28, as determined by the position of S4B. The C33 and C29 capacitances are used in the network on all bands. On band 1, driver-PA band selector switch S4B connects C21 to C28 inclusive in parallel with C33. On band 2, S4B removes from the circuit C21 and C25 to C28 inclusive. On band 3, S4B removes C23 and C24, in addition to those previously removed. On band 4, only C33 and C29 remain in the pi network. The PA tune control L10 tunes the pi network to the desired operating frequency within the selected band. With proper adjustment, the pi network presents a 50-ohm output impedance over all four bands.

Loading the transmitter is accomplished for each of the four bands by switching taps on L11, and by the selection of one of the capacitors C30, C31, or C32. Both the L and C selections are made by S4C. The loading network permits the transmitter output to be tuned over the entire 1.7- to 31.7-mc range with nearly constant output. Output power is delivered via r-f output jack J2 to an antenna network (if used) or to the antenna.

NEUTRALIZATION.—A bridge neutralization circuit is included in the power amplifier stage (V3 and V4) to balance out the feedback from plate to grid. This feedback is caused by the interelectrode capacitance of the tubes. Simplified diagrams of the neutralizing circuit are shown in figure 11-23.

The neutralizing feedback voltage is applied from the plates of V3 and V4 (fig. 11-23, A) to the grids of these tubes through C10, C8, and C12. These capacitors are lumped together as Cn in figure 11-23, part B. The grid-plate interelectrode capacitance is represented as Cgp, and Cgf represents the sum of the input capacitances to V3 and V4, which consists of the grid-cathode interelectrode capacitance and all stray capacitance. The combined capacitance, along with the driver tank inductance L4, form the bridge circuit in figure 11-23, B.

The grid-plate capacitance Cn can be adjusted within limits for different amounts of feedback voltage. The Cn capacity is adjusted properly when Ecn = Ecgp. Because L4 is connected between diagonally opposite corners of the bridge, it follows that the bridge is balanced when $\frac{Ecn}{Ec15} = \frac{Ecgp}{Ecgf}$. When this balancing occurs, the r-f feedback potential to ground from both ends of L4 is equal and in phase so that no feedback r-f voltage via Cn or Cgp is developed across L4. Only the output voltage across the L4 driver tank is applied to the V3-V4 grids.

TRANSMIT GAIN CONTROL CIRCUIT.—The transmit gain control circuit (fig. 11-24) automatically adjusts the gain of the transmitter i-f amplifier in the r-f tuner and of the TGC amplifier in the sideband generator. The TGC output (fig. 11-24) is a negative voltage applied to the grids of these stages. This action ensures that the driving signal to the power amplifier V3 and V4 (fig. 11-22) will operate the power amplifier tubes at maximum capability but that it will not overdrive the tubes.

The TGC output voltage is obtained by rectifying a small portion of the driver (V1-V2) output signal. This voltage exists from the bottom of the driver plate tank to ground (across C15).

The amplitude of the driver plate tank input controls the amplitude of the TGC output. With no audio input, the driver plate tank signal is zero. Thus the TGC bias across C51 comes from the PA bias supply.

With an audio input, the amplitude of the driver plate tank voltage increases, and C51 charges to a higher voltage. The C51 output is negative to ground and comprises the TGC signal.

POWER SUPPLIES

Plate voltage for the power amplifier tubes V3 and V4 (fig. 11-22) is obtained from the +2000-volt high-voltage supply shown in figure 11-25. The high-voltage power supply utilizes eight series-connected silicon rectifiers in each leg of a bridge circuit. Silicon rectifiers operate efficiently at much higher temperatures than selenium or germanium rectifiers. Additionally, silicon rectifiers have less reverse (leakage) current. This advantage results in less power loss and less heat radiation in the power supply unit.

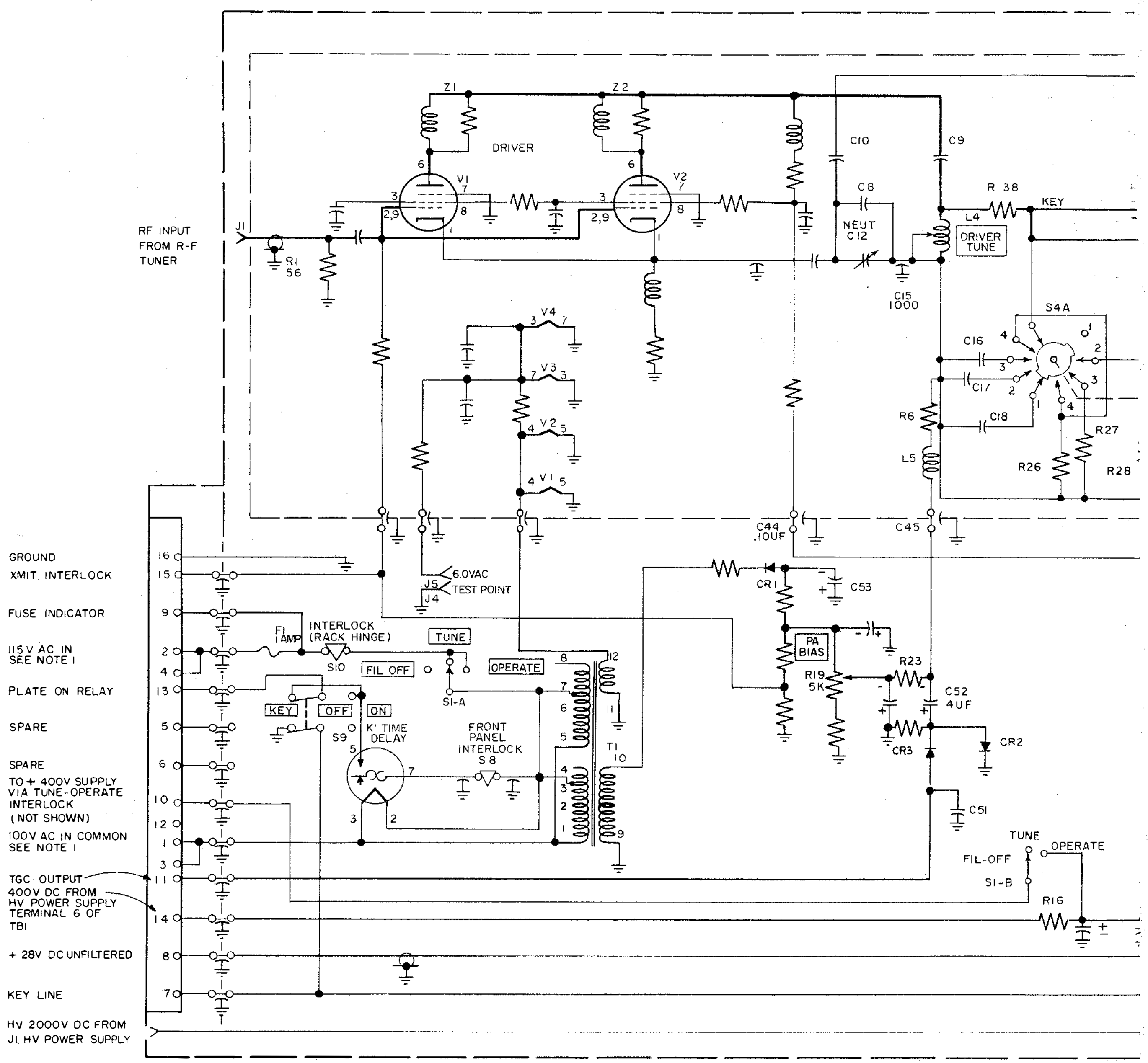
The input voltage is applied to transformer T1 through relay K1. The output of the transformer is coupled to the two rectifier bridges, which are connected in series to provide +2000-volt and +400-volt d-c output. Switch S1 is a case interlock that operates switch S2 to the open position (as shown) when the power supply cabinet is closed. The 400-volt d-c supply consists of rectifiers CR1 through CR12, connected in a conventional full-wave bridge rectifier circuit. The output is fused by F2 and filtered by inductor L2 and resistor R1. The 2000-volt d-c supply consists of CR13 through CR44. The output is filtered by L1, C1, and C2. Fuse F3 protects the circuit. Resistors R2, R3, and R4 are bleeders.

A low-voltage power supply (fig. 11-26) provides several outputs of relatively low voltage. The input voltage is applied to the primary of transformer T1 through switch S1. The secondary of the transformer supplies all the rectifier circuits. The +250-volt supply uses a full-wave bridge rectifier and choke input filter. The +130-volt supply is connected to the center tap of the +250-volt supply and contains an LC filter. Indicator light DS1 is tied across the 12.6-volt a-c supply. The unfiltered +28-volt supply is taken from directly across the full-wave rectifier diodes CR6 and CR7. The partly filtered +28-volt supply is taken from across a one-section LC network. Diode CR8 isolates the filtered, regulated 28-volt d-c supply from the other 28-volt d-c supplies. Isolation prevents C4 and C6 from discharging into the low impedance of the other supplies. After passing through an RC filter, the output voltage is clamped by Zener diode CR9, which conducts when the voltage across it rises above 27 volts d-c. The -90-volt supply uses a half-wave rectifier with an RC filter.

HIGH-FREQUENCY TRANSMITTER AN/WRT-2

This part of the chapter presents a brief description of high-frequency radio transmitter AN/WRT-2. The transmitter covers the same range of frequencies as the AN/URC-32, which is a transceiver, whereas AN/WRT-2 is a transmitter only. Coverage in this chapter is limited to the overall functional operation of the equipment.

The AN/WRT-2 transmitter covers the frequency range of 2 to 30 mc. It is installed in surface ships and submarines. Its single-sideband capability makes it a more versatile transmitter than the AN/SRT-14, -15, -16 series presented in chapter 8.


RF INPUT FROM R-F TUNER
J1
R1 56
DRIVER
Z1
Z2
V1
V2
C10
C9
C8
NEUT C12
R 38
KEY
L4
DRIVER TUNE
C15 1000
S4A
C16
C17
C18
R6
L5
R26
R27
R28
V4
V3
V2
V1
C44 .10UF
C45
GROUND
XMIT. INTERLOCK
FUSE INDICATOR
115V AC IN SEE NOTE 1
PLATE ON RELAY
SPARE
SPARE
TO + 400V SUPPLY VIA TUNE-OPERATE INTERLOCK (NOT SHOWN)
100V AC IN COMMON SEE NOTE 1
TGC OUTPUT
400V DC FROM HV POWER SUPPLY TERMINAL 6 OF TB1
+ 28V DC UNFILTERED
KEY LINE
HV 2000V DC FROM J1, HV POWER SUPPLY
6.0VAC TEST POINT
J5
J4
F1 1 AMP
INTERLOCK (RACK HINGE)
S10
TUNE
FIL OFF
OPERATE
S1-A
KEY
OFF
ON
S9
K1 TIME DELAY
FRONT PANEL INTERLOCK S8
T1
CR1
C53
PA BIAS
R19 5K
R23
C52 4UF
CR2
CR3
C51
TUNE
OPERATE
FIL-OFF
S1-B
R16

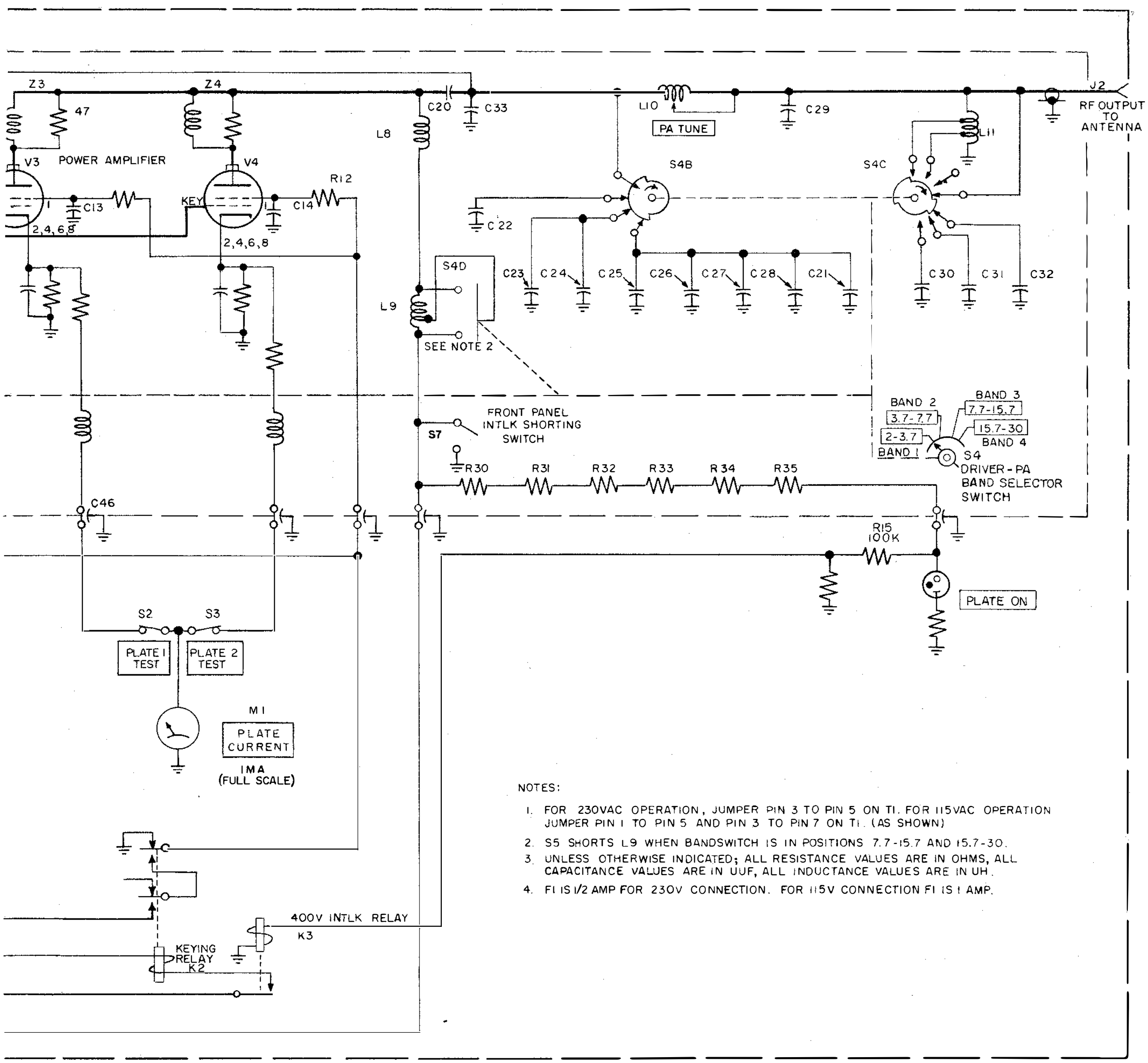


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Figure 11-22.—Power amplifier, schematic diagram.

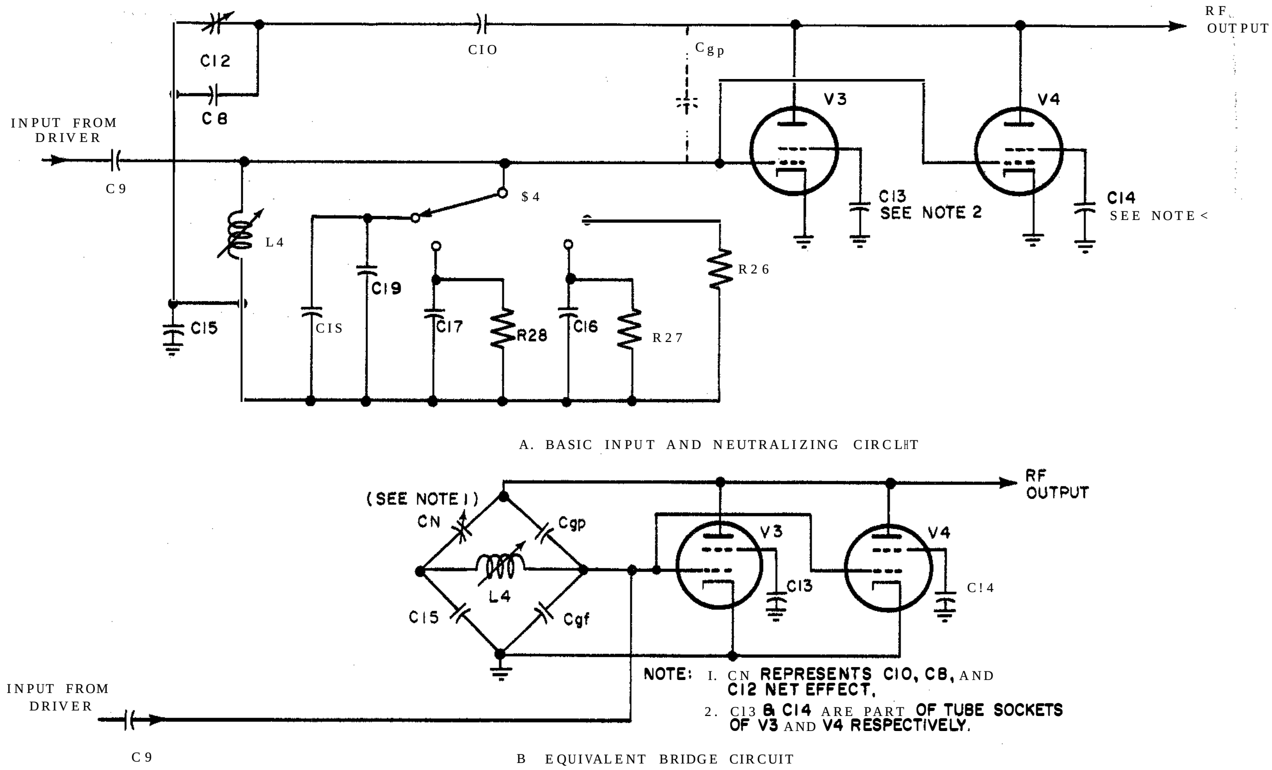

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Figure 11-23.—Power amplifier, neutralizing circuit.

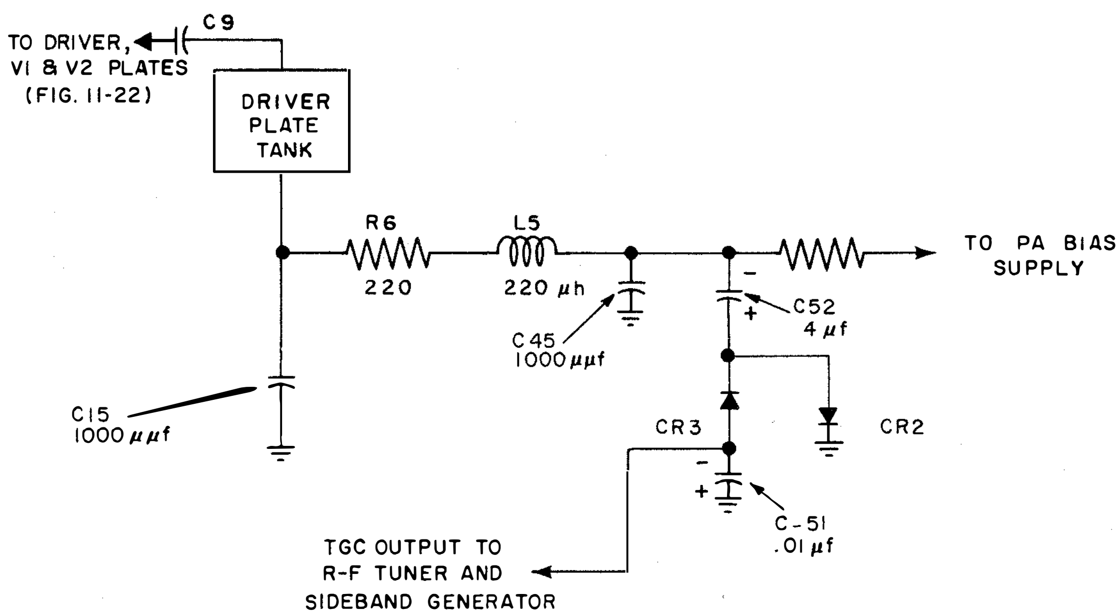

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Figure 11-24.—Transmit gain control (TGC) circuit.

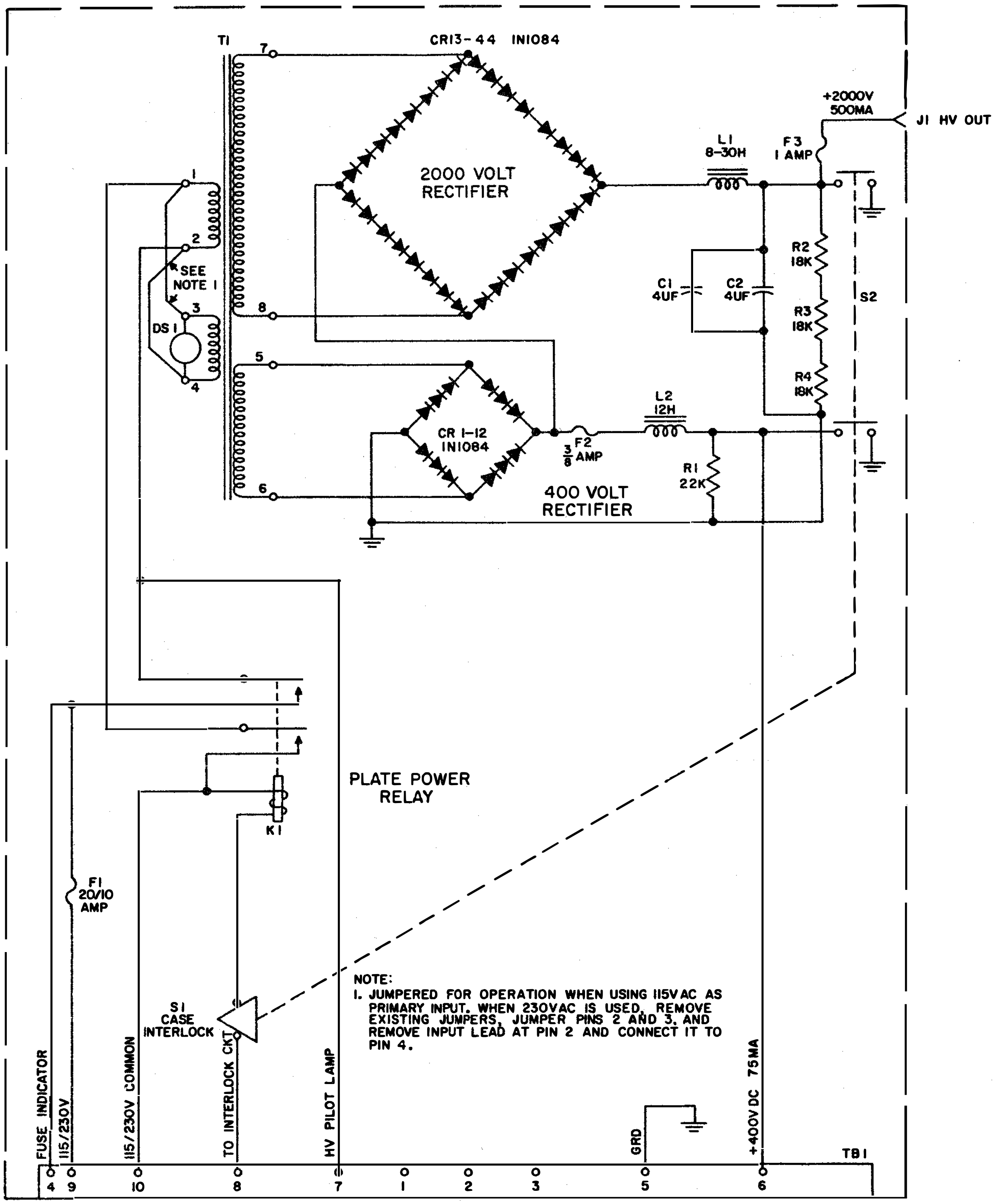

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Figure 11-25.—High-voltage power supply, schematic diagram.

