SHIPBOARD ELECTRONIC EQUIPMENT

Prepared by
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PREFACE

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This text has been prepared for a specific purpose. It is to furnish naval officers who are not electronic specialists with an overview (1) of the fundamental concepts of major electronic equipments on board ships of the U.S. Navy, and (2) of the capabilities and limitations of the more common equipments installed in the categories of communications, radar, sonar, and navigational aids.

In view of the objective of the text, technical details of circuits and of components of equipments have been kept to a minimum. Overall technical aspects of the systems have been covered in sufficient detail, however, so that students can acquire familiarity with the purposes, functions, and types of equipment.

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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.

CONTENTS

CHAPTER 1

NOMENCLATURE AND GLOSSARY

As in any technical or specialist field, many of the special words, phrases, terms, and symbols used in electronics are unfamiliar to the average person. To assist you in following the material presented in the ensuing chapters, this chapter is devoted to a description of equipment identification systems (nomenclature designations) and to a glossary of common electronic terms and symbols.

JOINT ELECTRONIC TYPE DESIGNATION SYSTEM

The Electronic Type Designator System (AN system) for electronic equipment, adopted in 1943, is intended to—

1. Be logical in principle so that the nomenclature type numbers will be understood readily, and the operation of the armed forces supply services will be facilitated.
2. Be flexible and sufficiently broad in scope to cover present types of equipment, as well as new types and uses of equipment that will be developed in the future.
3. Avoid conflict with nomenclature assigned at present to the equipment used by the armed services.
4. Furnish adequate identification on nameplates with or without the name part of the nomenclature.
5. Provide a ready means of identifying equipment in correspondence and other types of communication.

The system is so designed that its indicators reveal at a glance many details that pertain to the item. For example, it tells whether the item is a SET or a UNIT, and such other information as where it is used, what kind of equipment it is, and what it is used for.

SET IDENTIFICATION

To explain the AN system, a typical example of set nomenclature, Radar Set AN/APS-2, is included in table 1-1. Thus, Radar Set AN/APS-2 is a search radar set installed and operated in an aircraft.

Table 1-1. —Designation for Radar Set AN/APS-2.

Radar set	AN/	A	P	S-	2
Item name as prescribed	A major equipment.	See designated col. in table 1-2.			Second equipment in this category (col. 4).
		Airborne (col. 1)	Radar (col. 2)	Search (col. 3)	

Other equipments in the same category are the AN/APS-4 and AN/APS-6. Another set of a different category is the AN/SRC-1, which, as indicated in table 1-2, is a shipboard radio communication set for receiving and transmitting.

A modification letter is used to identify a set that has been modified, but which still retains the basic design and is functionally and electrically (power source is the same) interchangeable with the unmodified set. (See table 1-2, column 5.) Thus, if Radar Set AN/APS-2 is modified, it becomes AN/APS-2A. The next modification would be the AN/APS-2B, and so on.

A special indicator (table 1-2, column 6) is used when the only change to a set is in its input power, or when it is an experimental or a special model. For example, if the same basic design is kept, but the input power is changed from 13 volts to 26 volts, the letter X is added to the nomenclature, as AN/APS-2AX. The

Table 1-2. —Equipment Indicator Letters.

1	2	3	4	5	6
Installation	Type of equipment	Purpose	Model	Mod. ltr.	Misc. identification
			1, 2, 3, 4, etc.	A, B, C, D, etc.	X, Y, Z - Change in input voltage, phase, or frequency. Experimental indicators
A—Airborne (installed and operated in aircraft).	A—Invisible light, heat radiation.	A—Auxiliary assemblies (not complete operating sets).			XA—Communications - Navigation Laboratory, WADC, Dayton, Ohio.
B—Underwater mobile, submarine.	B—Pigeon	B—Bombing			XB—Naval Research Laboratory, Washington, D. C.
C—Air transportable (inactivated; do not use).	C—Carrier	C—Communications (receiving and transmitting).			
D—Pilotless carrier	D—Radiac	D—Direction finder, reconnaissance and/or surveillance.			XD—Cambridge Research Center, Cambridge, Mass.
	E—Nupac (nuclear protection and control).	E—Ejection and/or release.			
F—Fixed	F—Photographic				XF—Frankford Arsenal, Philadelphia, Pa.
G—Ground, general ground use (includes two or more ground-type installations).	G—Telegraph or teletype.	G—Fire control or searchlight directing.			XG—USN Electronic Laboratory, San Diego, Calif.
		H—Recording and/or reproducing (graphic meteorological and sound).			XH—Aerial Reconnaissance Laboratory, WADC, Dayton, Ohio.
	I—Interphone and public address.				
	J—Electromechanical (not otherwise covered).				XJ—Naval Air Development Center, Johnsville, Pa.
K—Amphibious	K—Telemetering	K—Computing			XK—Flight control Laboratory, WADC, Dayton, Ohio.
	L—Countermeasures	L—Searchlight control (inactivated; use G).			XL—Signal Corps Electronics Research Unit, Mountain View, Calif.

Table 1-2. —Equipment Indicator Letters—Continued.