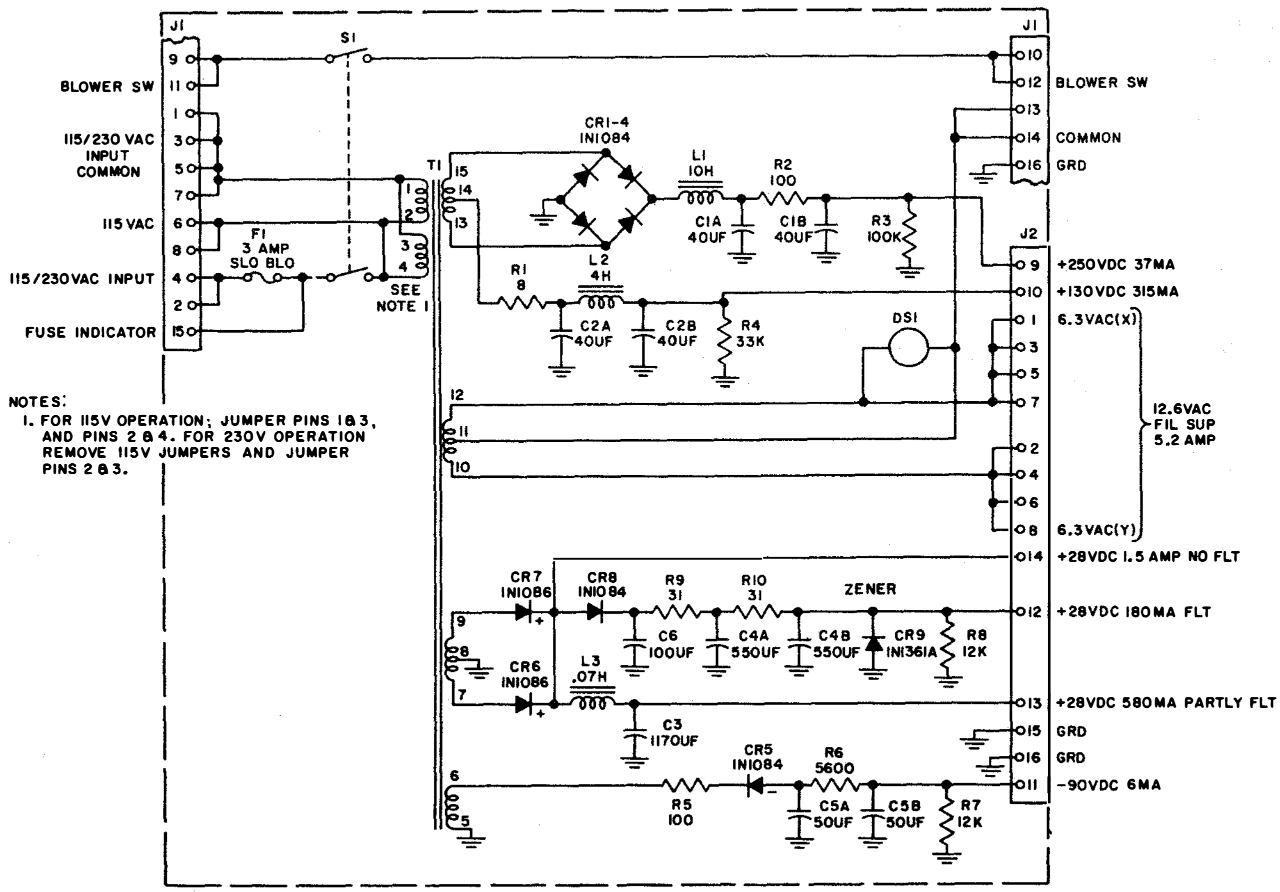

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Figure 11-26.—Low-voltage power supply, schematic diagram.

The AN/WRT-2 can be used for hand- or machine-keyed CW, single sideband (SSB), independent sideband (ISB), a-m radiotelephone, frequency shift RATT, and FAX. The power output varies with different transmission modes. For SSB operation on either upper or lower sideband, and for ISB, it has a peak envelope power (PEP) of 1000 watts. For CW and frequency shift RATT, the output is 500 watts. On a-m phone emission, the average output is 500 watts, with one sideband and carrier reinsertion.

GENERAL DESCRIPTION

Major components of the AN/WRT-2 transmitter (fig. 11-27) are the transmitter group and the radiofrequency tuner. The r-f tuner is mounted topside in the superstructure, close to the antenna. The tuner shown in figure 11-27 is used only in surface ships. For submarine installations, a different r-f tuner is required.

The transmitter group consists of the electrical equipment cabinet and five equipment drawers. These five drawers, from top to bottom, are—

Radiofrequency amplifier;
Radiofrequency oscillator;
Electrical frequency control;
Amplifier power supply;
Power supply.

Provision is made for a total of six audio inputs. Radiotelephone operation is available either from a local handset or from remote radiophone units. Interconnections to teletypewriter equipment and to a remote transmitter standby control are available also. One of the features of this transmitter is the internal dummy load for tuning under radio silence conditions.

FUNCTIONAL BLOCK DIAGRAM

Figure 11-28 is a functional block diagram of the AN/WRT-2 transmitter. It consists of the following functional sections: primary power circuits, low-voltage power supply, r-f generating, modulating, and power amplifier sections.

The primary power functional section contains all the circuits that supply a-c power to the transmitter. The transformers in the primary power section have taps, allowing for input voltages of 115 volts, 220 volts, or 440 volts at 60 cps.

The low-voltage functional section contains all the circuits that supply the d-c voltages to the transmitter, with the exception of the high-voltage rectifiers contained in the power amplifier section. Thus, the low-voltage section contains the ±350-volt power supplies, the -24-volt supply, the +250-volt, +24-volt, and -6-volt regulators. The low-voltage section also has the 12-volt POS and 12-volt NEG power supplies for use in the microphone circuits.

The +350-volt and -350-volt supplies are used as plate and bias voltages for the tubes in the transmitter.

The -24-volt supply is used in the d-c control circuits. The +250-volt regulated supply is needed in the critical circuits of the master oscillator and the frequency control circuits in the r-f generating section. The +24-volt regulated voltage is for circuits of the 1-mc oscillator in the r-f generating section and those of speech amplifiers in the modulating functional section. The -6-volt regulated voltage is used in the circuits of the 1-mc oscillator in the r-f generating section of the transmitter.

The r-f signal is generated by a master oscillator in the r-f generating section, and is fed to the power amplifier through frequency multiplier circuits. The master oscillator is slaved to the selected operating frequency by the frequency control circuits. A part of the master oscillator r-f output is fed to the frequency control circuits. Crystal oscillators in the frequency control circuits provide harmonics of 100-kc. These harmonics are mixed with the r-f signal from the master oscillator in a balanced modulator (mixer). The output from the mixer is a comparison i-f signal. This i-f signal is compared with the frequency of an interpolation oscillator. When the two frequencies are the same, the master oscillator is operating at the proper frequency. When the two frequencies differ, the control circuit returns the master oscillator to the proper frequency. The operating frequency of the AN/WRT-2 is also stabilized by slaving the interpolation oscillator to a 1-kc lock-in circuit. In this usage, the output of the interpolation oscillator is compared with 1-kc reference signals in a phase detector circuit. A d-c correction voltage is then applied to the interpolation oscillator to lock it in with the 1-kc crystal-stabilized reference signals.

In the modulating functional section, the keying circuits provide the proper modulation signals for CW keying and frequency shift keying. For phone operation, the audio input is amplified by speech amplifiers. The audio signal is then applied to the modulator circuit when single-or independent-sideband signals (with suppressed carrier) or a-m signals (with upper sideband and carrier) are to be generated. The output of the modulator circuit is applied to the input mixer in the power amplifier circuits as shown in figure 11-28.

The power amplifier section consists of the high-voltage power supply, the input mixer and driver circuits, the r-f amplifier, the r-f monitor, and the r-f tuner circuits.

High-voltage power for the r-f amplifier tube is provided by a three-phase rectifier circuit. The r-f signals from the r-f generating section and modulating section are applied to the input mixer in the power amplifier section. The output of the mixer is a modulated r-f signal, which is the sum of the two input signal frequencies. This modulated signal from the input mixer is then applied to the r-f amplifier through a driver stage. Power amplifiers raise the r-f signal to the desired operating power level. Then the output of the power amplifier is fed to the antenna through the r-f tuner circuits. The r-f monitor circuits in the power amplifier section consist of a modulation monitor and a reflectometer. The modulation monitor is used for measuring the modulation percentage. The reflectometer measures the output power level and voltage standing-wave ratio on the transmission line.

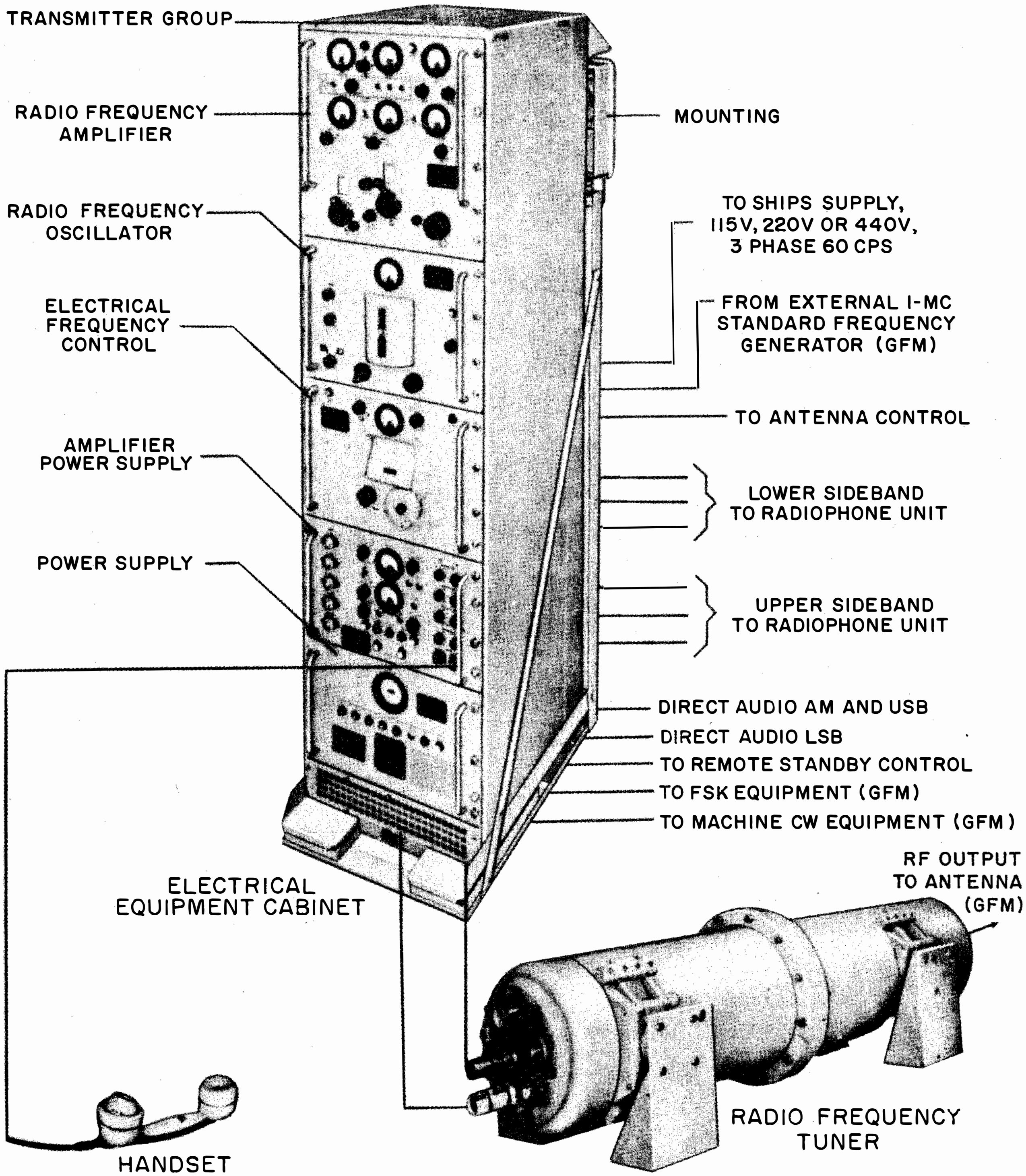

Figure 11-27.—Radio transmitter AN/WRT-2, relationship of units.

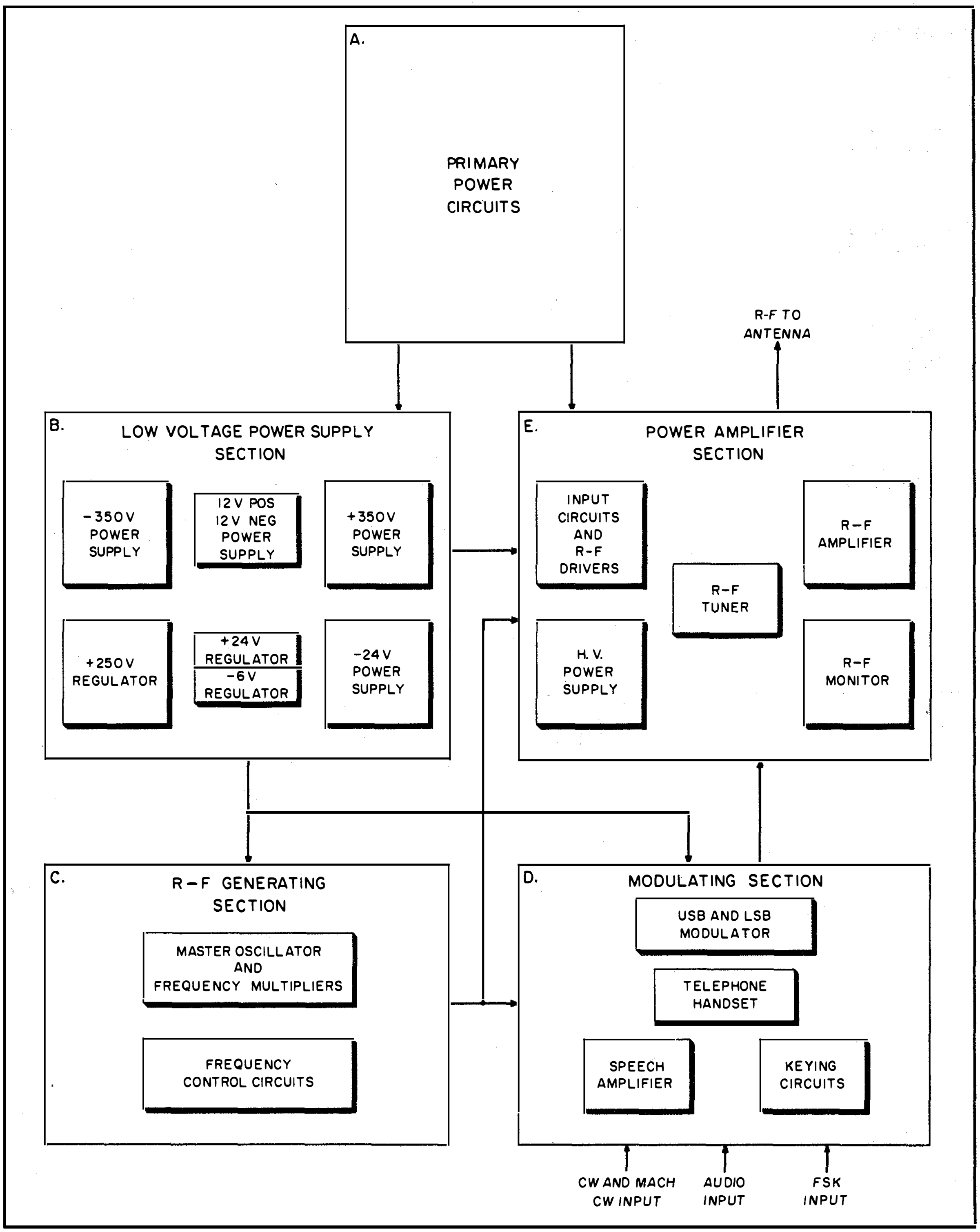

Figure 11-28.—Radio transmitter AN/WRT-2, functional block diagram.

CHAPTER 12

TELETYPEWRITER MAINTENANCE

Early methods of communication seem primitive compared with present-day teletypewriter systems. The teletypewriter and its associated equipment have made possible the enormous circuit capacity of naval communications. Teletypewriters provide fast and accurate service throughout the Navy, both afloat and ashore. This service means added responsibilities for every Radioman, especially for First Class and Chief. Duties of these RMs include, for example, supervision of RATT circuits and training lower rated men to operate and maintain teletypewriter equipment. Familiarity with teletypewriters and associated equipment is important as with transmitters and receivers.

This chapter describes the newer shipboard teletypewriter components installed throughout the fleet. Understandably, no attempt is made to supplant equipment technical manuals. Reference to those publications is necessary for making mechanical adjustments and for tracing the action of numerous moving parts. Complete instructions are given in equipment technical manuals for cleaning, lubricating, and adjusting equipment.

All corrective maintenance to teletype equipment should normally be performed by a qualified teletype repairman (a graduate of Teletype Maintenance School, NEC 2342). If no repairman is aboard, emergency repairs—including minor adjustments—may be necessary to keep equipment operating. A prerequisite, before attempting to repair equipment, is a thorough knowledge of adjustment and troubleshooting procedures outlined in the technical manual. Otherwise, permanent damage to the equipment may result.

THE TELETYPE CODE

As devised by Jean Baudot, a French signal officer, the teletype code requires that each character have a certain number of current and no current time intervals (mark or space pulses) to indicate a particular code combination. It was decided that the intelligence portion of each complete character should have five time intervals. Today, this method is referred to as five-level code. It is used exclusively in all armed forces communication systems. Modern teletype readout equipments used with computers, however, utilize eight intelligence pulses. This process is referred to as eight-level code.

With two possibilities (mark or space) for five intelligence pulses, 32 code combinations are possible ($2^5=32$). Twice the number of available code combinations can be performed by the teletype printer by adding uppercase figures. For individual pulses the length or time duration is determined by the operating period of various cams and levers that cause the signal line contacts to open and close. As operating speed increases, pulse length decreases. If, for every revolution of the transmitting shaft, a complete character is transmitted, 368 rpm may be referred to as 368 operations or characters per minute (opm). An expression of speed in words per minute (wpm) may be roughly approximated by dividing each figure by 6, assuming that a word is composed of five characters and a space.

Common speeds today, expressed in wpm, can be seen in the following chart.

OPM	Unit Code	WPM
368	7.42	61.1
390	7.00	65
404	7.42	67.3
428	7.00	71.3
460	7.42	76.6
600	7.42	100
636	7.00	106

Note that reference to "60 wpm" is actually 61.1 or 65, depending on the unit code used. For maintenance or other technical purposes, it is far more accurate to deal only with actual shaft speeds.

7.00 AND 7.42 UNIT CODES

To maintain synchronism between sender and receiver, a starting point and a stopping point must be established. To the character combination of five pulses (five-level code), consequently, a start pulse and a stop pulse were added. These pulses are not considered information pulses. The most common system used today adds a start pulse the same length as information pulses, and adds a stop pulse somewhat longer. In most instances, the stop pulse is 1.42 (142%) times as long as start or information pulses. If the start (or standard) pulse length is designated as one, the unit code is found to be 7.42 by adding unit quantities for start, information, and stop pulses. Thus:

		UNITS
Start pulse		1
Information pulses		5 (for five-level code)
Stop pulse		1.42
	Total	7.42

Many modern teletype systems utilize a stop pulse of the same length as start and information pulses. With all seven pulses the same duration, the system would be operating with the 7.00 unit code.

The present standard for naval communications is the 7.42 unit code. In the future, however, a change to the 7.00 unit code is expected. It should be understood that these two codes are fully compatible and will interoperate without loss of range at the receiving machine if their baud rates are consistent. For example, 100 wpm (7.42 unit code/74.2 baud) and 106 wpm (7.00 unit code/74.9 baud) are nearly the same baud rate, hence they will interoperate without a noticeable loss of range. The only exception to this principle occurs when transmitting at 7.00 unit code from a transmitter distributor (TD) through a security device. In such an instance the TD may transmit faster than the security device can accept. It then would be necessary either to convert the TD to 7.42 unit code or to step it from the security device. Conversion of the keyboard transmitting equipments is unnecessary, even though they are transmitting through a security device, because typing at a steady rate of 106 wpm is unlikely.

NEUTRAL-POLAR OPERATION

In normal (or rest) condition, the signal line is closed, that is, with current on the line. If normal condition is closed, the beginning or start pulse must alter that condition. Obviously, then, the start pulse must be no-current or spacing. At the end of the transmission, the signal line must be returned to its normal condition, hence the stop pulse must be current or marking. As seen on an oscilloscope, and assuming there is no distortion, character Y would be as shown in figure 12-1.

Character Y is used most often for illustration and test purposes because every other pulse is different. As indicated previously, however, information pulses (between start and stop pulses) may vary according to the character selected. It has been noted that the stop pulse normally is 1.42 times as long as the start or information pulses. This condition assumes that operation is continuous, otherwise the stop pulse will last until the next character is transmitted.

Only neutral operation has been considered up to now. In neutral operation, a space impulse occurs when there is no current on the line. A mark impulse refers to current on the line.

In polar operation, current is on the line at all times. It is the difference between the current polarity that determines whether a mark (plus) or a space (minus) impulse is being transmitted. Obviously, the teletypewriter printer could not be hooked directly to a polar signal line when selector magnets are wired in series, because current, regardless of polarity, would energize the selector magnets.

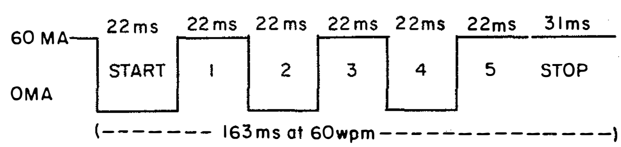

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Figure 12-1.—Character Y teletype signal.

BAUD RATE

A unit of signaling speed that combines shaft speed (or operations per second) and unit code into one usable term or figure is called the baud (from Baudot). This expression also indicates the maximum number of pulses per second. It is derived by multiplying the operations per second by the unit code. To illustrate: 368 opm ÷ 60 = 6.13 ops/sec X 7.42 (unit code) = 45.5 baud.

In the 7.00 unit code, both the operations per second and shaft speed differ: Thus: 390 opm ÷ 60 = 6.5 ops/sec X 7.00 (unit code) = 45.5 baud.

In the two illustrative cases cited, it may be seen that although both shaft speed and unit code differ, both equipments can be interoperated because their baud rate is the same.

DOT CYCLE FREQUENCY

Each mark-to-space transition and its complement, space-to-mark change, forms a rectangular wave. Any rectangular wave is made up of a fundamental sine wave, plus a number of subharmonic frequencies. This fundamental (or dot cycle) frequency of any character may be determined by dividing the length of 1 mark-to-space transition into 1. Every other pulse character Y changes from mark to space condition (fig. 12-1), so that 1 mark-to-space transition would equal the length of 2 pulses, or 0.044 second. In other words:

1 ÷ 0.044 = approx. 23 cps = dot cycle frequency of character Y.

Character M (2,4, and 5 mark) does not have as many transitions as Y. For M the start, first, and second pulses represent one part, and the third, fourth, and fifth pulses represent the other part of its rectangular waveform. Thus, adding the two parts:

Start, first, and second =	66 msec
Third, fourth, and fifth	66 msec
	132 msec

1 ÷ .132 = approx. 8 cps = dot cycle frequency of character M.

The dot cycle frequency is important in determining the necessary bandpass for teletype transmissions. If the highest frequency can get through, all others may. Character Y, consequently, with the maximum number of transitions, provides this maximum or reference frequency. It has been found that fundamental frequency, plus the next 10 or 11 harmonics, provides a good signal. The Bell System, however, uses only the third or fourth (around 89 cycles) for their bandpass.

MODEL AN/UGC-6 TELETYPEWRITER

Model AN/UGC-6 teletypewriter, shown in figure 12-2, is an electromechanical apparatus for sending and receiving both printed and tape-perforated messages.

Although discussion in this chapter is confined principally to the AN/UGC-6, the reader should understand the similarity between this and other models in the series. For example, the essential difference between AN/UGC-6 and AN/UGC-5 is that the latter does not include the typing reperforator. The AN/UGC-7 differs from the AN/UGC-6 in that it has a weather keyboard. (Certain keytops include aerological weather symbols instead of standard communication symbols.) The type box in the automatic typer unit and the type wheel in the typing perforator also have weather symbols to match the keyboard. Like the AN/UGC-5, the AN/UGC-7 also does not have a reperforator. Model AN/UGC-8 is like the AN/UGC-7, except that the typing reperforator is included.

As you can see, equipment nomenclature is changed as a result of changes in basic components. Additional nomenclature changes, moreover, depend upon the type of a-c motor installed. The AN/UGC-6, for instance, has synchronous a-c motors. With series governed motors (required for some installations), the model designation is changed to AN/UGC-6X.

The AN/UGC-6 teletypewriter was selected for presentation in this chapter because it contains all components for a complete message originating and receiving center, and because it is common throughout the fleet.

PURPOSE OF EQUIPMENT

Model AN/UGC-6 teletypewriter is a versatile communication equipment. It receives messages electrically from the signal line and prints them on page size copy paper. Moveover, it can receive messages and record them on tape in both perforated and printed form. With

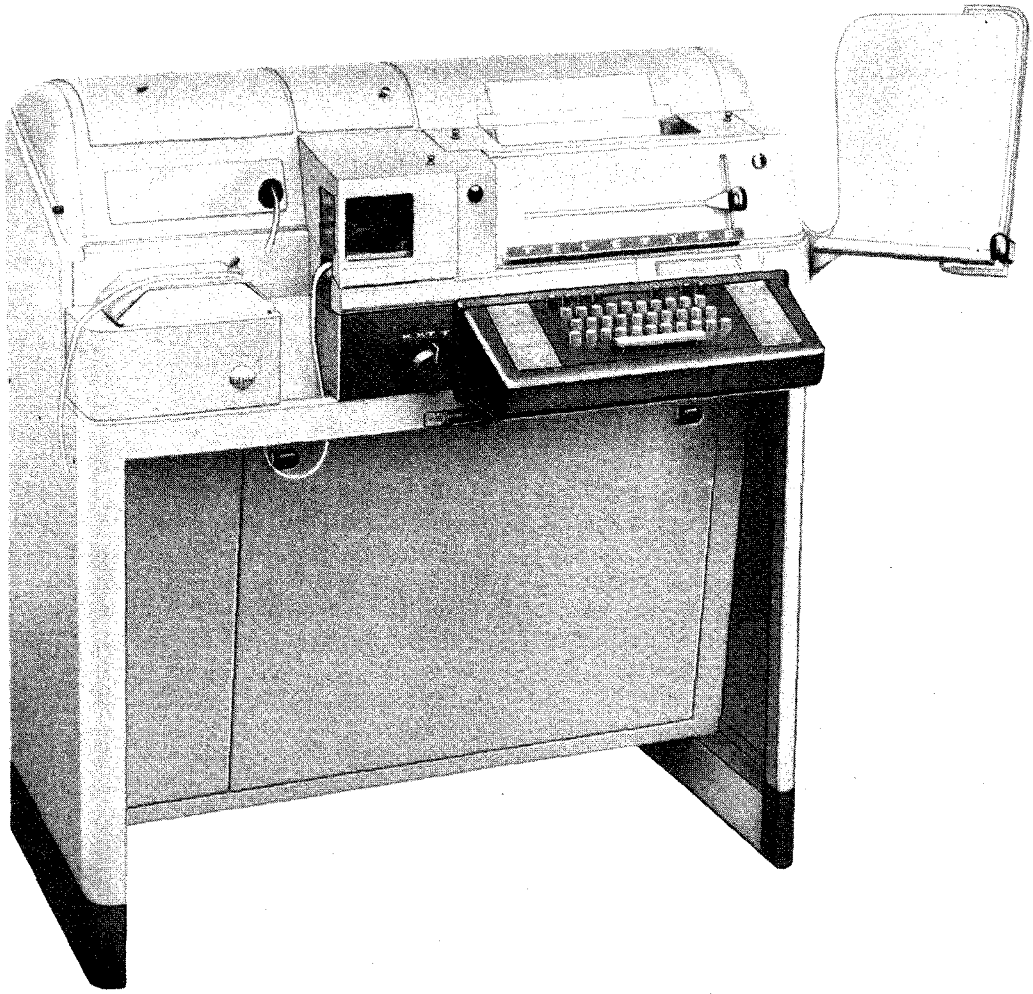

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Figure 12-2.—Model AN/UGC-6 teletypewriter.

page-printed monitoring, the teletypewriter electrically transmits messages that are originated either by perforated tape or keyboard operation. It mechanically prepares perforated and printed tape for separate transmission with or without simultaneous electrical transmission and page-printed monitoring.

Transmission between stations is accomplished electrically by use of the five-unit code described at the beginning of this chapter.

Nominal operating speed of the equipment is 60 wpm. Speeds of 75 wpm or 100 wpm can be attained by installing different gear sets. The trend today is toward the higher operating speed of 100 wpm.

The teletypewriter set is composed of these components: a cabinet mounting, a power distribution panel, a keyboard, an automatic typer, a typing perforator, a transmitter distributor, an auxiliary power distribution panel, and a typing reperforator.

In operation, the components are linked together by electrical or mechanical connections to offer a wide range of possibilities for sending, receiving, or storing teletypewriter messages. All equipment components are housed in the cabinet. Electrical connections between components are routed through the power distribution panels. Transmission signals are initiated through the keyboard or the transmitter distributor. Signals are received and local transmission can be monitored on the automatic typer. The typing perforator and typing reperforator are devices for preparing tapes on which locally initiated or incoming teletypewriter messages can be stored for future transmission through the transmitter distributor.

The keyboard, typing perforator, automatic typer, and transmitter distributor are operated by the motor mounted on the keyboard. Selection of these components for either individual or simultaneous operation is by the selector switch whose knob is located at the front of the cabinet, to the left of the keyboard. All these components are connected in series in the signal line, but the selector switch has provisions for shunting various components from the line. The typing reperforator is operated by a separate motor and power distribution system. It is connected to a separate external signal line.

The equipment is wired at the factory for operation on a signal line current of 60 ma. By making wiring changes in the power distribution panels and readjusting the armature springs on the selector magnets, it can be adapted for operation on 20 ma signal line current.

Page-printed messages are typed on standard size paper rolls 8 1/2 inches wide. Tape used for either perforating and printing messages for transmission or for recording incoming messages is 11/16 inch wide. It is supplied in 1000-foot rolls approximately 8 inches in diameter.

POWER DISTRIBUTION PANELS

Two power distribution panels in the AN/UGC-6 teletypewriter set serve as interconnecting points for wiring teletypewriter components. Panels are rectangular metal boxes, with a leg at each of the four corners. These panels contain terminal boards, switches, fuses, receptacles, relays, resistors, and other electrical components. Power distribution panels are mounted in the cabinet with their open ends down. The legs serve as supports when a panel is inverted for servicing. Both a-c and d-c line service are supplied to the power distribution panels through terminal boards in the cabinet.

The power distribution panel shown in figure 12-3 furnishes interconnecting points for all electrical circuits except those of the typing reperforator. This panel is mounted at the rear of the cabinet, behind the keyboard end of the cradle. Mounted in the panel, from left to right as installed in the cabinet, are a line test key, line shunt relay, receptacle for a line relay, rectifier assembly, power line fuse, convenience receptacle, and main power switch. This switch is remotely controlled by mechanical linkage from the front of the cabinet. The purpose of the line shunt relay is to short the signal line when the machine is turned off. This action prevents other machines in the same circuit from running open.

Two cables from the left end of the power distribution panel connect to terminal boards at the rear of the cabinet. Two additional cables from the left end of the panel connect to the keyboard and the transmitter distributor base. One cable from the right end of the panel connects to a cabinet terminal board. The other cable at the right end connects to the automatic typer.

The other power distribution panel, shown in figure 12-4, furnishes electrical interconnections for the typing reperforator. External configuration is similar to that of the other power distribution panel already described. It is mounted beneath the shelf of the cabinet on a special mounting rack. Components on the panel, from left to right, are a signal bell, line shunt relay, receptacle for a line relay, and a rectifier assembly. Power line connections are made through a connector on the reperforator base, which in turn is connected to terminal boards in the cabinet. Signal line connections are made to a terminal block on the underside of the panel.

To drive the selector holding magnets, many newer equipments have electronic selector-magnet driver units, which replace the line relay (such as the Western Electric 255A). This unit, a solid state device, couples a signal line to a receiving teletypewriter and repeats the line signal in a form that effectively operates the equipment's selector mechanism. Thus installed, it provides improved operation, greater reliability, and reduced maintenance. With different strapping arrangements, the driver accepts neutral signals of either 20 or 60 ma or polar signals of up to 30 ma. Regardless of input, the output is 60 ma. Input is essentially resistive rather than inductive (as is

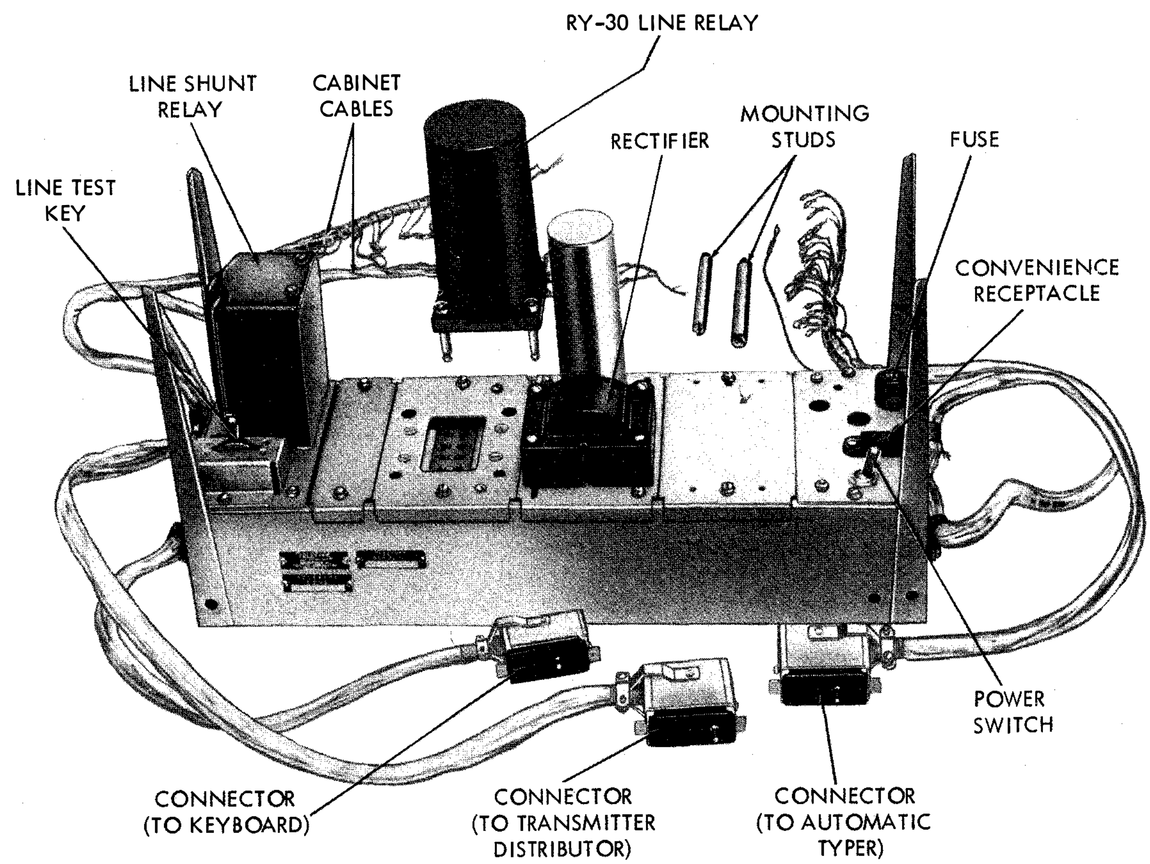


Figure 12-3.—Power distribution panel.

the WE255A relay), so that the driver permits inclusion of additional receiving units on a teletypewriter loop without introducing signal distortion.

MOTORS

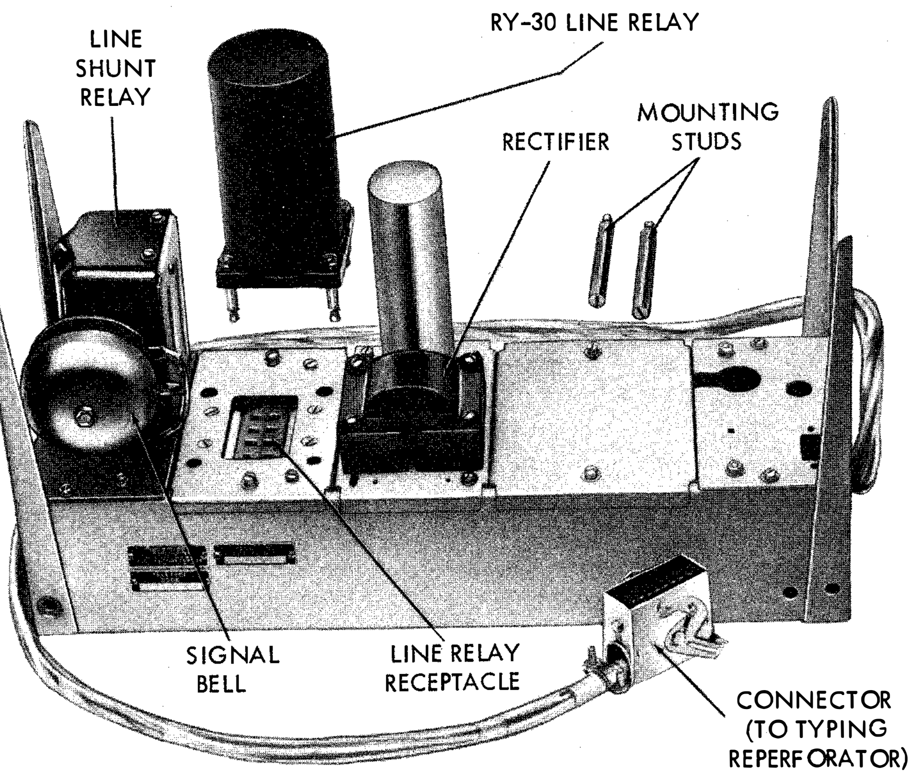
Two types of motors can be used with the AN/UGC-6 teletypewriter: synchronous and governed. Previously it was explained that the AN/UGC-6 uses synchronous motors. Installation of governed motors changes the model designation to AN/UGC-6X. The a-c synchronous motor is used in installations that have 60-cycle power with good frequency stability. Frequency stability is extremely important because the correct speed of the synchronous motor depends on a precise 60-cycle power source. Aboard ships and stations where the a-c power supply has poor frequency stability, teletypewriters are equipped with governed motors. Both types of motors are illustrated and described here.

Two a-c motors (either synchronous or governed) are required with each AN/UGC-6 teletypewriter. A heavy-duty motor supplies motive power for the automatic typer, keyboard, typing perforator, and transmitter distributor. The motor used exclusively to supply mechanical energy for the typing reperforator has a lower horsepower rating.

A-C Synchronous Motors

The a-c synchronous motors in the AN/UGC-6 are identical in size, appearance, and mounting requirements, though different in horsepower. The synchronous motor is shown in figure 12-5.

The heavy-duty synchronous motor is a 1/12-hp, 115-volt, 60-cycle a-c, single-phase,



50.107

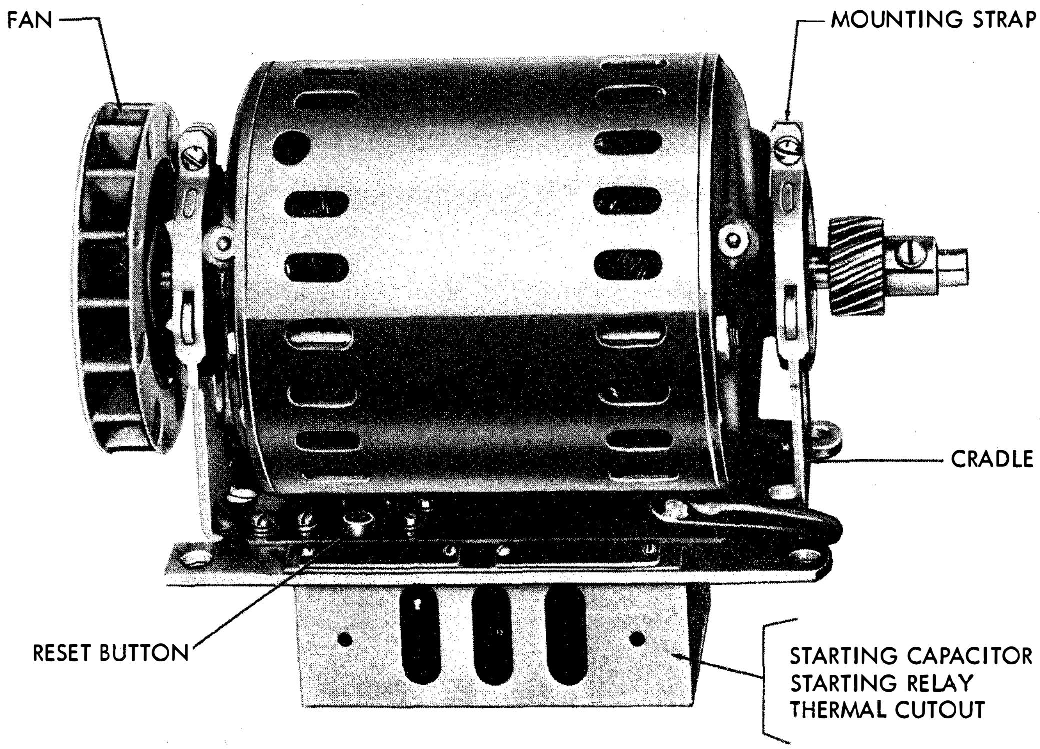
Figure 12-4.—Power distribution panel for typing reperforator.

capacitor-start motor, which runs at 3600 rpm. This motor has a two-pole wound stator and a squirrel cage type of rotor mounted on ball bearings. The stator has two windings, a main operating winding and an auxiliary starting winding (fig. 12-6). The auxiliary winding is in series with a current-operated motor starting relay. The initial starting current causes the relay to close, and its contacts in turn close the auxiliary winding circuit. As the rotor gains speed, current flowing through the motor and through the relay coil decreases. When a predetermined current value is reached, the relay armature is released, relay contacts are opened, and the auxiliary winding circuit is disconnected from the line. The rotor continues to accelerate until it reaches synchronous speed (3600 rpm).

The starting relay and capacitor, together with the thermal cutout switch, are mounted in a compartment on the underside of the motor. The thermal cutout switch is in series with both the main and the auxiliary motor windings, and if excessive current is drawn by the motor, the switch opens the circuit.

Thermal circuit breakers with which the synchronous motors are equipped protect the motors against excessively high temperature that might develop if a prolonged overload occurs that would be insufficient to stall the motors and blow the protecting fuses. Once operated, these cutout devices must be reset manually by pressing the reset button on the motor plate before the equipment can be restarted. Allow the motor to cool at least 5 minutes before manually depressing the reset button.

The motor is supported by a cradle to which it is held by straps at both ends. Resilient mounts on the hubs of the motor and bells reduce transmission of vibration. A combination handwheel and fan is mounted on one end of the motor



50.108

Figure 12-5.—A-C synchronous motor.

shaft. The shaft turns in a counterclockwise direction as viewed from the fan end of the motor.

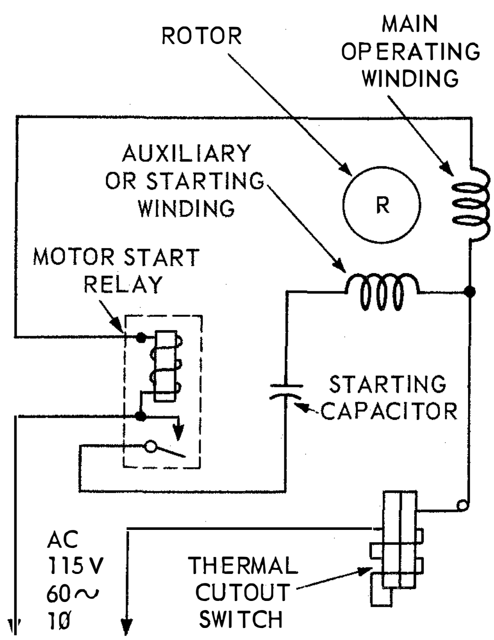
The synchronous motor in the typing reperforator is only 1/20 hp, consequently it has less torque than the heavyduty motor. Motor speed, power requirements, and other features are the same as the heavy-duty motor.

A-C Governed Motors

The a-c governed motors (fig. 12-7) also are in two horsepower ratings. The heavy-duty one supplies rotary mechanical motion to the main shafts of the automatic typer, keyboard, typing reperforator, and transmitter distributor. It is a 1/15-hp, 115-volt, 50- to 60-cycle, a-c governed motor, which depends on the electromechanical governor for its speed regulation.

The armature is wired in series with two field windings and the governor contacts (fig. 12-8). A 250-ohm, 40-watt resistor and a 0-5-mf capacitor are connected in parallel with the governor contacts. When these contacts are closed, the resistor is shorted out. When contacts are open, the resistor is in series with the motor, to limit its operating current and thus reduce its speed. The capacitor serves as a spark suppressor for the governor contacts.

The combination fan and governor is mounted on one end of the motor shaft. The fan draws cooling air through the motor housing, and also serves as a mounting plate for the governor sliprings and for the governor contact mechanism (mounted on opposite sides of the fan). Connections to the two sliprings, which are wired to the governor contacts, are made by means of two brushes mounted on the ends of the motor housing. Normally, the governor contact spring holds the governor contact against the contact screw (fig. 12-9). When the motor shaft exceeds a predetermined speed, the centrifugal force developed on the governor contact overcomes



50.109
Figure 12-6.—A-C synchronous motor, schematic wiring diagram.

the pull of the spring briefly, and the contact leaves the contact screw until the motor slows down. Tension on the contact spring is adjusted to maintain the motor speed at 3600 rpm.

Two 0.5-mf capacitors (fig. 12-8) are connected between the brushes and the grounded frame of the motor. These capacitors tend to bypass any electrical noise created by the brushes and to reduce sparking between brushes and commutator. Viewed from the governor end, the motor rotates counterclockwise.

The housing on the underside of the motor contains both the 250-ohm resistor and 0.5-mf capacitors in the governor circuit, as well as an electrical noise suppressor in the motor input circuit to prevent any radio interference that may be generated by the motor from being radiated by the motor power leads. To prevent this disturbance from being radiated directly from any of the motor components or wiring, the entire motor is enclosed by grounded metal housings with screened openings. Screening enables circulation of cooling air through the motor and across the governor resistor, and also permits the target to be viewed when checking the motor speed.

A threaded plug provided in the governor shield housing may be removed to permit insertion of a screwdriver when necessary to adjust motor speed. Access to the compartment on the underside of the motor may be gained by removing a screw and lockwasher, then sliding aside the bottom cover plate.

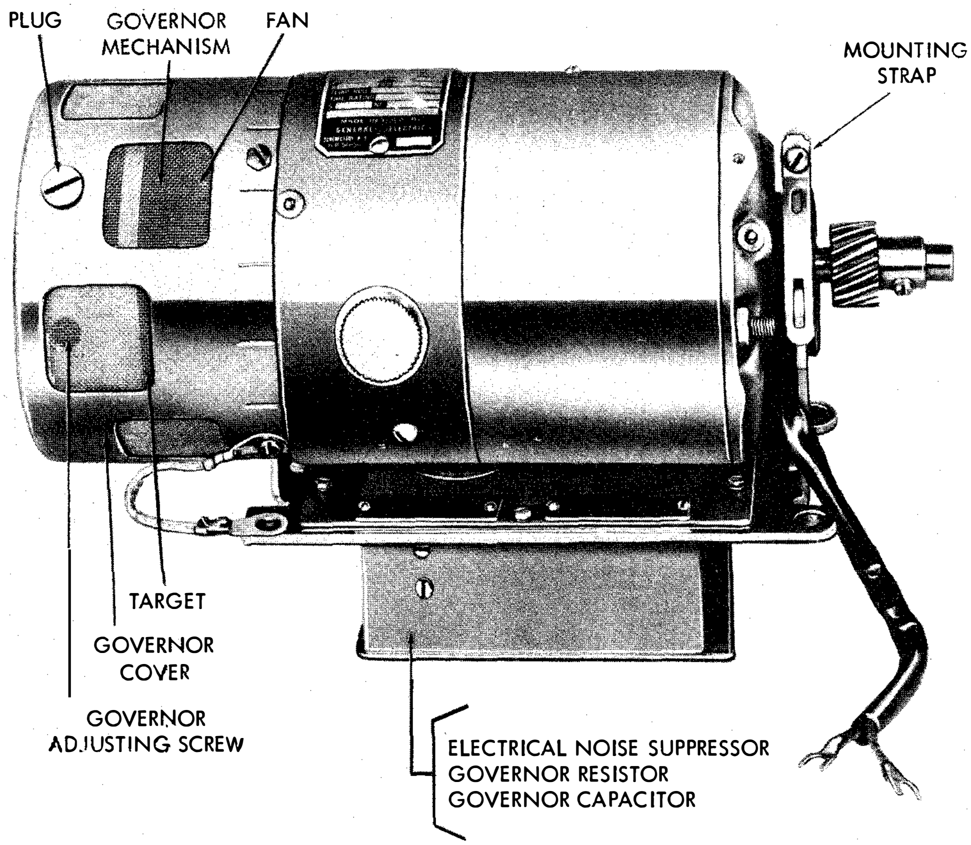
The lower powered a-c governed motor is identical in size and appearance to the motor just described. It is a 1/20-hp motor, and is used to drive the typing reperforator.

CABINET

A sheet metal cabinet (fig. 12-10) houses all components of the teletypewriter. The upper portion holds the keyboard, automatic typer, typing perforator, transmitter distributor and its base, power distribution panel, and typing reperforator and its base. The auxiliary power distribution panel for the typing reperforator is housed in a rack in the lower part of the cabinet.

A dome, extending completely across the cabinet, is hinged at the rear and latched at both sides. It is partially raised by two torsion bars when the latches are released. Small doors in the dome provide access to components without raising the dome. A door at the top right end of the dome opens above the rear of the automatic typer for changing paper. A window in front of that door affords a view of the platen, type box, and the line being typed. The rear of the window serves as a straightedge for tearing off printed copy. The window can be opened for straightening the paper or changing ribbon. A dome door in the center of the cabinet is for reloading the perforator type container. A hinged part of the front of the cabinet can be raised for access to the perforator. When closed, this part has two windows for viewing the perforated tape. The window at the left serves as a tape cutoff guide. A door at the left of the dome provides access to the typing reperforator.

The dome is wired to include a 6-volt copy and indicator lamp circuit. Associated with this circuit is a transformer and a three-position toggle switch accessible in the center of the cabinet dome when the right dome door is open. Also mounted in the dome are a lamp for illuminating tape copy in the perforator, two lamps for the automatic typer copy paper, and a margin indicator or end-of-line lamp.



50.110

Figure 12-7.—A-C governed motor.

Terminalboards, on which all wiring terminates, are located across the back panel of the cabinet.

The shelf separating the upper portion from the lower part of the cabinet serves as a mount for most of the components. A signal bell is located on the bottom side of the shelf. An electrical noise suppressor, incoming signal and power lines, and a cradle assembly are mounted on the top side of the shelf. The cradle rests on vibration counts. A switch lever, for controlling the power switch on the power distribution panel, extends under the cradle and protrudes at the right of the keyboard. A similar lever for controlling the line test key is positioned at the left of the keyboard.

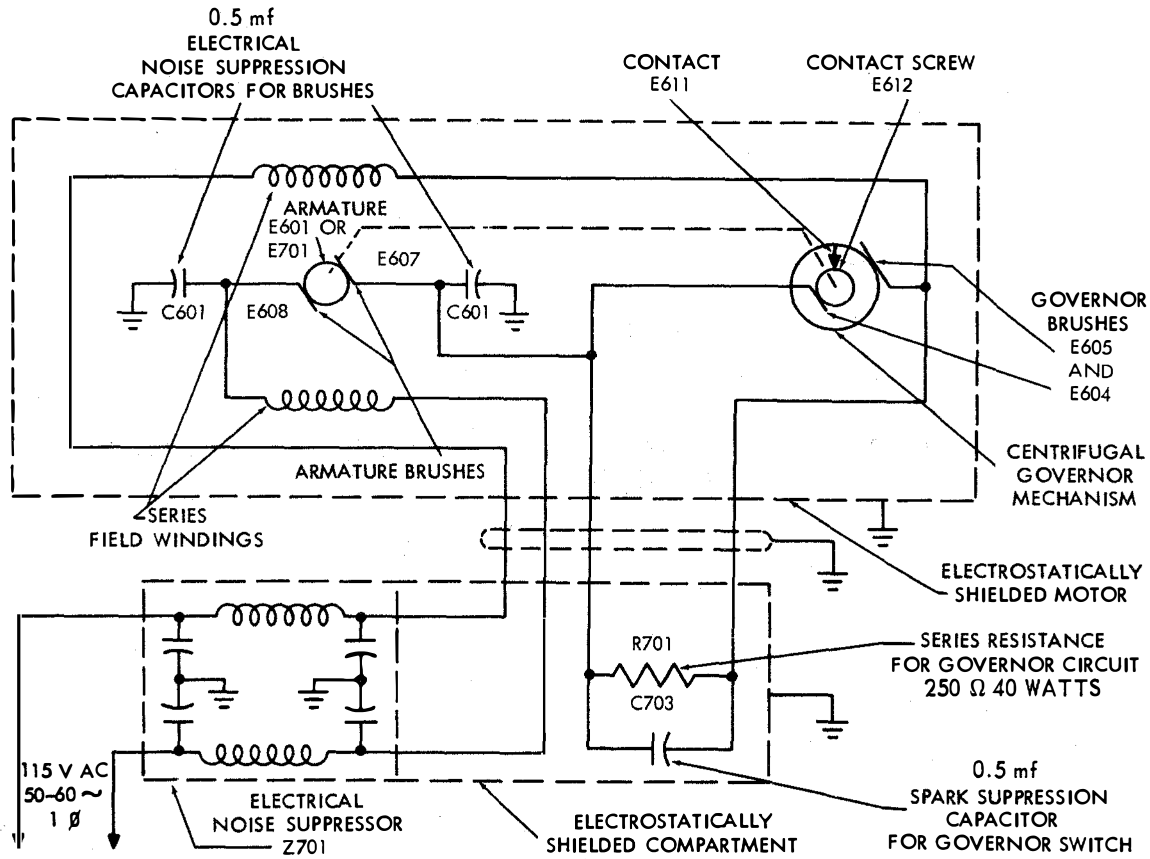
NOISE LEVEL REDUCTION

Later production models of the AN/UGC-6 teletypewriters are equipped with noise level reduction devices to provide quieter operation. Some earlier models were not so equipped, but the noise level reduction parts can be ordered separately and installed. These parts consist of silencing pads for lining the dome compartment, nylon gears, and isolation parts for the keyboard and transmitter distributor.

REPERFORATORS AND TRANSMITTER DISTRIBUTORS AS SEPARATE UNITS

Typing reperforators are available in two versions. The TT-192/UG typing reperforator is designed for receiving only. (It does not have a keyboard.) A keyboard on the TT-253/UG enables sending as well as receiving.

As a separate unit the transmitter distributor carries the designation TT-187/UG. You may



50.111

Figure 12-8.—A-C governed motor, schematic wiring diagram.

encounter similar equipments with different designations (TT numbers), because some equipments have slightly different or additonal features required for particular installations.

The foregoing units are essentially the same as the typing reperforator and transmitter distributor components of the AN/UGC-6 teletypewriter set. For this reason, only a brief presentation is included here.

TYPING REPERFORATOR TT-192/UG

Basic components of the TT-192/UG typing reperforator are shown in figure 12-11. The base, motor, and typing reperforator are seen without the cover in figure 12-12.

Power and signal lines connect through two receptacles at the rear of the base unit. The power distribution panel is mounted on a rack in the compartment underneath the table. Most

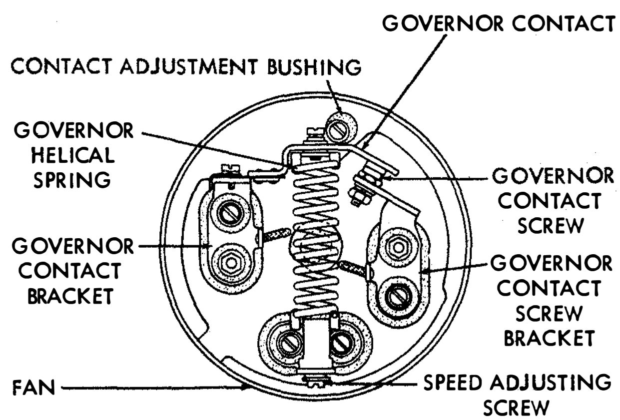


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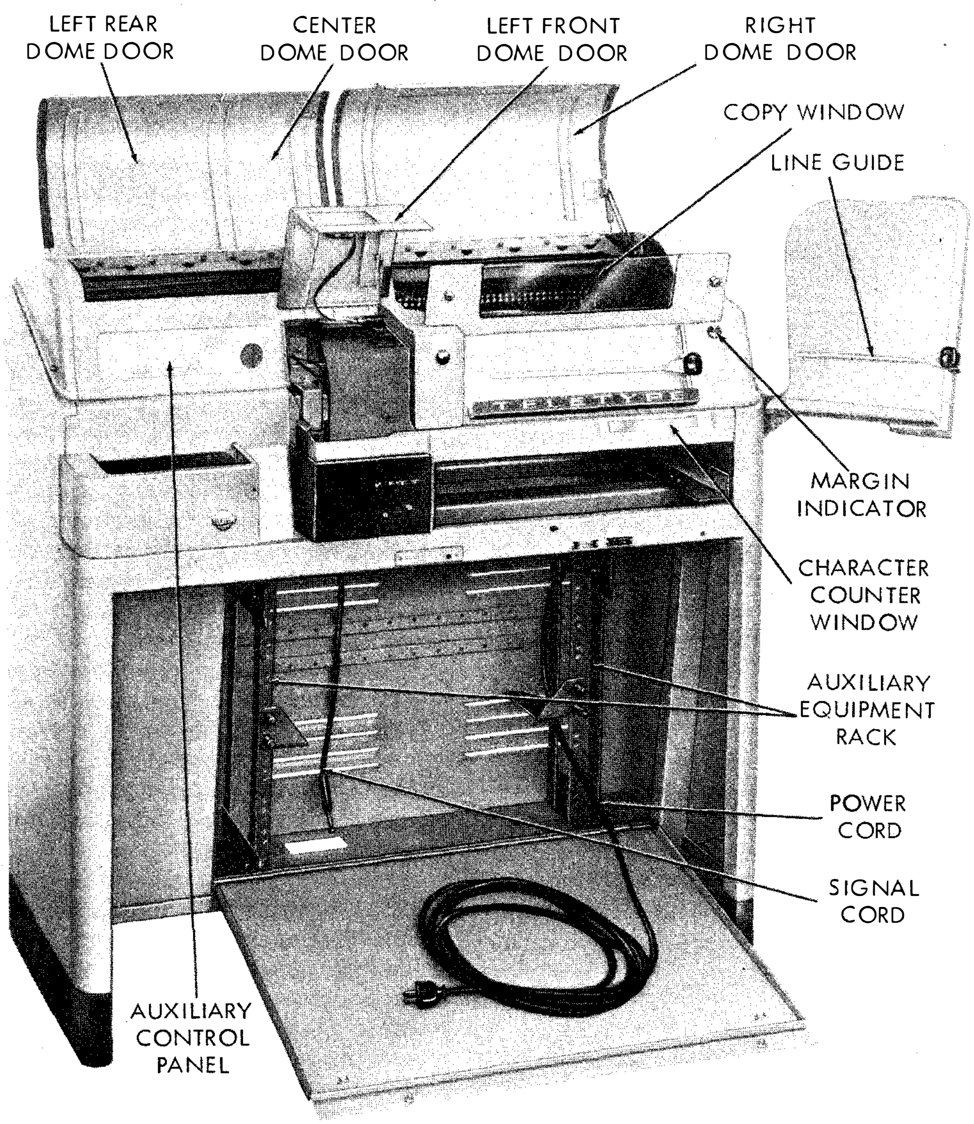
Figure 12-9.—Governor for a-c governed motor.



50.113

Figure 12-10.—AN/UGC-6 teletypewriter cabinet.

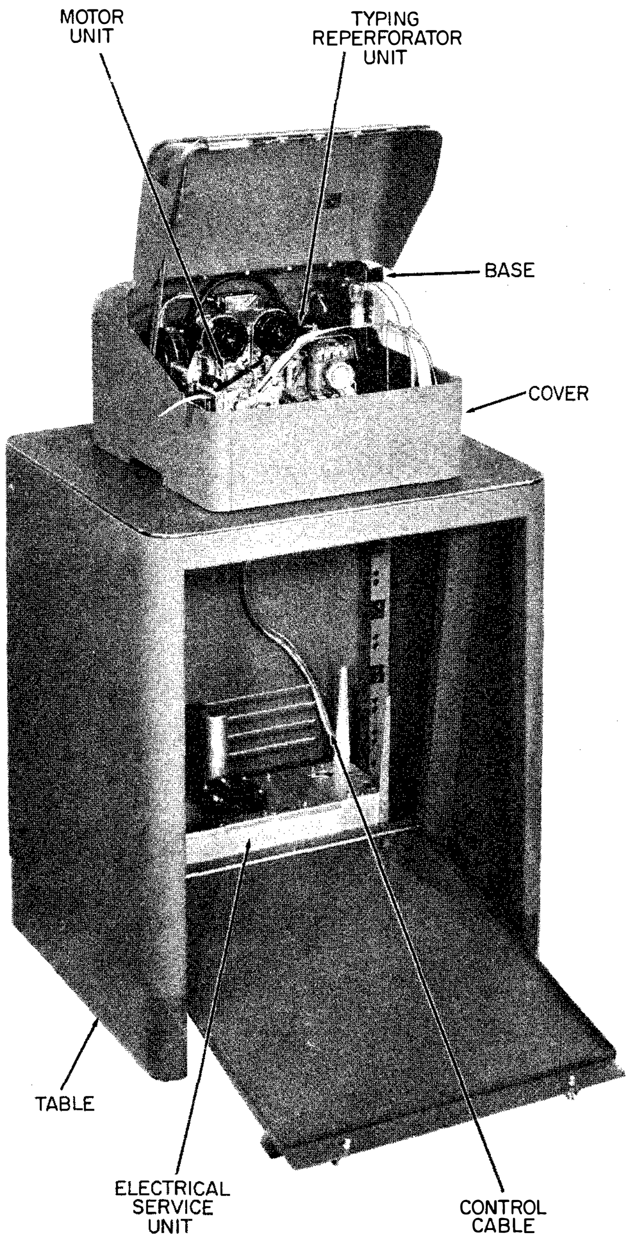
shipboard installations of TT-192/UG do not include the table, principally because of space limitations.

SEND/RECEIVE TYPING REPERFORATOR TT-253/UG

The TT-253/UG send/receive typing reperforator is shown in figure 12-13, and with cover off in figure 12-14. Addition of the keyboard necessitated a different base unit. The printing and perforating mechanism itself is identical to components of the AN/UGC-6 teletypewriter set.

TRANSMITTER DISTRIBUTOR TT-187/UG

The TT-187/UG transmitter distributor (fig. 12-15) is essentially the same as the TD in the AN/UGC-6. Its base unit is different and, because the transmitter distributor is a separate unit, it has its own motor. Power from the motor on the keyboard unit is supplied to the transmitter distributor by mechanical linkage.



50.114
Figure 12-11.—Typing reperforator TT-192/UG.

EQUIPMENT TECHNICAL MANUAL

Use of the equipment technical manual is required for routine preventive maintenance as well as for troubleshooting. A section of the technical manual is devoted to mechanical adjustments. Another section has exploded views for removal and repair procedures. Scope of the information contained in the technical manual is indicated in following sections.

PREVENTIVE MAINTENANCE

Preventive maintenance is applied for the purpose of detecting and correcting troubles before they develop to the point of interference with satisfactory operation of the teletypewriter equipment. Proper lubrication—but not over-lubrication—is an important preventive maintenance measure. When work on equipment is necessary, use care to prevent introducing trouble. Do not disturb adjustments unnecessarily.

A thorough visual inspection of the equipment during periodic checks may uncover conditions that could possibly cause trouble later. Appearance of oxidized (red) metal dust adjacent to any bearing surface indicates insufficient lubrication. Adjustable clearances of working parts should be observed also.

A visual examination should be accompanied by a manual test. Connections at terminal boards should be checked for tightness. Vibrations sometimes loosen these connections just enough to give intermittent troubles that are difficult to locate. Nuts and screws that lock adjustable features should be carefully observed for looseness, and should be tightened if necessary. While cleaning the units, care should be exercised to avoid damage or distortion to delicate springs that might weaken their tension. Electrical contact points should be kept free and clear of dirt, oil, corrosion, or pitting. Check that operating clearance is maintained when a contact is cleaned.

ROUTINE MAINTENANCE CHECK CHART

A routine maintenance check chart for the AN/UGC-6 teletypewriter is included here. Reference in the "how to check" column are made to appropriate sections and illustrations in the equipment technical manual. Refer to the technical manual for specific illustrations and required tolerances.

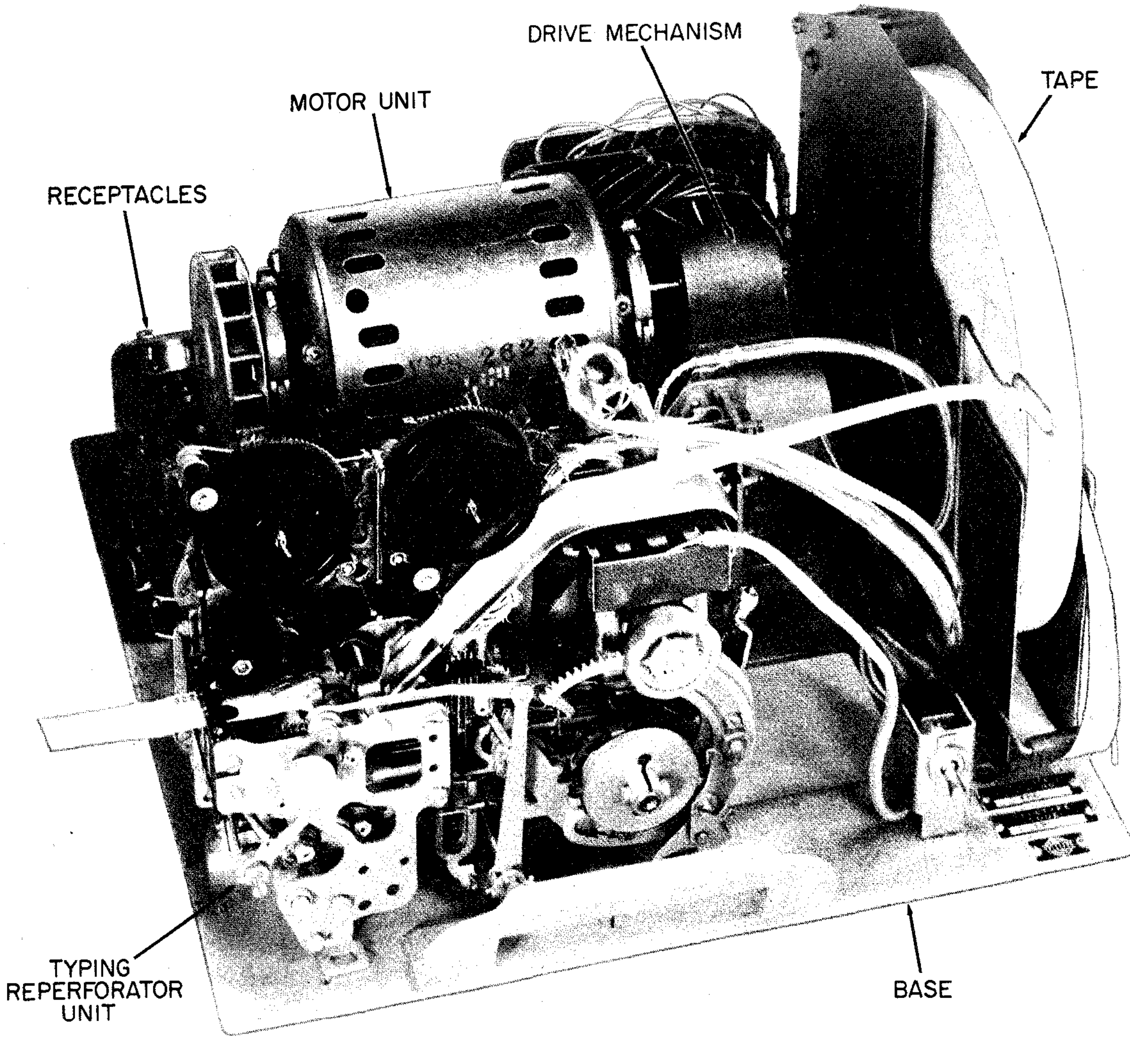
TELETYPEWRITER TOOLS

The days of the "screwdriver mechanic" are over, at least insofar as teletypewriter maintenance is concerned. Many special tools, AN/UGC-6 Routine Maintenance Check Chart

WHAT TO CHECK	HOW TO CHECK	PRECAUTIONS
1. Accumulation of dust and dirt.	Check for dust from paper beneath its path through typer and for dust and dirt on other parts of equipment. Clean by wiping with soft lintfree cloth. Cleaning with airhose should be avoided.	Be sure springs are not disengaged or other parts disturbed in cleaning. Avoid getting dust or dirt into bearings or other moving parts.
2. Selector response.	No maintenance required if selector responds to distorted signals in manner specified in service and repair section of technical manual. If requirements are not met, the following routine should be observed. a. Clean magnet pole faces by running clean piece of paper between them and armature. b. Examine selector parts for wear, and replace if worn. c. Check adjustment of selector mechanism. d. Check selector mechanism springs and replace if necessary.	
3. Adjustments.	Most adjustments will remain within specification limits for the life of the equipment and, therefore, do not require checking unless trouble occurs. The following adjustments should be checked and remade if necessary. a. Dashpot b. Carriage wire rope c. Signal generator contact d. All clutches	Exercise extreme precaution to guard against overtightening screws, which might result in striping.

AN/UGC-6 Routine Maintenance Check Chart—Continued

WHAT TO CHECK	HOW TO CHECK	PRECAUTIONS
4. Motor brushes.	Remove and replace if length is less than 3/8 inch. Wipe and blow off accumulation of carbon dust.	Relationship of brush to armature should be maintained (governed motors only).
5. Governor brushes.	Examine length and replace if less than 3/8 inch remains. Wipe and blow off accumulation of carbon dust.	Be sure brush springs are in place (governed motors only).
6. Governor contacts.	Replace if badly burned.	Be sure contacts are aligned properly.
7. Governor speed.	See governor adjustments in technical manual.	Applies to governed motor only. Motor may be considered on speed if no more than 12 target spots pass a given point in 10 seconds.
8. Lubrication.	For disassembly prior to lubrication, see instructions in technical manual. Remove typer from keyboard. Examine all of its mechanism for signs of lubrication failure, usually evidenced by presence of red powdery substance at point of failure. If failure is observed, parts should be examined; and, if damaged, they should be replaced. Lubricate equipment in accordance with lubrication charts in technical manual. Wipe off excessive lubrication with clean cloth.	Be sure that springs are not disengaged and that other parts are not disturbed during examination and lubrication.



50.115

Figure 12-12.—Typing reperforator (cover removed).

gages, spring scales—even a magnifyingglass—are required for making numerous fine adjustments on modern teletypewriter equipment.

Some of the special tools needed for maintenance of the AN/UGC-6 teletypewriter are seen in figure 12-16. They are in addition to the usual assortment of tools contained in the repairman's TE-50 tool equipment kit.

ADJUSTMENTS

Adjustments to be made to each unit of the teletypewriter are arranged in the technical manual in a sequence that would be followed if a complete readjustment of the equipment should be undertaken. Within each component (automatic typer, keyboard, perforator, reperforator, transmitter distributor), adjustments may be made in sequence, provided that any cross references to related components are observed.

Over 150 illustrations depict adjustments in the technical manual. Only one such illustration is included here. Always assume that mechanisms illustrated are viewed from a position in front of the equipment, unless (see fig. 12-17) specifically identified as another view.

50.116

Figure 12-13.—Send/receive typing reperforator TT-253/UG.

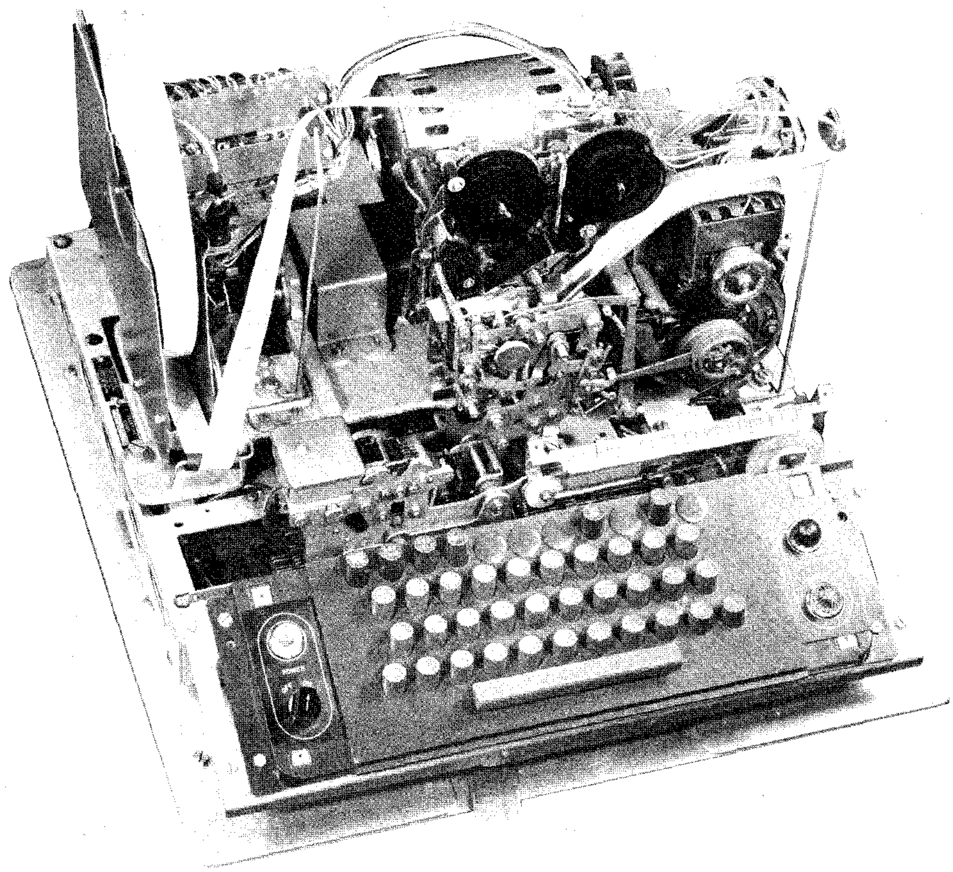
References to "left" or "right" designate the viewer's left or right as he faces the front of the fully assembled equipment.

In addition to adjustment tolerances, positions of moving parts, and spring tensions, adjustment illustrations also show the angle at which a spring scale should be applied when measuring spring tensions. Tensions must be checked with proper spring scales in the position indicated. Springs that do not meet the requirement, and for which no adjusting procedure is given, should be replaced by new springs.

When adjustment instructions call for removal of components, assemblies, subassemblies, or individual parts, all adjustments that might facilitate removal of these parts should be made before parts are replaced or as equipment is reassembled. When a part mounted on shims is removed, the number of shims at each mounting screw should be noted, so that identical pileups can be made when the part is replaced. After an adjustment is made, all nuts and screws that were loosened should be tightened unless stated specifically to the contrary.

All electrical contact points should meet squarely. Contracts with the same diameter should not be out of alignment more than 25 percent of the contact diameter. Always check contacts for pitting or corrosion. Clean or burnish contacts before making a specified adjustment or tolerance measurement. When adjusting contacts, avoid sharp kinks or bends in the contact springs.

Satisfactory operation of teletypewriters geared for 100 wpm demands more exacting adjustments than 60-wpm machines. Adjustments should always be made within tolerances specified. In meeting tolerances specified in the technical manual, it is best to avoid either extreme. Limits of an adjustment—both minimum and maximum—are intended to compensate for differences in size, shape, and wear of parts, as well as for various operating speeds of the equipment.



50.117

Figure 12-14.—Send/receive typing reperforator (without cover).

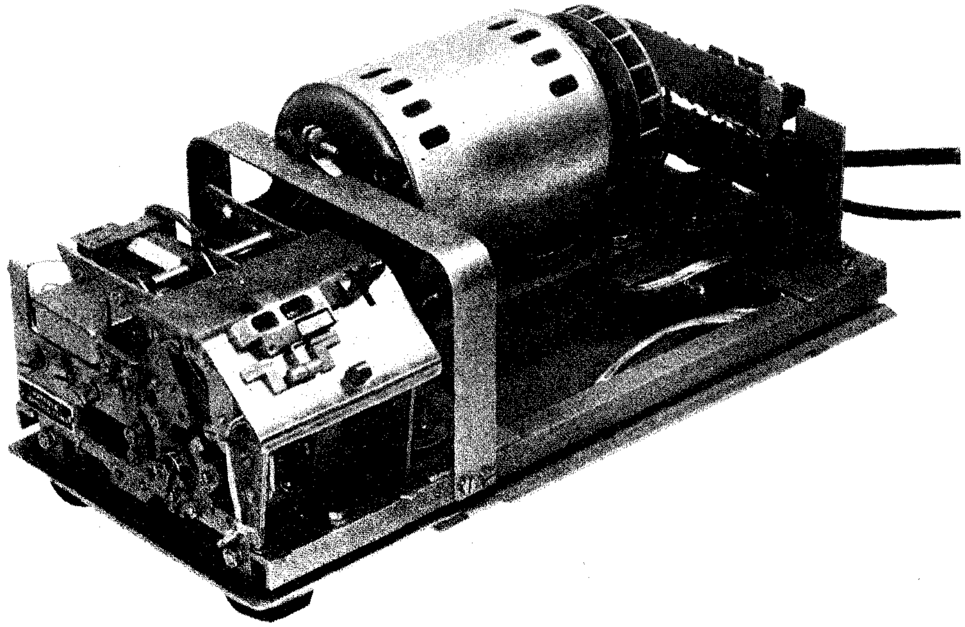
At 100 wpm, adjustments for spring tensions on the printing hammer mechanism in the automatic typer become critical. Extreme care must be exercised to assure correct tension on these springs at all times. Too much tension causes excessive wear on the type pallets, and in some instances splits the type box. It is recommended that these spring tensions be no greater than required for satisfactory printing of the characters.

Particular care must be taken when adjusting perforators and reperforators, with emphasis on the punch blocks. Any maladjustment of the punch block mechanism is a potential source of trouble.

When checking adjustments, it is obvious sometimes that certain parts are worn. Rather than maladjust associated parts to compensate for this wear, it is better to replace the worn part and readjust the associated train of parts. Most moving parts in teletype equipments are casehardened. It must be remembered, however, that once the surface is worn through, wear is rapid and sometimes causes undue strain on associated parts.

At the conclusion of any adjustment, always operate the machine by hand to be assured that there are no binds in the machine before operating under power. This action is true also at lower speeds, but becomes even more important at higher speeds.

Only a qualified teletype repairman (NEC 2342) should make adjustments to the equipment. When emergency repairs and/or minor adjustments are necessary to keep equipment in operation, however, a thorough understanding of



50.118

Figure 12-15.—Transmitter distributor TT-187/UG (cover removed).

adjustment and troubleshooting procedures, as outlined in the technical manual, is in order.

LUBRICATION

More than 60 pictures and diagrams in the equipment technical manual illustrate lubrication points of the AN/UGC-6 teletypewriter. One (fig. 12-18) is included here to emphasize the explanation in the following paragraphs.

In addition to points to be lubricated, technical manual pictures show the type and quantity of lubricant to use. A new teletypewriter should be lubricated before it is placed in service for the first time. After a few weeks in service, relubricate to make certain that all points are lubricated adequately.

LUBRICATION SCHEDULE

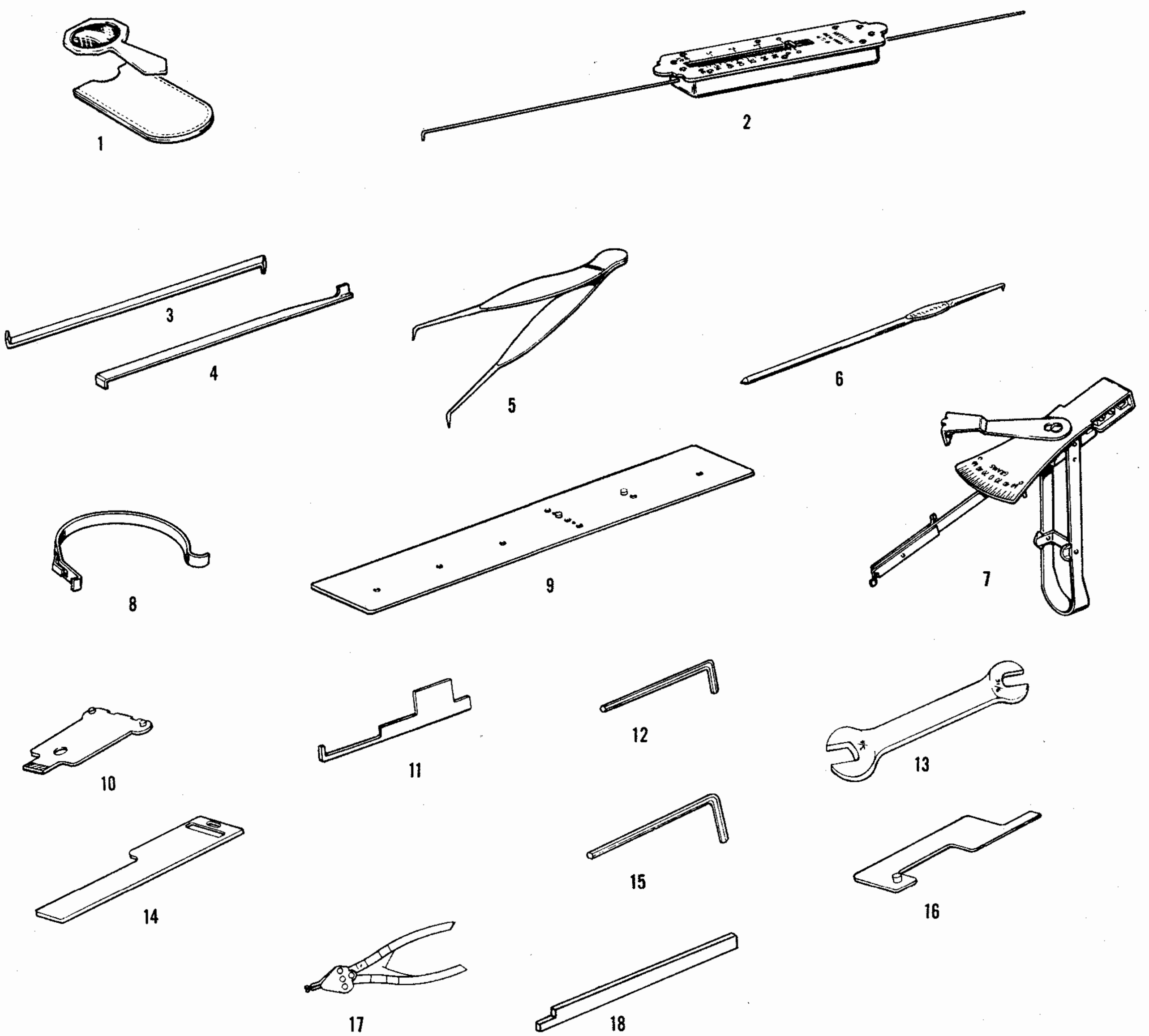
A teletypewriter must be lubricated more frequently as operating speed increases. Thus, a machine geared for operating speed of 100 wpm requires lubrication oftener than one operating at 60 wpm. Here is the recommended lubrication schedule:

OPERATING SPEED (words per minute)	LUBRICATING INTERVAL (whichever occurs first)
60	3000 hours or 1 year
75	2400 hours or 9 months
100	1500 hours or 6 months

Regarding the lubricating interval, an important point to remember is the words "whichever occurs first." To illustrate, a machine in continuous use at 100 wpm will accumulate 1500 operating hours in only 2 months. For machines used occasionally or intermittently, some kind of log is needed to keep track of total operating hours. The Electronic Equipment Operational Time Log (NavShips 4855), illustrated and described in chapter 5 of this training course, is used for this purpose.

OIL AND GREASE

For normal or high temperatures (above 41°F), apply KS-7470 oil at all locations where the need for oil is indicated. For lower



1. Magnifying lens
2. 64-oz spring scale
3. Offset screwdriver
4. Offset screwdriver
5. Tweezers
6. Spring hook push tool
7. 70-gram spring scale
8. Armature clip
9. Tape gauge w/pins
10. Tape lid gauge
11. Contact adjusting tool
12. Hexagon key wrench (No. 4 set screw)
13. Double end wrench
14. Top plate adjusting gauge
15. Hexagon key wrench (No. 10 set screw)
16. Punch bail arm gauge w/pins
17. Truarc puller pliers
18. Universal function bar tool

50.119

Figure 12-16.—Special teletypewriter tools.

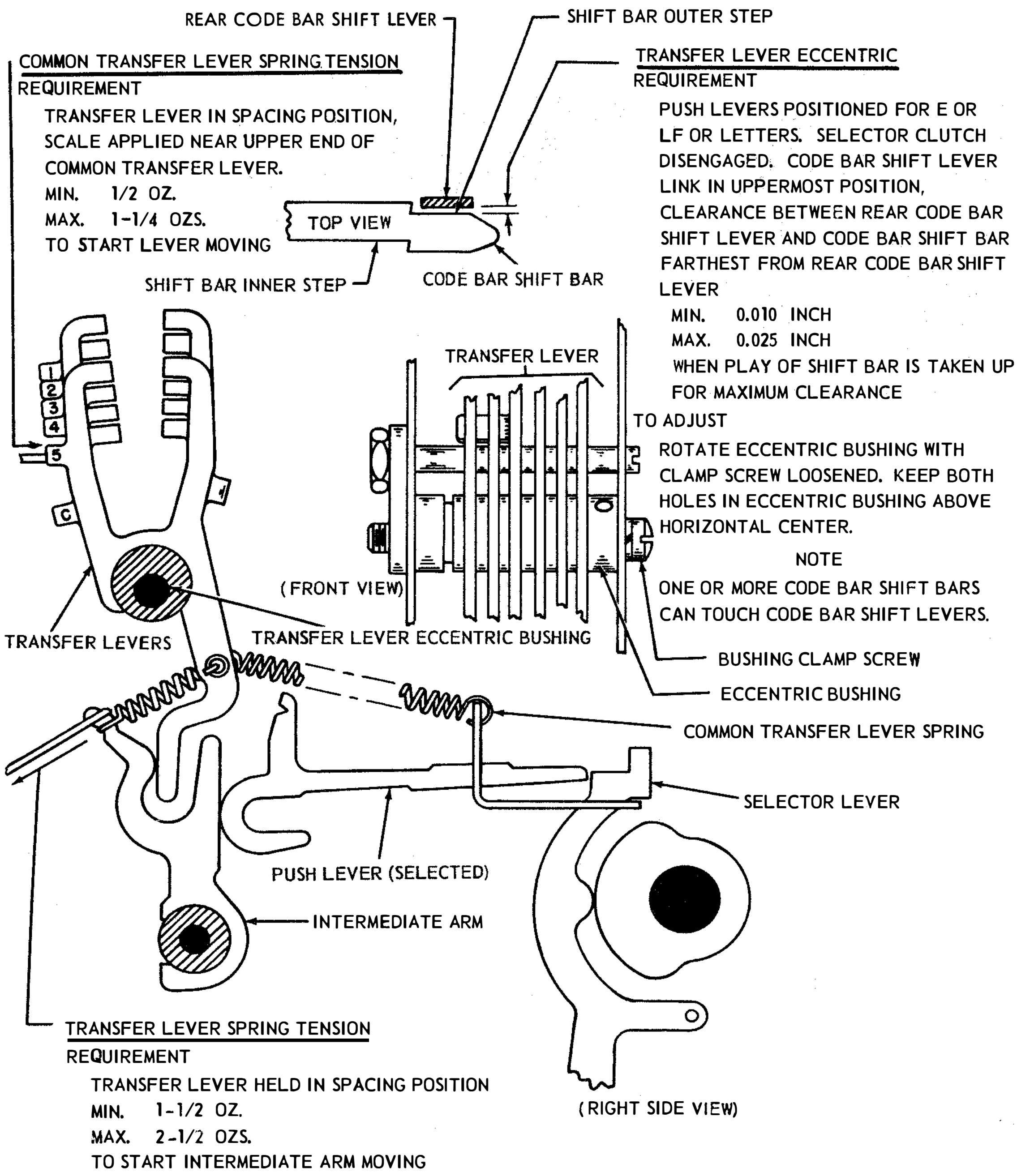


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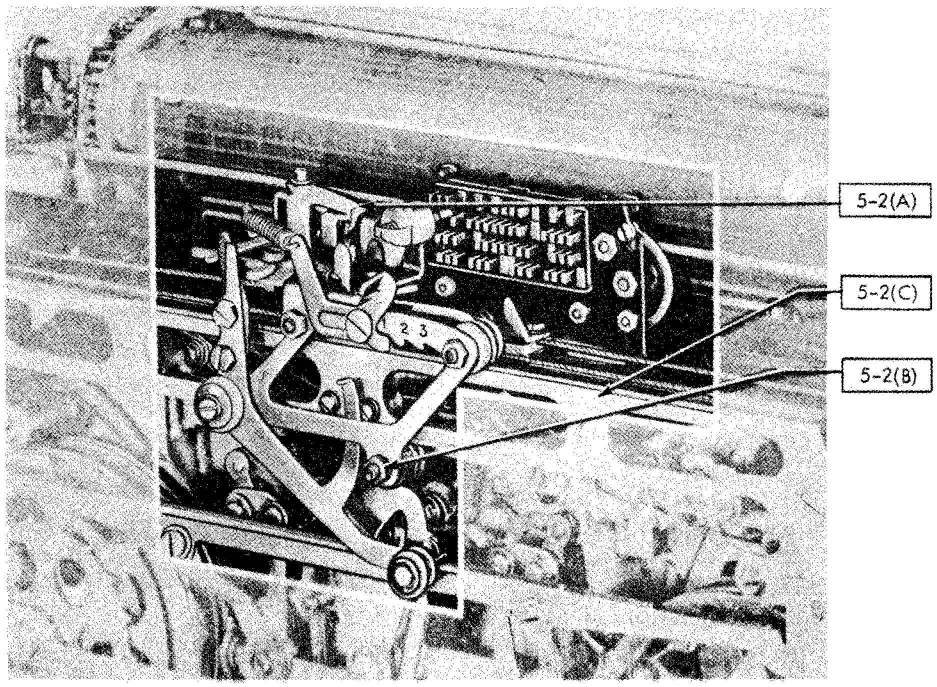
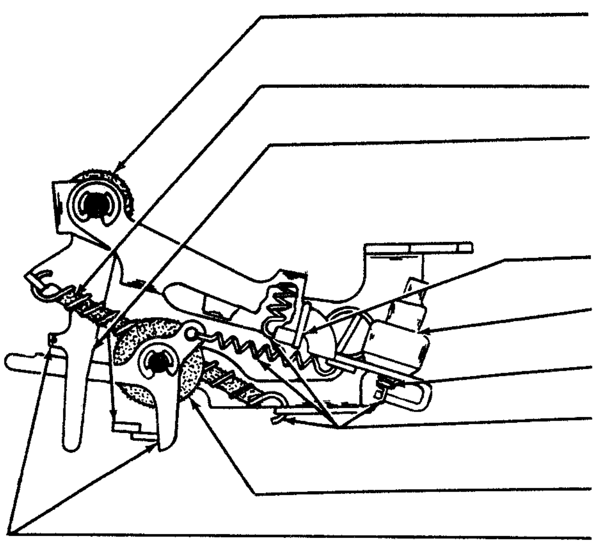
Figure 12-17.—Adjustments for code bar shift mechanism in automatic typer.



AUTOMATIC TYPER
(FIGURES 5-8 TO 5-32)

(REST AUTOMATIC TYPER IN UPRIGHT POSITION)

5-2(A) PRINTING MECHANISM



SAT	FELT WASHERS (2 WASHERS)	PRINTING HAMMER OPERATING BAIL
SAT	FELT WICK	SPRING WICK
G	ENGAGING SURFACE	SECONDARY PRINTING ARM
G	ENGAGING SURFACE	PRINTING HAMMER STOP
G	ENGAGING SURFACE	PRINTING HAMMER STOP
SAT	FELT WICK	SPRING WICK
O	HOOKS--EACH END (4 SPRINGS)	SPRING
SAT	FELT WASHER	OPERATING BAIL LATCH
O2	ENGAGING SURFACES (2 PLACES)	OPERATING BAIL LATCH

50.121

Figure 12-18.—Lubrication chart for printing mechanism in automatic typer.

temperatures, dilute the KS-7470 oil with kerosene (half and half). Use type MIL-G-3278 grease on all surfaces where grease is prescribed, except motor bearings. Apply two drops of KS-7470 oil to motor bearings every 4 months. If the motor is disassembled at any times, repack bearings with MIL-G-3276 grease.

All springs, wicks, and felt oilers should be saturated. Friction surfaces of all moving parts should be lubricated thoroughly. Overlubrication, when permits oil or grease to drip or be thrown on other parts, must be avoided.

Electrical contact surfaces must be kept free of oil. Take special precaution to prevent any oil or grease from accumulating between armatures and pole pieces of selector magnets, transmitter distributor clutch magnets, tape backspace magnets, or tape feedout magnets.

Apply a thick film of grease to all gears and to the spacing clutch reset cam plate. When gear changes are made, such as changing from 60-wpm to 100-wpm operation, lubricate replacement gears at the time the change is made.

LUBRICATION CHARTS

For visual identification, lubrication instructions are keyed to a photograph of the equipment. (See fig. 12-18.) The first digit is a hyphenated numeral corresponding to the figure number in which the photograph is found. The second part of the key is a letter to indicate the reference point on that photograph. For example, 5-2(A) is a lubrication instruction for a part shown photographically in figure 5-2 and at point (A) on that illustration.

Specific lubricant requirements and the amount of lubricant are indicated on the chart in accordance with the following code.

0 Apply 1 drop of KS-7470 oil.
02 Apply 2 drops of KS-7470 oil.
03 Apply 3 drops of KS-7470 oil.
020 Apply 20 drops of KS-7470 oil.
SAT Saturate (felt oilers, washers, wicks) with KS-7470 oil.
G Apply thin film of MIL-G-3278 grease.

In addition to routine lubrication intervals, relubrication is necessary whenever parts of assemblies are removed and reassembled, or when handling the equipment for adjustment purposes may have removed some or all of the lubricant.

TROUBLESHOOTING

Equipment failures can be traced functionally by means of a troubleshooting chart, one page of which is shown in figure 12-19. A step-by-step analysis of the behavior of the equipment in response to the tabulated checks indicates the area of trouble in which to apply remedial measures referenced in the chart. Because each check step (in most instances) is conditioned by the procedure in preceding steps, examine the condition of all controls, particularly the keyboard selector switch mode, before rechecking any step or performing any troubleshooting check out of sequence. Process of elimination of probable troubles given in the troubleshooting chart should facilitate clearing faulty operation at any point in the equipment.

When check of an adjustment is indicated, be careful not to disturb related adjustments. If adjustment is found to be needed, always check the technical manual to see if related adjustments may be required.

A comprehensive electrical analysis of the teletypewriter generally is not required in troubleshooting. An understanding of phrases or terms used in the technical manual to describe certain circuit conditions is essential.

- Reference to an open condition is to a circuit through which current will not flow. This condition could be caused by a loss of d-c signal power, a break in the signal line, a poor connection, or a poor or dirty contact mechanism.
- A closed condition is the normal, static condition of the machine, with no keyed signal and a steady current flowing through the circuit holding the selector magnets in an energized or marking condition. A start (no current) impulse is needed to release the magnet armature and start the machine on a printing evolution.
- Running closed is the condition resulting from a closed signal circuit characterized by failure of typing and printing mechanisms to respond to an incoming signal. This condition can be due either to the absence of the start and spacing elements in the signal or to a mechanical failure
- Running open is created by an open signal circuit, resulting in operation of typing and printing mechanisms because of absence of a stop signal to latch the function clutches. Normally, no printing or functions such as line feed, carriage return, signal bell, etc., will occur when a machine is running open.

STEP	PROCEDURE AND NORMAL INDICATION	TROUBLE	NEXT STEP	CORRECTION (REF. PARAGRAPH)
1	Main power switch ON; cabinet switch in NORMAL position; cabinet lamps lighted; keyboard motor starts	No cabinet illumination	Check external power	5-4b(1)(a)
			Check power line noise suppressor (if used)	5-4b(1)(b)
			Check main fuse	5-4b(1)(c)
			Check cabinet transformer	5-4b(1)(d)
		Some cabinet copy lamps not illuminated	Check bulbs and sockets	5-4b(1)(e)
		Margin indicator end-of-line lamp not illuminated	Check steps 17 and 23 in normal checking sequence	
2	Auxiliary power switch ON; auxiliary motor starts (applicable only to Teletypewriters AN/UGC-6, AN/UGC-6A, AN/UGC-6X, AN/UGC-8, and AN/UGC-8X	Motors do not start	Synchronous motors (teletypewriters AN/UGC-5, AN/UGC-5A, AN/UGC-6, AN/UGC-6A, AN/UGC-7, and AN/UGC-8):	
			Check power connections	5-4b(2)(a)
			Check auxiliary fuse	5-4b(2)(b)
			Check motor thermal cut-out switch	5-4b(2)(c)
3	Motors run	Motors run at incorrect speed	Check power line frequency	5-4b(2)(d)
			Governed motors (Teletypewriters AN/UGC-5X, AN/UGC-6X, AN/UGC-7X, and AN/UGC-8X):	
1,2 (ref)	Motors start	Motors do not start	Check power connections and auxiliary fuse	5-4b(2)(a) 5-4b(2)(b)
			Check motor brushes and governor brushes	5-4b(3)(a)
			Check governor adjustment	5-4b(3)(b)
3 (ref)	Motors run	Motors run at incorrect speed	Check 115 V ac line voltage	5-4b(3)(b)
			Check motor and governor brushes	5-4b(3)(a)
			Check governor adjustment	5-4b(3)(b)
			Check governor resistor	5-4b(3)(c)
		Motor speed uncontrollable	Check governor capacitor and resistor	5-4b(3)(d)
			Check for sticking governor contacts	5-4b(3)(d)
4	Keyboard selector switch in K mode; line test key in LINE position; automatic typer runs closed on idle signal; operates on signal impulse	Automatic typer runs open	Check connection of cables from power distribution panel	5-4b(4)(a)
			Check signal line noise suppressor (if used)	5-4b(4)(b)
			Check for open selector unit magnets	5-4b(4)(c)

50.122

Figure 12-19.—One page from AN/UGC-6 troubleshooting chart.

• Garbling is a condition in which the response of typing and printing mechanisms does not correspond to the mechanical or signal input.

An easy way to determine whether mechanical or electrical troubles are causing a machine to run open or closed is to observe the selector magnet armature during receipt of an incoming signal. If the armature is latched closed and the machine runs open, a mechanical trouble is indicated. If the armature is unlatched and not responding to the incoming signal, and the machine is running open, the trouble is electrical. If the armature is unlatched and responding to the incoming signal and the machine is running closed, the trouble is mechanical.

SERVICE AND REPAIR

An entire section in the equipment technical manual pertains to servicing and repairing the AN/UGC-6 teletypewriter. The section includes almost 100 exploded view illustrations that provide maintenance personnel with effective means for locating and clearing troubles. Insofar as possible, grouping of exploded illustrations (see fig. 12-20) is on a functional basis. Part numbers are keyed to the maintenance parts list. References to the appropriate exploded view illustration makes it easy to locate and visually identify parts and detailed disassembly and reassembly features.

Most maintenance, lubrication, and adjustment can be accomplished by removing major components from the cabinet. Further disassembly, where possible, should be confined to assemblies. Frequently they can be removed without disturbing adjustments. When reassembling, be sure to check all adjustments, clearances, and spring tensions.

AN/UGC-6 ELECTRICAL CIRCUITS

Experienced teletypewriter repairmen may contend that, although the teletypewriter is an electromechanical device, emphasis is more mechanical than electrical. Electrically, they may say, the teletypewriter is as simple as a doorbell. Although you may not quite agree with such oversimplification, particularly when an electrical trouble has you temporarily baffled, even a cursory examination of the schematic diagram of the AN/UGC-6 teletypewriter shows that electrical circuits are indeed much less complex than those in radio transmitters, receivers, and other communication equipment.

OPERATOR'S EMERGENCY MAINTENANCE

Even though some teletype operators may have received no maintenance training, they can be authorized to perform emergency maintenance to the extent of replacing fuses and lamps.

FUSES

Power circuits of the AN/UGC-6 teletypewriter are protected by two cartridge-type fuses. The main fuse for the basic equipment is on the right end of the power distribution panel under the cabinet dome behind the keyboard. A separate fuse for power circuits of the typing reperforator is located on the terminal board bracket to the left of the printing unit on the typing reperforator base. Fuse location and symptoms of failure are summarized in the accompanying tables.

LAMP REPLACEMENT

Four bayonet-type lamps for the AN/UGC-6 teletypewriter are located beneath the cabinet dome. Maintenance and copy illumination lamps are 6-volt lamps in a circuit supplied by a transformer at the rear of the cabinet. These lamps are installed on either side of the right front dome door and above the typing perforator (three lamps) and the margin indicator or end-of-line lamp (one lamp) at the extreme right of the dome. All lamps are accessible when the dome is raised. The accompanying lamp replacement data table tives the location and electrical characteristics of lamps.

MODEL TT-299 TELETYPEWRITER AND AN/TGC-14(V) TELETYPEWRITER SET

The TT-299 teletypewriter and the AN/TGC-14(V) teletypewriter set are part of a series of equipments designed for use when available space and weight are of primary consideration. They are used principally aboard submarines and aircraft, and also for mobile and field stations.

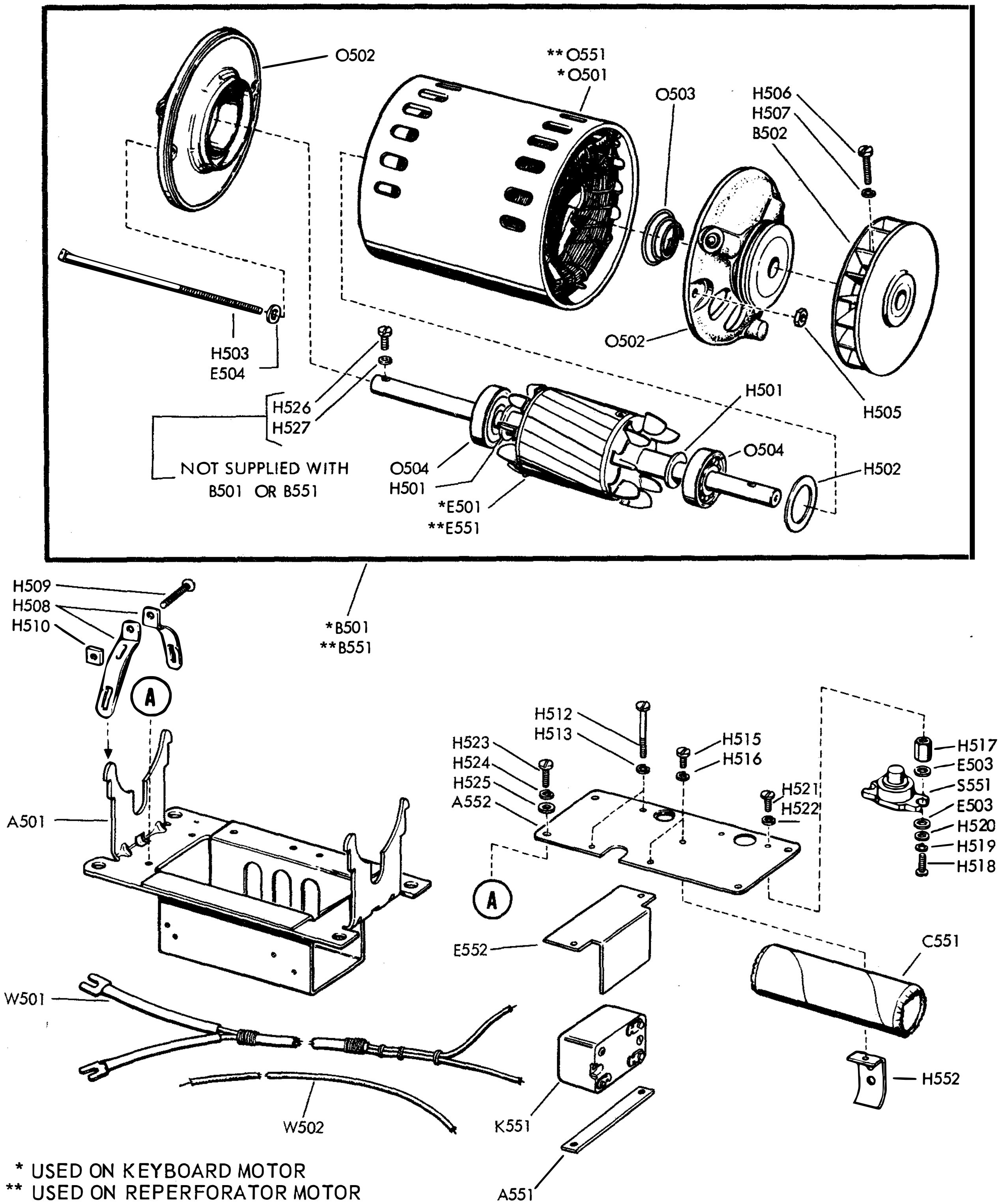


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Figure 12-20.—Exploded view of a-c synchronous motor.

SYMPTOMS OF FUSE FAILURE

Maintenance lamps	Keyboard motor	Reperforator motor	Blown fuse	Value (amps)	Comments
Out	Off	Operating	F800	6.25	In power distribution panel.
On	Operating	Off	F2300	4	On typing reperforator base.

WARNING: Never replace a fuse with one of higher rating except in emergency or battle condition when continued operation of equipment is more important than probable damage.

If a fuse burns out immediately after replacement, do not replace a second fuse until the cause is corrected.

FUSE LOCATION

Reference designation symbol	Location	Protects	Amps.	Volts
F800	In power distribution panel	Main a-c supply	6.25	250
F2300	On typing reperforator base	Reperforator a-c supply	4	250

MODEL TT-299 TELETYPEWRITER

Two models of the TT-299 teletypewriter are available. One is designated A; the other (fig. 12-21) is called B. They are similar in appearance and operation. Following are some of the differences between the two models.

- Model A operates on a 7.00 Baudot signal code; model B, on a 7.42 Baudot signal code.
- Model A does not have a copylight dimmer switch, but model B does.
- Model A does not have a line-feed-on-carriage-return function; model B does.

Both models are designed to operate under conditions of space limitations, as aboard aircraft. These teletypewriters, as well as the AN/TGC-14 set, are fully compatible with other commercial and military teletype equipments employing the standard Baudot code, and can be integrated into existing landline and radio link communication systems.

AN/TGC-14(V) TELETYPEWRITER SET

The AN/TGC-14(V) (fig. 12-22) includes two different models. These two sets consist of a basic group of components, which are supplemented by other components selected to fit requirements of a given installation. Hence the designations Teletypewriter Sets AN/TGC-14(V) and AN/TGC-14A(V) effectively cover not one but a series of teletypewriter sets.

LAMP REPLACEMENT DATA

Reference designation symbol	Function	Location	Volts	Watts	Amps.	Base
I4250	Maintenance and copy illumination.	Left of right front cabinet dome door.	6-8	6	1.14	Bayonet, double contact.
I4251	. . .do. . .	Right of right front cabinet dome door.	. .do. .	. .do. .	. .do. .	Do.
I4252	. . .do. . .	Left front door of cabinet dome.	. .do. .	. .do. .	. .do. .	Do.
I4350	. . .do. . .	Right front end of cabinet dome.	. .do. .	. .do. .	. .do. .	Do.

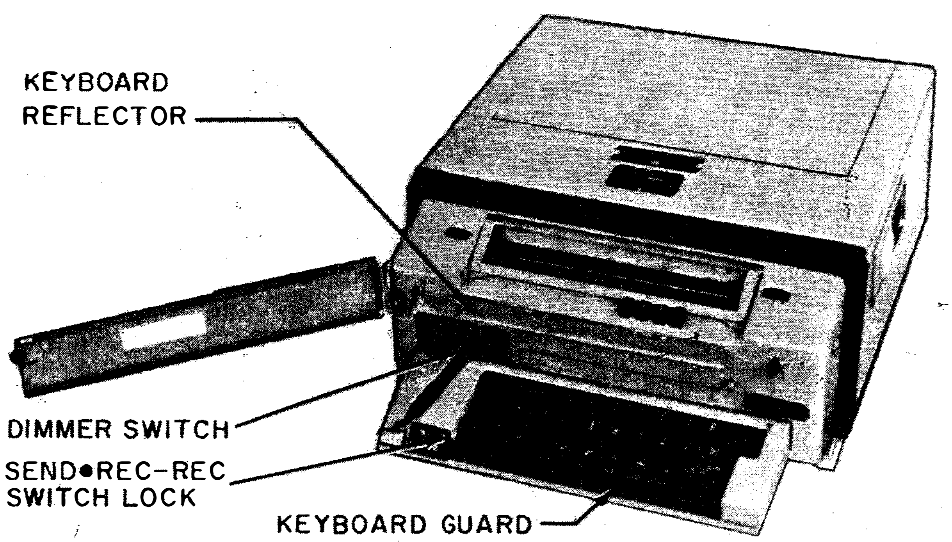

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Figure 12-21.—TT-299B/UG teletypewriter.

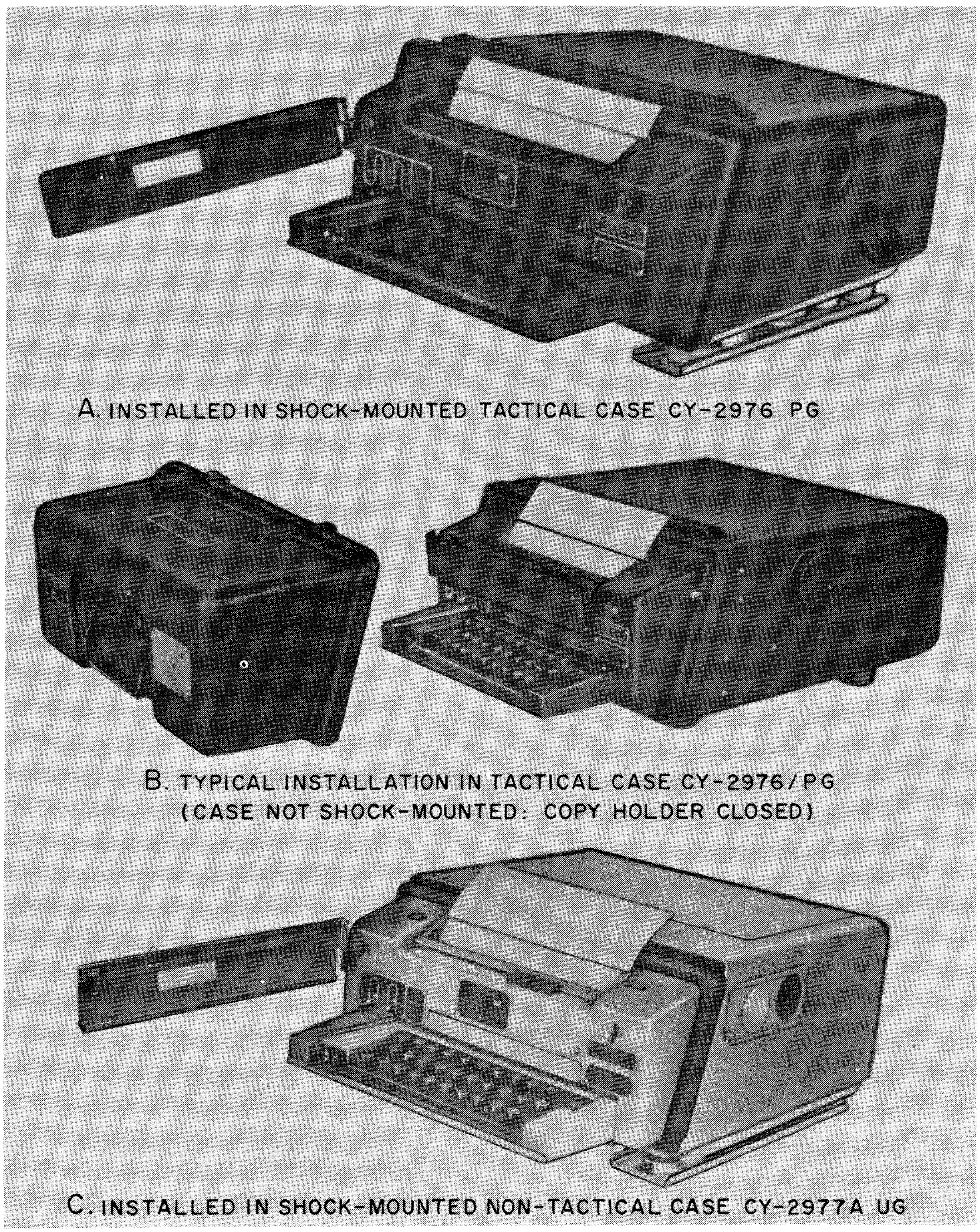

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Figure 12-22.—Teletypewriter sets AN/TCG-14(V) and AN/TGC-14A(V).

The basic teletypewriter set is comprised of a keyboard, a printer, and an electrical chassis. To this set is added a power supply kit, which contains a signal line power supply, line sensor, service cable, heating element, and fuses. A motor must be selected separately. An hysteresis-synchronous a-c motor is available for 115-v, 60-cps operation. An additional 115-v motor is available for 400-cps, single-phase operations.

For housing these teletypewriter components, either a tactical or nontactical case is selected. Optional shock mounts, available for either case, are used for installation sites in which equipment will be subjected to severe shock or vibration.

Versatility of the teletypewriter sets is further extended by patching options. These characteristics allow half-duplex (simplex), full-duplex, or off-line local operation. By proper patching, the teletypewriter sets supply signal line current, at 28-v d-c, up to 100 ma. Operational speed can be varied. Speed-change gears for 60, 75, and 100 wpm are supplied with the AN/TGC-14(V). The AN/TGC-14A(V) has speed-change gears that can be set for 45.45, 50, and 75 bauds.

TELETYPE MAINTENANCE SCHOOLS

For training teletype repairmen, the Navy has two Teletype Maintenance Schools. One is at Norfolk, the other at San Diego. These schools graduate qualified teletypewriter repairmen who are able to identify, locate, and repair quickly any type of trouble that may develop in the equipment. If you never attended one of these schools, endeavor to do so at your earliest opportunity.

In substance, the course of instruction covers—

1. General description and theory of operation.
2. Adjustments and lubrication.
3. Troubleshooting.

During the description and theory of operation phase of the course (called electrical and mechanical orientation), the student learns the electrical circuits and each mechanical train of parts. This training includes memorizing the correct name of each part, source of power to move it, and the direction it moves.

In the adjustments phase of the course, trains of parts are thrown out of adjustment by the instructor, and the student makes correct adjustments as directed in the technical manual. One by one, each train of parts is maladjusted by the instructor and corrected by the student until the trainee makes every adjustment in each component of the entire machine. This practical experience of learning by doing is quite effective and cannot be duplicated in any other way.

The troubleshooting phase of the teletype maintenance course is exactly what the name implies. The instructor introduces troubles into the equipment (while the student is out of the room), and the student is required to locate and correct these troubles. This method of instruction tests not only the repairman's knowledge of the equipment, but also his ability to diagnose trouble.

In the performance of the teletypewriter repairman's practical work, proficiency comes with practice and experience, for which no training manual, however helpful, can be an adequate substitute.

CHAPTER 13

TRAINING AND SUPERVISION

A First Class or Chief Radioman will take on many supervisory and training responsibilities. You must be able to train Radiomen and strikers at underway condition watches, instruct other communicators in CW and radiotelephone procedure, and supervise a communication office afloat or ashore.

TRAINING

Training is the main factor contributing to battle readiness. Battle readiness, in turn, is the ultimate goal of all naval units. Training, then is of major importance to all hands.

This chapter treats aspects of training affecting communication personnel. It discusses training procedures that have become standard through custom and usage. Covered also are training concepts stated in governing publications issued by the Chief of Naval Operations, principally the effective edition of NWP 50. (This chapter is not, however, meant to replace that important publication.) The type commander's written instructions relating to training should be consulted to provide a detailed knowledge of what is expected regarding communication training and readiness.

A review of the following sources of information will help prepare you for training duties. If you already have served as an instructor, the references may provide additional information to help improve your methods of instruction.

- As a starter, study Military Requirements for Petty Officer 1 & C, NavPers 10057. Training responsibilities are outlined and factors and steps in training are discussed. It also has good material on training aids, performance tests, and written tests. Radiomen can apply this information in specific training situations afloat or ashore.
- The Manual for Navy Instructors, NavPers 16103 contains information of value to a conscientious instructor. This is a basic manual for improving instructional techniques.
- Study also Shipboard Procedures, NWP 50. In it is described a shipboard training program, which offers many ideas that can be applied in related situations.
- Make a habit of reading the Naval Training Bulletin, NavPers 14900. It features articles on the latest training methods practiced ashore and in the fleet. Answers to many training problems may be found therein.
- Appendix I in this training course lists training films that will be helpful in preparing for training duties.
- Films and publications referenced in preceding paragraphs provide general information useful in teaching almost any subject. From them, instructors can learn much about organizing a training program and improving instruction methods.

SUPERVISION

For a well-trained communication division to function properly, proper supervision and good supervisors are necessary. Without proper supervision, any training program that may be adopted will be of little value.

A supervisor is responsible not only for seeing that message traffic is handled properly but also, in most instances, for training lower rated men. You must understand the need for a training program and its continuous application. Duties and responsibilities of communication supervisors are discussed later in this chapter.

COMMUNICATION TRAINING

Setting up a training program within a communication division is not an easy job. Many matters must be considered, including: (1) type of ship or station, (2) number of personnel available, and (3) daily workload of the communication division. If at all possible, one man should be assigned the task of supervising the overall training program, and coordinating the training between different watch sections and communication spaces.

It may become the job of a First Class or Chief Radioman to act as training petty officer. In order to handle this duty effectively and efficiently, the following "rules of procedure" are suggested.

1. Become thoroughly familiar with all jobs within the division. This may seem likea large order, but you should already be familiar with these jobs because you performed most of them, at one time or another, as you advanced in rating. To instruct other personnel to take over these jobs, you first must know how to do them yourself and be able to answer any questions that may arise.

2. Study all information concerning the Radioman in the Manual of Qualifications for Advancement in Rating, NavPers 18068 and Training Publications for Advancement in Rating, NavPers 10052. Training petty officers need to know this information to help other Radiomen study for advancement. Also become familiar with the Record of Practical Factors, NavPers 760 in order to judge properly whether a man is trained sufficiently in each qualification.

3. When setting up or administering a training program, do not depend entirely on personal knowledge. There are many excellent publications that should be used as reference material. A few of the principal reference sources are mentioned at the beginning of this chapter. All of these publications should provide a sound foundation for any training program.

4. Make a list of subjects that need to be taught, based on individual needs of men in the division, as shown in table 13-1. Keep a record of what is taught, together with each individual's progress. An example of an equipment training record is seen in figure 13-1.

SCHEDULED TRAINING

It must be assumed from the start that an inflexible training schedule cannot work. Extreme variations in workload, caused by a ship's operating schedule, do not always permit a fixed training schedule. As a result, training time must be taken whenever opportunity is available. That is, it is scheduled only to the extent that it will be done, if at all possible, some time during the day, but the time varies. If training is absolutely precluded because of a heavy workload, a notation to that effect should be entered in the training log. Time missed can be made up when the workload is lighter.

In planning communication drills and exercises, FXP 3 is considered the best guide to consult.

A suggested communication training program for Radiomen includes drills and exercises listed in table 13-1.

Prepare a lesson plan for each subject. When lesson plans are completed, they must be approved by the division officer. He is officially responsible for the content of such training programs.

Procure space for carrying out the lecture-type portion of the training program. Usually lectures are held in one of the radio rooms. If other space is available, however, check such features as possible seating arrangements, ventilation, lighting, and outside noise levels.

The following training program can be used both ashore and afloat. It is sufficiently flexible to fit into most situations. Also, it can be made to work for various sizes and types of ships and stations, whose workloads are different and varying. Possibly only one or two of these ideas can fit a particular situation, but the suggestions may bring to mind some other ideas.

First of all the training program should be written up as an instruction so that men administering the program will have guidelines to spell out their duties and responsibilities. Duties and responsibilities of the training petty officer and watch section instructor follow. Presented next is the training program itself. The training program instruction should adhere to a similar format.

- Training Petty Officer:

1. Sets up the training program under guidance of the chief in charge and the communication officer.

2. Coordinates training between watch sections.

3. Keeps correct and up-to-date progress records, lesson plans, and assignments.

4. Makes sure all lesson plans and exercises are approved by the communication officer before they are used.

5. Assists the watch section instructor to administer training, when necessary.

Table 13-1. —Lesson and Exercise Plans for Communication Shipboard Training Program

Title	Lesson	Exercise
Voice radio procedure	x	
Tactical voice radio drill	-	x
Administrative voice radio drill	-	x
Radio circuit operation	x	
Radio procedure	x	
Use of frequency meter	x	
Adjustment and calibration of radio transmitters and receivers	x	
Calibration and frequency shifting under normal conditions	-	x
Frequency shifting during conditions of radio silence	-	x
Cryptography and security	x	
Codes, ciphers, and crypto devices	x	
Cryptoboard instruction	x	
Cryptographic drill	-	x
Radio interference	-	x
Radio jamming and heckling	-	x
Radio equipment transfer panels	x	
Coordination and dissemination of tactical signals between radio, CIC, and bridge	x	
Communication publications	x	
Security of classified publications	x	
Encrypted traffic handling	x	
Authentication systems	x	
Radio call sign cipher	x	
Transmission security	x	
Distress traffic	x	
Tactical radio communications	x	
Casualties, failures, and use of emergency equipment	x	
Logs and records	x	
Preventive maintenance	x	
Radioteletypewriter procedures	x	
Teletypewriter equipment safety precautions	x	
Maintenance of teletypewriter equipment	x	
Emergency destruction procedures	x	
Transfer of control of radio transmitters and receivers to remote positions	-	x
Internal handling and tactical communications	-	x
Authentication drill	-	x
Radio call sign cipher drill	-	x
Equipment casualty drill	-	x
Main radio destroyed in battle	-	x
Rigging and use of emergency antenna	-	x
Emergency destruction of classified matter	-	x
Telephone talker instruction	x	
Telephone talker drill	-	x

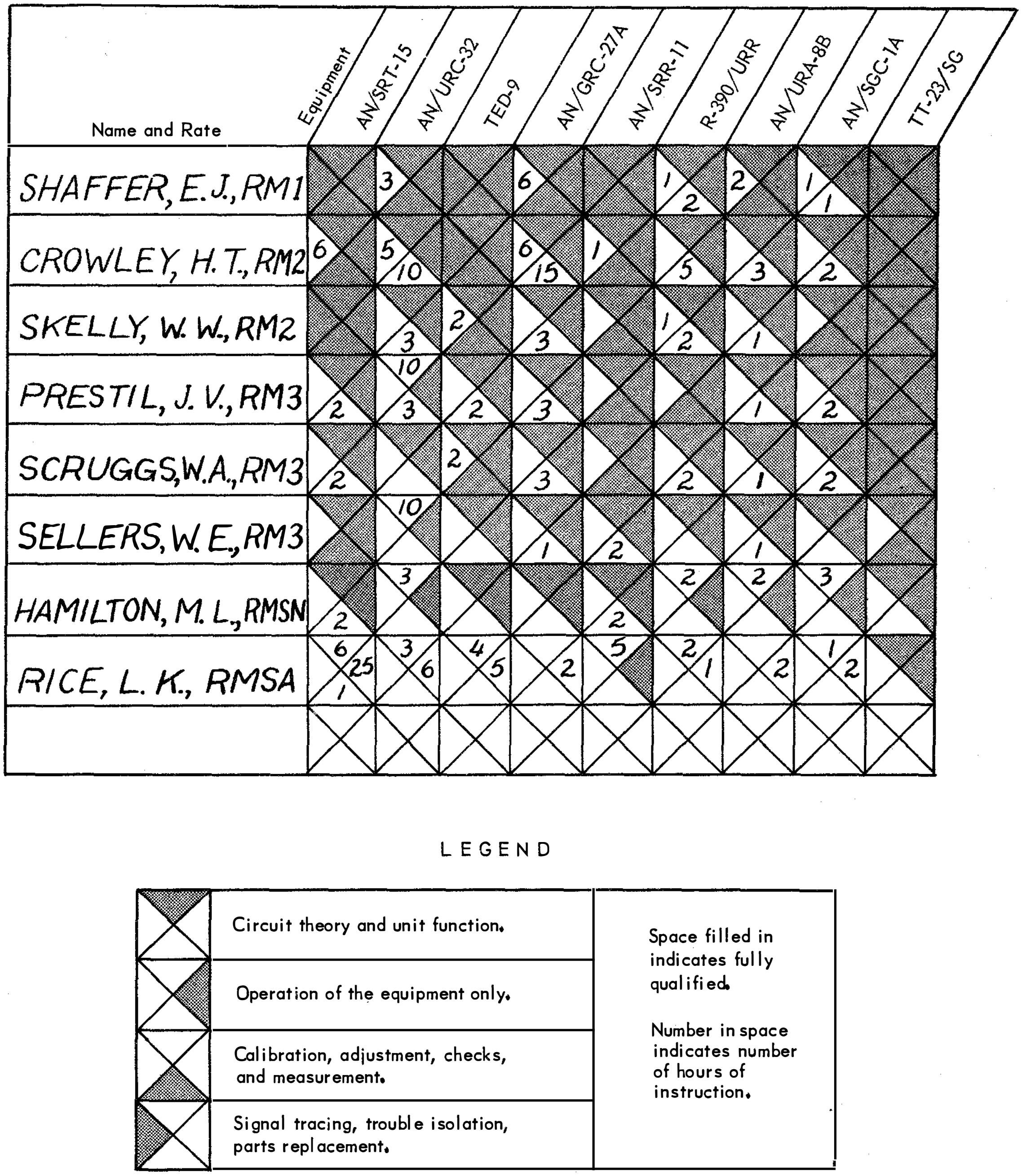

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Figure 13-1.—Equipment training record.

- Watch Section Instructor:
  1. Normally is the watch section supervisor.
  2. Administers training program to his watch section under guidance and (when necessary) with assistance of the training petty officer.
  3. Helps men in his watch section find answers to written questions (given at training

sessions) that trouble them. He should not answer questions outright, but show them where or how to find correct answers. If they still have trouble, he should explain the question(s) to them and (if necessary) supply the answer with an explanation of how it fits into their daily duties.

The Program

Designate the days after the first and second evening watches as training days. Have the evening watch for these two days report at least 1 hour before they are to assume the watch. Explain to the men that these periods will help make their jobs easier, help them make the next rate, and be generally beneficial both to them and to the Navy. Such an approach will help them develop a positive attitude and a willingness to learn.

The first of the two training days is divided into two periods. If each day is set up for 1 hour, each period will run for 30 minutes. The first period should be utilized for reviewing the assignment from the last two periods of the last training day. If time permits, a review can be made of subjects covered in the last two periods but not covered in the assignment.

The second period of this day should be used as an application period devoted to the subject of the last lesson—CW drill, voice circuit drill, and authentication drill, for example. This period can be used also to apply the previously learned knowledge on repair and maintenance of different equipment carried aboard.

The second day is designated as lecture and assignment day. It too can be divided into two periods, each period to cover a different subject or two parts of the same subject. Because it is a regular classroom situation, a lesson plan should be used.

Assignments should be so arranged that they may be worked on during slack periods of succeeding watches. A lesson assignment is given on the second training day, and is turned in on the first training day of the next string of watches. Such a plan gives a total of 11 days for completing the assignment. Make sure there is enough material, so that the assignment will be challenging, but not more than can be handled during the time available. If a man is in training to take over another position on the watch bill, for example, assignment questions can be made up to have him give answers on what is done at that position. During any slack period he can check with the man currently doing the job, and discuss the answers with him. It is possible that both men will learn something from the discussion. The man in training is more likely to remember the answers if he writes them down.

One point must be remembered: For any training program to work, it must be worked at.

NONSCHEDULED TRAINING

Nonscheduled training consists merely of seizing unforeseen opportunities for training purposes. To illustrate, a teletypewriter printing unit, withdrawn from its cabinet for routine maintenance, may present an opportunity to launch into a discussion of it. It would be an ideal time to indicate lubrication points and operating adjustments on the machine. Any information that can be passed, to the men—regardless of time, place, or subject matter—is actually a form of training. An accurate record should be kept of subjects taught and how thoroughly each subject was covered. The same records used for scheduled training can serve also for checking off a man on the subject covered during nonscheduled training. (Refer to fig. 13-1.)

TRAINING SCHOOLS AND COURSES

Radiomen should take advantage at every opportunity of courses offered by fleet training schools and class C schools. These schools last anywhere from 2 days to 2 months. Loss of a man from the watch bill for schooling periods, may impose a temporary hardship, but knowledge gain by the man will help him do his job more effectively, and he probably can become an instructor in the training program. Any selection to a training school is, of course, subject to approval of the division officer.

Selection of men to attend school should be made far enough ahead of time that a replacement can be obtained for an experienced man before he is transferred. Need for someone trained in teletype maintenance or crypto repair, for instance, should be anticipated in advance.

The nuclear, biological, and chemical (NBC) warfare defense, and firefighters' schools offer preparations for casualties. Each Radioman should have some knowledge of these subjects.

Make sure the men know what materials they need to study to advance in rate, and that they order correspondence courses in ample time before the next exam. Let them know that you will be available to help them with the courses if they run into trouble. Because Basic Electricity and Basic Electronics courses are difficult, some men may need encouragement in order to finish these courses successfully. They contain material that is included in the exams, for advancement to all pay grades of Radiomen. Any knowledge the men can gain from these two courses will benefit the maintenance program.

COMMUNICATION TRAINING AFLOAT

When a new man reports to the communication division, an indoctrination schedule should be set up for him.

INDOCTRINATION

The sooner a newcomer becomes adapted to his new assignment, the sooner he becomes a valuable member of the communication team. A man's background and previous duty stations should be considered in determining how long his orientation period should last. Normally a few days to a week should be enough time for indoctrinating him.

After the new Radioman is assigned a bunk and locker, introduce him to all hands in the OR division. Arrange a tour of the ship for him, concentrating on communication spaces. Encourage him to ask questions about unfamiliar equipment or procedures. A thorough explanation will square him away more quickly. Go over the communication division watch, quarter, and station bill and show him just where he will fit in. He should realize that soon he will be filling a responsible position on that bill.

Several publications should be made available to the new man to acquaint him with the ship's functions and with his own division's responsibilities. Check out copies of the ship's organization and regulations manual, and the operations department or communication division organization manual. It's a tall order to read through these publications page for page, so point out sections that are particularly applicable and important to a a new man, and see that he has sufficient time to read them.

The radio shack is the best place to review ACPs, JANAPs, and other communication publications. There the new man can study them during the watch stander's slack periods.

Spend as much time as possible with the new communicator during his orientation period. He will "catch on" faster, and will need less of the instructor's time later on.

QUALIFYING FOR CIRCUIT WATCHES

Graduates of Radioman school reporting aboard are often inexperienced in shipboard communications. They need further training to qualify for circuit watches. Men recruited from other divisions, who did not attend Radioman school, must be trained immediately in fundamentals of radiotelegraphy and touch typing. A situation of this kind calls for an intensive training program capable of producing quick and satisfactory results.

An audio oscillator for code practice, similar to the one shown schematically in figure 13-2, can be patched into remote positions throughout the ship. The one-tube oscillator illustrated can be built from scrap parts.

Transmitter and receiver switchboards installed in Navy ships make it a simple matter to patch any number of operating positions for code practice or intraship drill circuits.

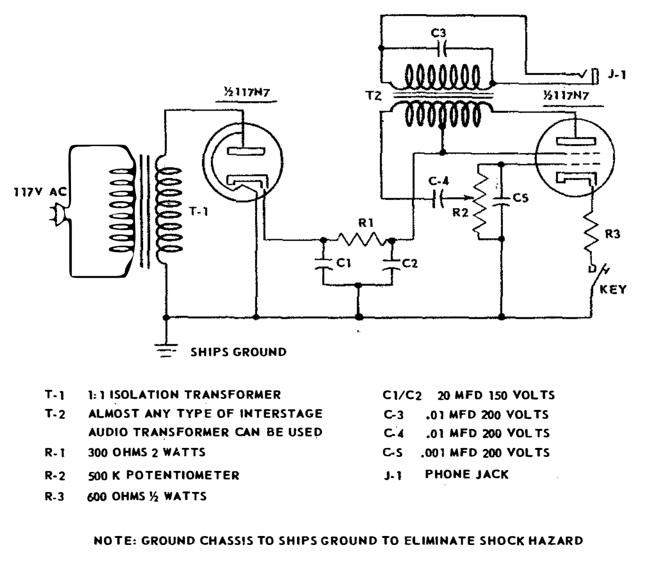

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Figure 13-2.—Code practice oscillator.

Other sources of audio signals are also available in any ship for beginners' code practice. The "squeal" can be keyed from the frequency meter, for instance. Power is switched on all the time, anyway, so as to maintain constant temperature and frequency stability. Additional sources of audio signals are radio receivers, such as models AN/SRR-11, -12, and -13, which have crystal calibrators for resetting accuracy of dial readings. Turn on the calibrator switch to obtain a beat note for patching into remote operating positions.

Be sure strikers take advantage of drill circuits available in many United States ports and U.S.-controlled ports overseas. These drill circuits provide an opportunity for live, on-the-air CW, radiotelephone, and RATT practice under strict supervision.

When Radiomen strikers are checked out sufficiently on drill circuits, have them submit afterhours fleet broadcast and weather copy. A graduate from these assignments is ready to stand regular watches on a fleet CW circuit.

COMMUNICATION SPACES

Depending on her size and type, a ship may have as many as five radio spaces. In a few instances there may be more than that number. As many men as possible should be checked out in all (or most) of the communication spaces. Rotate the watch bill occasionally, so that every man has a chance to qualify for watches in more than one space. Be sure the supervisor for each space is qualified to instruct the men under him in his particular space.

Men should also know the types and location of antennas on board. Be sure some of the men know how to rig emergency antennas. One or two antennas should be made up in advance, ready for rigging. All supervisors should know where the antennas are stowed.

All of the foregoing details can be incorporated in the training program. The more training men receive in these routines, that much easier is everyone's job.

OPERATOR TRAINING

Men should receive proper training from the beginning. It is much easier to teach a new man the correct way to operate on a circuit than it is to break him of any bad habits he may pick up if left on his own. The next three topics deal with training new operators.

Radiotelegraphy Operator (CW)

A new man on the CW circuit soon learns that an unhurried, steady pace results in faster delivery. In addition to correct sending technique, make sure the new operator observes proper circuit discipline from the start of his training. Use of unauthorized plain language and incorrect procedure results in confusion and ambiguity. It's just as easy—and always better—to practice correct procedure.

Be sure that all CW operators are thoroughly trained to handle authentication procedures. Improper use of authentication can cause a loss of valuable time and possibly have disastrous effects upon an operation.

Check a new operator's radio log for consistent accuracy. Make certain he realizes that his log constitutes a legal record, for which reason it is absolutely necessary that the radio log be complete and accurate at all times.

Radiotelephone Operator

Give every new talker the benefit of close supervision. Be sure he acquires a natural delivery and uses only standard phraseology. Soon he will realize that proper delivery cuts down needless repetitions.

Excessive testing, adlibbing, and improper microphone technique are old foes of correct operating procedure. Warn new operators about these pitfalls as soon as they don earphones.

Radiotelephone operators must have a thorough knowledge of radiotelephone authentication procedures. Hold frequent authentication drills, stressing conformity to prescribed procedures.

Radioteletypewriter Operator

The mark of a good teletypewriter operator is speed without sacrificing accuracy. A light, quick, positive touch of the keys is the best sending technique. See that operators adhere strictly to authorized procedure and that they correct typing errors.

PREVENTIVE MAINTENANCE PROGRAM

Plan the communication division preventive maintenance program in a systematic fashion.

Assign each trainee a specific piece of equipment, then give him a thorough indoctrination on it. Show him how to perform operating tests, proper method of routine lubrication and cleaning, and correct troubleshooting procedure. Have at hand, for ready reference, the equipment technical manual and current checkoff sheets designated by the PMS program. Let the trainee locate pertinent sections on preventive and corrective maintenance. He should become familiar with the books and realize the importance of following recommended procedures.

When convinced that the trainee can take over on his own, have him make the daily and weekly tests designated as routine or operational. As his training and experience progress, give him increasingly difficult technical items.

COMMUNICATION TRAINING ASHORE

Communication for a shore station is much the same as aboard ship in that the same general communication procedure and similar equipment are used.

It would follow, then, that a shore station training program can be set up in much the same manner as that used aboard ship.

Probably the main difference between afloat training and ashore training is that at a shore station equipment used is spead out over a wider area. Each man ashore has little opportunity to be trained in operating equipment and procedures not employed in the immediate vicinity of his duty station.

Radiomen stationed at a tributary station, for example, rarely have an opportunity to work with antennas, transmitters, or receivers. Practically all their time is spent with shore-station teletype equipment and message center procedures. Most training in this area can be accomplished on the job. A good message center supervisor takes advantage of every opportunity to train a new man by breaking him in at an operating position as soon as he completes his indoctrination. On-the-job training is the best way of increasing a new man's efficiency. At the same time the trainee has status as a regular watch stander. Each operating position in the message center or relay center offers a chance for on-the-job training.

Scheduled training time, such as the program mentioned previously, can be concentrated on subjects not covered by on-the-job training. These subjects are what Radiomen at a shore station do not come in contact with during tours ashore but need to know in order to advance in rate and on future tours at sea.

Usually, such training aids as chalkboards, training films, and mockups are more easily obtainable ashore than aboard ship. These training aids can be used for instruction on transmitters, receivers, and other subjects not readily available at shore stations.

COMMUNICATION SUPERVISORS

Supervision includes organizing activities of group members toward accomplishment of a given task. Duties and responsibilities of each member of the watch section are spelled out in detail so that every man knows exactly what is expected of him. Merely listing duties does not necessarily ensure that they will be accomplished, however. To gain a specific objective, a supervisor must regulate activities of his men by establishing a standard operating procedure for all routine tasks.

Problems of supervision and discipline are complicated because they affect human beings. Discipline not only demands obedience from subordinates but also requires that the supervisor lead and command. Discipline demands that the supervisor assume responsibility, exercise initiative, and issue instructions. His failure to exercise authority, or misuse of authority, can destroy discipline just as surely as can disobedience. Discipline is comprised of two elements: one component coming from above (the will of the man in charge), and the other from below (the willingness of subordinates to obey). In the Navy, willingness to obey is founded on reason, reinforced by habit. Not only must trainees be taught that the law compels obedience, they also must know why obedience is an indispensable element of collective action and survival. Discipline develops character instead of stifling it.

Operation and maintenance of electronic equipment call for the utmost concentration. For this reason, trainees need periods of relaxation. If no allowance for fatigue is taken into consideration, work may fall behind schedule. On the other hand, if the supervisor grants an excessive number of breaks, he may lose control over the group. He must strive for a happy medium in each situation, and be flexible enough to allow for changing conditions. Many times an all-out effort must be made to complete a task in the least possible time. Under these circumstances the maximum effort is demanded of all hands.

RADIO

The manner in which different radio spaces aboard ship are manned and supervised depends on the size and type of ship and the number of personnel available.

A supervisor of a radio space is directly responsible to his watch section supervisor for proper operation of his space. He must see that all equipment within the space is in good operating condition and that all circuits function properly.

To carry out his duties effectively, the radio-space supervisor must know how to tune, operate, and patch equipment in a minimum amount of time without making errors. He needs a working knowledge of what different circuits within a piece of equipment do and how they do it, so that when trouble occurs he can make necessary adjustments or repairs in the shortest practicable time. If a technician is needed, the supervisor should be able to explain, knowledgeably, the nature of equipment trouble. His explanation will help the technician find the trouble more quickly, thereby reducing the time required to place equipment back on the line.

Circuits for which the radio space supervisor is responsible must be operated according to established procedures. He must see that good circuit discipline is maintained at all times. To accomplish these ends, he must learn thoroughly the CW voice circuit procedures set down in ACPs 124 and 125.

Although each radio space has its own job to do, the overall job for all of them is sending and receiving messages as accurately and quickly as possible. A good supervisor, therefore, not only knows his own space well but also has a good working knowledge of all other spaces. When he brings up a receiver or transmitter on a particular circuit, or patches some equipment to another space, he must realize how and why it is being used. This awareness helps him to know what circuits have to be watched more than others, and he can set up a priority system for circuit restoration in the event of outages.

The radio space supervisor must comprehend information contained in the communication plan pertaining to his space so that he will know when, where, how, and why different circuits are set up. Thus, when his ship is about to go on an operation, he should make himself familiar with that part of the communication annex of the operation order pertaining to his space, so that his space will be up and ready to go when the operation begins.

WATCH SECTIONS

The watch section supervisor is directly responsible to the CWO for proper operation of all radio spaces and their circuits. During his watch, he also must ensure that message traffic is handled accurately and without delay.

Besides understanding thoroughly all information mentioned previously for the radio space supervisor, the watch section supervisor should be able to coordinate activities of all spaces and see that they work smoothly together. He supervises men on his watch in doing their jobs of message handling, using correct circuit procedure, tuning transmitters and receivers, setting up crypto equipment, and operating teletype and associated equipment. He also checks to see that all equipment is patched correctly to make up the different circuits in use.

A good watch supervisor makes sure that all incoming messages are delivered as quickly as possible in a complete and legible form. All outgoing messages should be routed promptly and sent out accurately and in complete form the first time, to ensure rapid delivery and thus prevent overloading circuits with service messages. He must see that good circuit discipline is maintained on all circuits. All supervisors should know how and when to encrypt call signs, and make sure that encryption is done properly. When necessary to authenticate on a circuit, the supervisor must ascertain that correct publications are referred to and that correct procedures are followed.

All watch supervisors should have a good understanding of frequencies that work best during different times of day. In this way the outages on broadcast circuits and on the NavOpNet circuit, if used, are kept to a minimum. Along with this duty he supervises setting up transmitters and receivers so that they are on frequency. A receiver slightly off frequency causes incoming traffic to be garbled. A transmitter off frequency might possibly cause the same trouble at the other end. A watch-to-watch check of publications must be made. Moreover, the supervisor should be familiar with the content of those publications so that he will know where to look for information needed on a certain subject.

The teletype range should be checked periodically so that the optimum setting always is used. Associated equipment should be tuned correctly so that the best signal possible is received, thus ensuring that incoming messages are not garbled.

All circuits must be patched correctly to ensure that the foregoing precautions and procedures are fully effective. Make sure that equipment is patched only when necessary and that only proper equipment is used on the different circuits.

Many responsibilities of a supervisor can be made lighter if he is assured that men on his watch can handle the various jobs efficiently. To accomplish such a goal, continuous and effective training should be part of their daily routine. On-the-job training, adequately supervised, is one of the best ways to ensure that men of a watch section work together smoothly.

COMMUNICATION WATCH OFFICER

Aboard some ships and stations a chief or even a first class petty officer will possibly stand watches as a communication watch officer (CWO).

While on watch, the CWO is in active and immediate charge of ship or station communications. As provided for in a communication organization, he is responsible for incoming and outgoing traffic. In this capacity, he ensures that all messages sent and received are in correct form and that they are handled promptly and efficiently. During his watch, he is responsible for proper operation of the cryptocenter and for security of all spaces. The CWO is also responsible for the security and proper operation and maintenance of equipment and other material in all spaces. He likewise must ensure that higher classified traffic is delivered on a "need to know" basis only, and that each copy is numbered and accounted for at all times.

CHAPTER 14

EQUIPMENT CASUALTY, SAFETY, AND ANTIJAMMING PROCEDURES

EXPEDITIOUS ACTION

The speed with which corrective action is applied to a communication casualty depends on effective personnel utilization and constant training. When your ship puts out on a mission, all hands must do everything possible to keep the ship afloat and to protect the lives of the crew. A Radioman supervisor must know what to do and how to do it when accident, fire, or enemy action threatens the safety and fighting ability of his ship and men. He must indoctrinate his subordinates with the necessity for prompt action in instances of material failure or battle casualty. Wasted time may cause needless damage to equipment or even loss of life.

ADVANCE PREPARATIONS

You can avoid confusion during actual emergencies by making advance preparations. Have each man study the watch, quarter, and station bill so that he knows his assigned station and duties perfectly. See that each man checks the bill frequently for possible changes. Query each radioman, especially a newcomer, on the exact location of his abandon ship station as well as on his assigned station for all other emergencies. Ask him the location of the first aid station nearest radio central and other radio spaces, and the site of the decontamination station. Ask him what piece of firefighting equipment he would use to extinguish a class C fire. Make sure he knows the quickest and safest route to emergency radio spaces.

Every member of the radio gang has a part in carrying out the emergency destruction bill. Your men should know the exact location of destruction material (sledges, wire cutters, screwdrivers) and weighted perforated bags. Each man should read the destruction bill carefully, and note particularly the items he is to destroy when directed.

Examine battle lanterns daily and make sure spare flashlights are available for immediate use.

Check first aid kits to see if they are fully stocked. If a kit's seal wire is broken, an item may be missing. Have the medical department replenish as necessary. (In some ships only medical department personnel are authorized to inspect first aid kits.)

Make sure that emergency, distress, scene of action, and SAR frequencies for your area are posted conspicuously. Each operator must be alert and acutely aware of the fastest means for delivery of distress or emergency traffic.

Ensure that any defect that could affect the safety of an individual or cause electric shock is corrected immediately.

See that your damage control petty officer does not neglect ports, doors, hatches, and other closures under the various damage control conditions of readiness.

On most ships, engineering personnel are responsible for weighing CO extinguishers monthly. Be sure they are weighed, and check to see that the date and charge weight are entered on the bottle tag.

In the damage control bill and associated bills, review procedures for controlling blast and thermal radiation damage resulting from attacks by nuclear weapons. Because radiological hazards occur only with nuclear weapons, procedures for controlling the effects of nuclear radiation on personnel are found in the radiological defense bill, one of the associated bills. Know the contents of this bill and make sure your men are familiar with its provisions.

Detailed information on the subject of defense against atomic attack may be found in the effective editions of <u>Basic Military Requirements</u>, NavPers 10054, <u>Military Requirements for Petty Officer 3 & 2</u>, NavPers 10056, <u>Military Requirements for Petty Officer 1 & C</u>, NavPers

10057, and in the Bureau of Ships Technical Manual.

STANDBY EQUIPMENT AND STATIONS

Designate backup frequencies, transmitters, receivers, antennas, and terminal equipment for emergency operations in locations as widely separated as possible. Ensure that spare emergency receiving and transmitting antennas are made up and stowed in appropriate locations for rapid rigging when required. See that all standby stations have all necessary communication publications, such as call sign books, authentication tables, call sign cipher devices, logs, and message blanks. Your operators at standby stations should monitor circuits constantly so they can take over instantly if a breakdown or more serious casualty occurs in main radio.

KNOW YOUR EQUIPMENT

Knowledge is the keystone of casualty control. During emergencies there is no time to teach a man how to tune a transmitter or patch transmitters and receivers to the various remote stations. Loss of key COMMCEN or radio central personnel may leave your strikers to carry on. Each man should know each type of equipment thoroughly. When new equipment comes aboard, study the technical manual thoroughly, then show your men how the equipment works. Stress safety precautions spelled out in the technical manual, and don't let a man touch the gear on his own until he is checked out completely.

If a frequency meter is knocked out, you must refer to calibration charts to tune some of the older model transmitters. Hold drills to see that each man can set up frequencies from these charts. Stress proper procedures for tuning transmitters under radio silence conditions. See that operators' instruction charts for tuning each transmitter are posted near the equipment.

Each man should understand the flexibility of transmitter and receiver switchboards in the various radio spaces. If a shorted trunk line occurs between radio II and radio I, for example, the desired transmitter can be patched through radio III in seconds if your men are well trained in switchboard operations.

HEAVY WEATHER PRECAUTIONS

Damage and loss of equipment sometimes occur during heavy weather when equipment is not secured properly. Loose gear can cause injuries to personnel and may start a fire if it slides into electronic equipment.

Check all radio spaces as soon as word is passed to rig ship for heavy weather. Chairs, wastebaskets, and all loose gear must be lashed down securely. Once you are certain that all necessary steps have been taken in your spaces to rig for heavy seas, notify the COMM officer and the OOD.

SAFETY PRECAUTIONS

Fast action and an automatic regard for safety precautions are extremely important in coping with casualties to communication equipment and personnel aboard ship. Too often, however, measures recommended to prevent accident or damage are overlooked during actual emergencies.

Each man should appreciate fully the hazards of working with electricity. You should stress special precautions necessitated by using high-voltage power supply circuits and even higher radiofrequency potentials; effect of fields existing in vicinity of antennas and antenna leads that introduce fire hazards; danger of shock to personnel; explosion hazards where ammunition or explosive vapors are present; and dangers from electrical shock and toxic stack gases to men working aloft.

Frequently review the following important points with your men:

1. Basic electrical precautions and safeguards;
2. Proper methods of resuscitating a man unconscious from electrical shock;
3. Proper treatment for shock and burns;
4. Safety precautions associated with communication equipment;
5. Proper procedures in event of electrical accident; and
6. INSTILL AN ELECTRICAL SAFETY CONSCIOUSNESS IN ALL HANDS.

If you find a man is hazy regarding safety precautions, have him reread chapter 15 of the Radioman 3 & 2 training course and the following references given in that chapter pertaining to safety precautions: Chapter 1, "Safety and First Aid" in the BuShips Electronics Installation

Practices Manual; Electric Shock, its Causes and Prevention, NavShips 250-660-42; Electric Shock and its Prevention, NavShips 250-660-45; and chapter 18 of U.S. Navy Safety Precautions, OpNav 34P1.

LECTURES AND DEMONSTRATIONS

Make arrangements with the medical department for lectures and demonstrations. Schedule these talks on your training program so that all hands in the division get the latest word on artificial respiration, decontamination procedures, types of bandages and splints, and other lifesaving aids and techniques.

SCHOOLS

Nuclear, biological, chemical (NBC) warfare defense and firefighters' schools offer further preparations for casualties. Subject to approval of your division officer, select men to attend courses offered at these schools. Choose men who can help you as instructors in these subjects during regular shipboard training. You will have to adjust the watch bill accordingly, but it is well worth the effort.

The NBC warfare defense course for rated men normally lasts several weeks. There are two short courses for firefighters. The 2-day course teaches basic firefighting techniques. Methods of distinguishing the classes of shipboard fires and use and maintenance of firefighting equipment are offered in the 5-day course.

SIMULATED CASUALTIES

Have your radio gang demonstrate ability to make repairs quickly and handle each simulated casualty or failure satisfactorily. For best results, follow a detailed plan of action, stressing necessity for speed and accuracy. To get the most from your men in the shortest possible time, follow the general procedures described in the remainder of this topic.

After first clearing through the radio officer or communication officer, ask the OOD for permission to hold a casualty drill. Brief participating personnel thoroughly on the purpose and importance of the drill and the procedure to be followed in conducting the exercise. Each man must know exactly what his job is. Questions should be asked at the briefing—not during the drill.

When you are ready to proceed with the drill, declare the casualty. State, for example, "Main radio completely destroyed," and specify "All personnel in main radio are casualties." (Or you may delcare only certain individuals as casualties.) Participating personnel should then carry out the objective of the drill.

Normal communications should not be disrupted in your simulated casualty drills. Be sure to analyze errors and discrepancies, if any, and show each man how to correct them. Notify the OOD upon completion of your drill.

ACCURATE REPORTS

Many precious minutes can be saved by communication personnel in reporting casualties promptly and accurately. Drill your men in the following procedures so that, when the next emergency comes up, the casualty will be reported swiftly and correctly.

To report the casualty, use sound-powered phones, MC units, ship's service telephones, voice tubes (if installed), or messenger. The initial report should contain the following information:

1. Nature of damage (class C fire, bomb hole, shock casualty);
2. Location of damage;
3. Extent of damage (flooding, fire, smoke, or toxic gases present, etc);
4. Measures being taken to combat damage (firefighting, type of extinguishing agent, etc.);
5. Assistance required.

CASUALTY SITUATIONS

Every Radioman knows that the damage control organization aboard ship is mainly responsible for accomplishing emergency repairs or restorations after damage occurs. During battle, collision, heavy weather, or serious fires, the damage control and firefighting parties are ready with trained men and special tools for action against fire and damage. A damage control party may supply casualty power, regain a safe margin of stability and buoyancy, replace essential structures, and man essential equipment. But no one can foresee just where the damage or fire will strike. Remember, COMM spaces are vulnerable to bomb and shell hits causing fires or personnel casualties. If there is a casualty in a radio space, the regular damage control party may be tied up in other parts of the ship. Your men on the spot in radio central or other communication spaces may have to fight the fire and repair the damage.

The remainder of this chapter describes common types of communication casualties and suggests remedial measures to correct them. Bear in mind that a method suggested may not be the ONLY solution. As supervisor, be ready to improvise, because you may not have time to follow an established pattern. Remember to adapt yourself and your men as expeditiously as possible to the conditions confronting you.

RIGGING AN EMERGENCY ANTENNA

Loss or damage to an antenna from shell or bomb hits, heavy seas, or violent winds can cause serious disruption of vital communications. Sections of a whip antenna may be carried away, external insulators may be damaged, or a wire antenna may snap loose from its moorings or break. Your job is to supervise the rigging of an emergency antenna to restore communications on a temporary basis until repair or replacement of the antenna.

In rigging emergency antennas, have your antennas already cut to proper length, with necessary insulators and turnbuckles secured to the ends. Keep them coiled and stowed so as to be readily accessible. With these preparations made beforehand, a jury rig can be set up with minimum delay. Methods of rigging vary, of course, in accordance with the type of ship, location of transmitting and receiving equipment, and the extent of loss or damage.

Before rigging an emergency antenna, make sure transmitter power is secured, then get permission from the OOD. Men assigned to go aloft must have proper equipment, such as safety belts and necessary tools. Notify the OOD when the antenna is rigged satisfactorily, and have the transmitter retuned to the proper frequency.

ELECTRICAL FIRE

The senior officer or, in the absence of an officer, the senior man present is in direct charge of extinguishing the fire until arrival of the damage control party. He makes certain that the fire is reported immediately to the OOD. If you are the one in charge, proceed as follows:

Deenergize circuit, then attack the fire with a portable CO_2 extinguisher. For best results, direct the stream from the extinguisher at the base of the flames.

If the fire reaches a dangerous degree of heat radiation, bulkheads separating adjacent compartments will have to be water cooled.

If all efforts with CO_2 fail, apply high velocity fog or foam. Fog should be used first, however, due to high incidence of residual damage caused by foam. Keep these points in mind when using fog or foam. The fine diffusion of fog particles reduces but does not entirely remove danger of electric shock, and condensation of fog on the equipment may cause serious damage. Foam also causes serious damage but to a greater extent than fog. Regardless of these disadvantages, however, employ fog or foam on class C fires whenever circumstances warrant.

To prevent spread of fire to other compartments, station men with fog nozzles near adjacent spaces on the same deck and on the decks immediately above and below. These standby firefighters are necessary if the fire begins to radiate heat to a dangerous degree in their area. If essential, remove equipment in the vicinity likely to be damaged by water.

Remember: Carbon dioxide is your first choice in fighting an electrical fire. Fog and foam are poor seconds.

CASUALTIES TO EQUIPMENT

Communication equipment failures during fleet operations or in battle are casualties that, if not corrected immediately, can have disastrous results. Communication personnel must be able to detect and remedy such casualties as quicly as possible.

In an equipment casualty, your first responsibility is to reestablish communications on alternate equipment. After shifting, direct your efforts to restore the defective equipment to proper operating condition. Equipment casualties can occur because of such a variety of causes that the remedial action needed to restore communications may be a simple matter, or it may be difficult. A power failure, for instance, may disrupt every communication circuit in radio central. The remedy may be as simple as throwing a single emergency power switch from the normal power to emergency power position. The cause of the failure may be so serious, however, as to require rigging of emergency power cables by the damage control party.

Let us consider another example: failure of the RATT broadcast receiving system. The trouble may be in the antenna, antenna filter patch panel, radio receiver, receiver switchboard, frequency shift converter-comparator, on-line cryptodevice, teletypewriter patch panel, rectifier power supply, teletypewriter switching control unit, or the teletypewriter itself. In addition to each of these system components, the trouble may be in the interconnecting lines. You have learned from experience what to check first in your own system of troubleshooting diagnosis. Shipboard equipment installations provide the needed flexibility for patching alternate equipments into the system.

After communications are reestablished, the next task is to troubleshoot the defective equipment. An important step in this process is to localize the source of trouble to a small section or stage of the equipment before making detailed checks on individual parts. Proper isolation of the trouble to a definite section avoids time-wasting detailed checks in sections or circuits that may in themselves be completely free of defective operation. Consider the existing trouble indications carefully and properly isolate the trouble instead of making spot checks all over the equipment. Many troubles, particularly in transmitters, can be traced to a section or stage with the meter readings available on the front panel of the equipment.

All equipment technical manuals include a chapter on troubleshooting. By means of charts, the repairman is guided step by step through the various stages of the equipment. The charts show him what action to take, the normal indication to be expected, and where to proceed if the normal indication is not obtained. Be sure your men consult the technical manual in their attempts to correct an equipment casualty. Because the troubleshooting chapter is not numbered the same in each book, it is a good idea to paste an index tab to mark the place in each technical manual. This method saves your men time when the information is needed in a hurry.

CASUALTIES ASHORE

Disaster control bills and emergency communication plans for your communication activity emanate from the local district communication officer (DCO) and conform to directives from DNC. These instructions specify procedures to follow in fire, flood, accident, enemy attack, hazardous weather, and other disasters. Common examples of disaster control bills are fire bills, flood bills, and hazardous weather bills. From time to time these instructions are supplemented by station regulations.

You are particularly concerned with the fire regulations and bills posted in the COMMCEN, terminal buildings, and other operational communication spaces. Keep up with any changes in these bills, and frequently quiz your men on their contents.

FIRE FIGHTING

Communication activities ashore maintain fully equipped fire departments capable of dealing successfully with practically any type of fire. At locations where COMM units are within easy reach of each other, a central fire department serves all units in the area.

What you do as supervisor of the watch until the fire department arrives is governed by conditions at the time. In general, however, the following procedures apply to most situations.

- If fire is in equipment, first secure power, attempt to extinguish the fire, and always notify the fire department immediately—even for small fires. Fire spreads rapidly, and at shore stations fire extinguishers are no more effective than first aid appliances.
- For continuity of communications, come up on alternate circuits or use other available equipment as soon as possible, and notify associated communication units of your actions. For example, a fire in the main building at a receiving station must be reported immediately to the associated COMMCEN and transmitting station.
- Close windows and doors. Have your men shut off any air-conditioning or forced draft air heating, cooling, or ventilating system. As a last resort, it may be necessary to secure or cut electric service lines to the building.
- In fighting the fire, ensure that the most appropriate extinguisher is used. Fight class A fires with extinguishers of the hand pump type (water), pressure reaction type (carbon dioxide cartridge and water), sand, or high/low velocity fog. Use the pressure reaction, foam, high/low velocity fog, or CO_2 types on class B fires. Extinguish class C fires as previously discussed.
- Make sure exposures are protected. (Exposures are structures in danger of becoming ignited by fire originating in an adjoining or

neighboring building.) Evacuate and protect exposures by wetting surfaces, closing windows and doors, and protecting roofs and other combustibles from sparks and burning brands. Break up radiating heat waves with heavy streams of water.

EVACUATION

If it becomes necessary to evacuate the building, evacuation is under the direct supervision of the senior officer present, supervisor of the watch, or other enlisted personnel (if designated).

Before evacuation, take the following steps to ensure protection of classified and unclassified material:

1. See that all windows are closed.
2. Make certain that all steel file cabinets and desks are closed.
3. Ensure that all classified publications and correspondence are locked in steel file cabinets or carried from the building.
4. Where practicable, have all power shut off from equipment in the building. After these precautions are accomplished, march all personnel to a place of safety. Follow the evacuation routes prescribed in your station's fire and evacuation bill.

ANTIJAMMING MEASURES

Jamming and harmful interference are capable of disrupting communications just as effectively as an equipment breakdown. Although some modes of radio transmission are more vulnerable to successful jamming than others, you must remember that no type of equipment can be considered to be completely safe against this form of warfare.

The success you have in the face of jamming depends to a large extent upon the antijamming procedures and techniques you use. To combat enemy jamming successfully, you must use the three R's of antijamming: RECOGNIZE jamming, REPORT it, and READ through it.

RECOGNIZING JAMMING

Because radio jamming has many of the symptoms of a receiver trouble, your operator may decide that the noises he hears are caused by a faulty receiver. Or, if he recognizes that the cause of the trouble is external to his set, he is quite likely to blame the whole thing on static, an off-frequency station, or electrical interference. In short, he is not certain to recognize jamming when he encounters it.

The very fact that an enemy is jamming your communications is in itself important operational information. Therefore you must recognize and report it as soon as possible.

Radio jamming is best described according to the type of modulation. There are several types of signal jamming you may encounter; spark, sweep-through, stepped-tone, and noise jamming.

One of the simplest and most primitive types of radio jamming is caused by an electrical spark. You are familiar with this type if you have tried to listen to your broadcast receiver while someone nearby was using an electric razor or running a vacuum cleaner while you were trying to listen to an important event. Spark consists of numerous jagged peaks of noise of short duration having high intensity and a high repetition rate. Although they are of short duration, they can blanket the desired signal effectively because of the receovery times of the receiver, the earphones, and your ear. You probably will encounter spark jamming more frequently than any other type because it is fairly easy to generate and its broad radio-frequency characteristics enable the enemy to cover a number of communication channels with one jammer.

Sweep-through jamming produces an effect similar to spark jamming. As its name indicates, this type of jamming is the result of sweeping a carrier back and forth across a frequency band at a relatively rapid rate. The effect on any one channel in the band is to produce numerous pulses of noise spaced in time at the rate of the jamming carrier sweep. The result is a noise that sounds very much like an airplane engine. The recovery time of the circuits and of your ear makes this form of jamming very effective.

Stepped-tone jamming, frequently referred to as bagpipes, consists of a number of audio tones, usually three to five, repeated over and over. Because it is very annoying, it is an extremely effective type of jamming.

Noise is a highly effective form of radio jamming. Because the noise signal is flat in its audio spectrum for several thousand cycles, it places a blanket of uniform intensity over the range of the desired signal. You can recognize noise jamming because it sounds like the noise you hear if you turn up the gain of a receiver that is not tuned to a signal. It may be mistaken for receiver or atmospheric noise, thus it is particularly dangerous.

Although the jamming that you may meet in actual practice may not correspond exactly to one of the foregoing types, it probably will be somewhat like one of them or a combination of several. Sometimes recorded music may be used by an enemy for successful jamming of radiotelephone channels. The jamming is made to appear like an ordinary broadcast to conceal the fact that it is deliberate. It can be particularly effective because your operator may not even realize he is being jammed.

The next two topics describe some steps the Radioman can take to help decide that the interference he is receiving is a jamming signal and not trouble in his receiver or some kind of local interference.

How To Tell Jamming From Receiver Trouble

If you receive interference about which you are not sure, disconnect the antenna from the receiver. A drop in the noise level of the interference means that the source of interference is outside your receiver and is being picked up by the antenna. The source of trouble is therefore not in the receiver. If the noise level of the interference does not diminish when you disconnect the antenna, the trouble is in the receiver, and you should shift over to alternate equipment until the defective receiver is repaired.

How To Tell Jamming From Local Interference

As already stated, a decrease in the intensity of the interference when the antenna is disconnected means there is nothing wrong with your receiver. Try tuning your receiver on each side of your operating frequency. If the level of the interference remains constant, you probably are receiving interference from an electrical source close by. The cause of this noise may be a faulty generator or other electrical source. It may even be interference from a friendly radio or radar station. If, however, you find that the interference seems to be strongest around your operating frequency and diminishes as you tune away from this frequency, then you're being jammed.

REPORTING JAMMING

As soon as you determine that the enemy is deliberately jamming you, notify the communication officer immediately so that he can make the reports required by NWP 33. The mere fact that you are being deliberately jammed by the enemy is important—and could be of vital importance to operations and intelligence staffs at higher levels of command. Also report promptly all instances of interference from friendly stations so that corrective action can be taken.

Always endeavor to obtain as much information as possible about the jamming source, and report all pertinent details called for in NWP 33. The more detailed your description, the more helpful your report will be. In addition to the type of jamming, other valuable information includes the frequencies involved, the type of equipment affected, the effectiveness of the jamming, as well as the time and date when the jamming occurred.

READING THROUGH JAMMING

The most important contribution you can make against enemy jamming is to keep your station operating. Whatever else you do, do not shut down, for that is exactly what the enemy wants you to do. Use all the skill and tricks you know. But, whether they work or not, keep operating.

Defense Against Jamming Signals

In general, spark and sweep-through jamming may be countered by limiting action. Even if your particular receiver does not have a limiter, you can obtain this effect by overloading the receiver or the headphones. Turning the gain as high as possible may enable you to clip the peaks of the jamming signal so that you can hear the desired signal. You may have to put cotton in your ears or use some other technique to accomplish this limiting action. For example, reduce the r-f gain, increase the a-f gain, and use the crystal filter (if the receiver has one) to tune to the least jammed sideband. This procedure may enable you to read through the jamming.

Bagpipes and noise jamming have no particular weak spots that make them vulnerable to some specific treatment. Bagpipe modulation is a carrier modulated by several tones.

If your receiver has a crystal filter, tune to one sideband to copy the desired signal. In contrast to the high audio level recommended against spark and sweep-through to accomplish limiting, a low audio level is a more effective antijamming measure against bagpipes and noise jamming. Decreasing the gain to a point where you can barely hear the signal may make it possible for you to read through these types of jamming. Reducing the r-f gain and reducing the bandwidth of the receiver are especially helpful against noise jamming. Remember that this method is not a sure-fire solution however; it works at times but fails at other times.

Work Through Jamming

Often you may find it possible to work through some types of jamming. With practice and training, a good operator may be able to work CW through jamming that is more than 16 times stronger than the power of the desired signal. Remember that the ability to work through interference is more important than attaining high speed. The ability to copy 30 words per minute with no jamming is of no use to the operator who is being jammed deliberately. In addition to practicing at working through jamming, your operators must learn every antijamming technique they can use. Some suggestions and hints for radiotelegraph operation that may prove helpful are given here.

TUNE RECEIVER.—If the receiver has a crystal filter, be sure your operator uses it. Its selectivity may enable him to shut out any of the jamming that is not exactly on frequency. Slowly tune the receiver back and forth across the operating frequency to find the position where the signal can be read through the jamming.

SET GAIN CONTROL.—Turn up the gain as high as it will go. (Yes, it may be hard on your ears, but turn it up anyway.) Put cotton in your ears, or put a handkerchief between the headphones and your ears, or just turn the phones around so that they are facing away from your ears. If this method doesn't improve the signal-to-noise ratio so that you can make out the signal, try turning the volume down to a very low level, and see how this plan works. Work through the entire range of this control until you find the best setting for hearing the signal.

RESET BFO.—The chances are slight that the jamming is just exactly on your frequency. If you're using CW, therefore, try changing the BFO setting. This procedure may give you the message on one audio tone and the jamming on another. With some types of jamming against CW, the signal can be heard better with the BFO cut off.

CHANGE FREQUENCY.—If you are unable to work on your primary frequency, switch to an alternate one. If the number of personnel and amount of equipment allow, traffic should continue on the primary frequency, giving the impression that the jamming is not effective. Tune the alternate transmitter accurately and quickly. Employ a dummy antenna if you have one; if not, tune at reduced power. Try to get through on this new channel before the enemy jammer finds your frequency.

CHECK MESSAGES.—Be alert against deception. Don't let the enemy trick you into accepting any fake messages along with the jamming. Be careful. Authenticate. Look with suspicion upon any signal, especially one that comes in unusually strong, or that manages to lose its authenticator in the jamming every time you ask for it.

SEND CAREFULLY.—If you are trying to send a message through jamming, be especially careful with your sending. Send slowly and distinctly, and send each word or group twice. If your transmitter has MCW capability, it may be of some help against certain types of jamming. In general, however, CW is the most difficult of all transmission modes to jam. If you are transmitting radiotelephone, speak slowly and distinctly. Use the phonetic alphabet and speak each word twice. Remember that the jamming may be much worse at the receiving end.

RADIOTELETYPEWRITER

Of the two types of radioteletypewriter operation—frequency shift keying and tone shift keying—FSK is less susceptible to successful jamming.

Interference encountered on frequency shift circuits may be partially or wholly eliminated by making any or all of the antijamming adjustments suggested for radiotelegraph. You must be careful, when adjusting the BFO control, to hold the tone of the signal to certain limits—in most instances 750 to 950 cycles. A greater change in tone causes malfunction of the teletypewriter.

Teletypewriter circuits using the tone shift system of keying are more susceptible to jamming than straight frequency shift keying methods. The keyer-converter used in the tone shift system has filter circuits to separate the marking and spacing tones. Any interference at or very near the frequencies passed by these filter is transferred to the teletypewriter and results in garbling the desired signal. The only procedure you can follow is shift to another operating frequency.

SINGLE SIDEBAND RECEIVERS

Single sideband transmissions without carriers are difficult to jam. Receivers especially designed for single sideband reception are equipped with a number of circuits that can be switched in or out to minimize the effects of interference.

Filters separate the various channels in each sideband as well as the two sidebands from one another. Although these filters are not tunable, they permit satisfactory operation if the interfering signals are 1 or 2 kc outside the edges of the passed bands.

In some types of receivers, an automatic frequency control (AFC) circuit uses the transmitter carrier to tune the first oscillator stage automatically. The purpose of this arrangement is to keep the receiver tuned to the transmitter frequency regardless of minor frequency variations. It has the major disadvantage, however, of becoming disabled under conditions of jamming that are on or near the transmitter frequency. In some receivers a squelch circuit disables the AFC circuit under conditions of high noise peaks or subnormal carrier levels. When the interfering signal or noise becomes weaker, the AFC then automatically resumes operation and retunes the receiver to the transmitted frequency.

Most receivers have noise limiter or input attenuator switches. Try receiving with each of these switches first in one position then in the other; choose the switch positions that afford you the best signal-to-noise ratio. If the receiver has AFC adjustments, use them carefully to reduce the jamming signal.

OPERATOR TRAINING

Be sure that each operator has a thorough knowledge of antijamming measures. Place emphasis on the necessity for authentication. Guard against panic at the first sign of jamming. Each operator must be trained so that he is familiar with his equipment and knows its capabilities and limitations.

Keep working. You have an excellent chance of working through any jamming to which you may be subjected. However, you must remain calm, concentrate on your job, and keep trying all the time. Remember: There is one setting for each receiver control that is best for combating the type of jamming you are receiving. Find that setting. When you are jammed, the important thing to remember is to keep working. Try all the suggestions given and any others you may have discovered—but keep trying.

APPENDIX I

TRAINING FILM LIST

Certain training films that are directly related to the information presented in this training course are listed below under appropriate chapter numbers and titles. Unless otherwise specified, all films listed are black and white, with sound, and are unclassified. For a description of these and other training films that may be of interest, see the United States Navy Film Catalog, NavWeps 10-1-777.

Chapter 5

ELECTRONICS ADMINISTRATION

MN-10043A The Planned Maintenance System—Introduction. (20 min.—Color—1964.)
MN-10043B The Planned Maintenance System—Maintenance Data Collection. (15 min.—color—1965.)

Chapter 6

TYPES OF COMMUNICATION LINKS

MA-9819 Signals in Space. (27 min.—color—1962.)

Chapter 11

SINGLE-SIDEBAND COMMUNICATION EQUIPMENT

MH-8939 Single Sideband Radio—Introduction. (19 min.—1960.)

Chapter 13

TRAINING AND SUPERVISION

MN-6929A Instructor Training—The Trainee. (12 min.—1952.)
MN-6929B Instructor Training—Subject Matter. (11 min.—1952.)
MN-6929C Instructor Training—The Lesson. (17 min.—1954.)
MN-8050 Functional Teaching in Electricity and Electronics. (16 min.—1953.)

Chapter 14

EQUIPMENT CASUALTY, SAFETY, AND ANTIJAMMING PROCEDURES

MN-6754	Safety Precautions for Electronics Personnel—Introduction. (15 min.—1951.)
MN-8990	115 Volts, A Deadly Shipmate. (19 min.—color—1960.)
MN-9559	First Aid, Mouth to Mouth—Mouth to Nose Resuscitation. (19 min.—color—1960.)

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