1	2	3	4	5	6
Installation	Type of equipment	Purpose	Model	Mod. ltr.	Misc. identification
M—Ground, mobile (installed as operating unit in a vehicle that has no function except transporting equipment).	M—Meteorological	M—Maintenance and test assemblies (including tools).			
	N—Sound in air	N—Navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach, and landing).			XN—Department of the Navy, Washington, D. C.
P—Pack or portable (animal or man).	P—Radar	P—Reproducing (inactivated; do not use).			XP—Canadian Department of National Defense, Ottawa, Canada.
	Q—Sonar and underwater sound.	Q—Special, or combination of purposes.			
	R—Radio	R—Receiving, passive detecting.			
S—Water surface craft.	S—Special types, magnetic, etc., or combination of types.	S—Detecting and/or range and bearing, search.			XS—Electronic Components Laboratory, WADC, Dayton, Ohio.
T—Ground, transportable.	T—Telephone (wire).	T—Transmitting			
U—General utility (includes two or more general installation classes, airborne, shipboard, and ground).					XU—USN Underwater Sound Laboratory, Fort Trumbull, New London, Conn.
V—Ground, vehicular (installed in vehicle designed for functions other than carrying electronic equipment such as tanks).	V—Visual and visible light.				
W—Water surface and underwater.	W—Armament (peculiar to armament not otherwise covered).	W—Automatic Flight or Remote control.			XW—Rome Air Development Center, Rome, N. Y.
	X—Facsimile or television.	X—Identification and recognition			XAN—Naval Air Facility, Indianapolis, Ind. (For complete details, see MIL-STD-196.)

second power input change would be identified by the letter Y.

A special indicator (T) for training sets is also available. It is used in conjunction with the other indicators to show that it is a training set for a specific equipment. Likewise, it may be used to indicate a trainer for a special family of equipment. For example, the first training set for the AN/APS-2 would be AN-APS-2T1.

The AN system also provides for identifying a series of sets by placing parentheses after the type number. Thus, the AN/APS-2 ( ) refers to the AN/APS-2 set and all of its modifications, such as the AN/APS-2A and AN/APS-2B, as well as its experimental versions, such as the AN/APS-2(XB-1).

Experimental sets are identified by the use of the development organization indicators (table 1-2, column 6). A number indicates a particular developmental or reproduction model. The first developmental model of the AN/APS-2, for example, could be identified as the AN/APS-2(XB-1), assuming, of course, that the Naval Research Laboratory did the work.

COMPONENT IDENTIFICATION

So far, consideration has been given only to the indicators used in set nomenclature. Now, let's examine the indicators for major components of a set.

Components are identified by means of indicating letters, which tell the type of component it is (see table 1-3); a number, which identifies the particular component; and, finally, the designation of the equipment of which it is a part or with which it is used.

The receiver for the AN/SPS-2, for example, would be identified as shown in table 1-4. To illustrate, the R-7/APS-2 is a receiver used with or as a part of Airborne Radar Search Set No. 2. Another receiver, such as the R-8/ARN-8, would be indicated by the tables as a receiver used with or as a part of Airborne Radio Navigation Set No. 8.

A modification letter identifies a component that has been modified but still retains the basic design and is interchangeable physically, electrically, and mechanically with the modified item. Thus, the R-7A/APS-2 would be a modified version of the R-7/APS-2.

Components that are part of or used with two or more sets are identified in the usual way, except that only those indicators that are appropriate and without a set model number appear after the slant bar. A modulator that is part of or used with the AN/APS-2 and the AN/APS-6, for instance, might be identified as MD-8/APS.

NAVY MODEL LETTER SYSTEM

The assignment of a particular model letter to Navy equipment depends on the chief function of the equipment, such as receiving, direction finding, and the like. This system of assigning model letters is applicable to all radio, radar, and sonar equipment. Once learned, this method makes easy the recognition and identification of all Navy equipment.

In the Navy model letter system, the first letter indicates the basic purpose of the equipment. These designations, listed in table 1-5, are followed by another letter of the alphabet to denote the order in which designations are assigned. Thus, TA is the first transmitting equipment assigned, TB is the next, and so on. When the alphabet is exhausted, triple letters are used; for example, TAA. The next order of assignment is indicated by a change in the third letter. The model letter assigned after TAA is TAB. When the alphabet is exhausted again, a third series of model letters is formed by changing the second letter to B. For example, TBA, TBB, TBS, and so forth.

Numbers following model letters indicate a modification of the equipment or the award of a new contract. To signify a change in equipment after delivery is made, lowercase letters are assigned.

Now that the AN system has been instituted, the Navy model letter system of equipment designation is no longer in general usage. Some equipment, however, still is identified by this type of designation in the naval establishment.

GLOSSARY OF COMMON ELECTRONIC TERMS

You doubtless are familiar with some of the terms listed in this glossary. It is not expected, however, that you will know all of the terms used with operational electronics. Accordingly, a study of the terms on page 8

Table 1-3. —Component Indicators.

Ind. ltr.	Family name	Examples of use
AB	Supports, antenna	Antenna mounts, mast bases, mast sections, towers, etc.
AM	Amplifiers	Power, audio, interphone, radiofrequency, video, electronic control, etc.
AS	Antennae, complex	Arrays, parabolic type, masthead, etc.
AT	Antennae, simple	Whip or telescopic, loop, dipole, reflector, etc.
BA	Battery, primary type	B batteries, battery packs, etc.
BB	Battery, secondary type	Storage batteries, battery packs, etc.
BZ	Signal devices, audible	Buzzers, gongs, horns, etc.
C	Controls	Control box, remote tuning control, etc.
CA	Commutator assemblies, sonar.	Peculiar to sonar equipment.
CB	Capacitor bank	Used as a power supply.
CG	Cable assemblies, r-f	R-f cables, waveguides, transmission lines, etc., with terminals.
CK	Crystal kits	A kit of crystals with holders.
CM	Comparators	Compares two or more input signals.
CN	Compensators	Electrical and/or mechanical compensating, regulating, or attenuating apparatus.
CP	Computers	A mechanical and/or electronic mathematic calculating device.
CR	Crystals	Crystal in crystal holder.
CU	Couplers	Impedance coupling devices, directional couplers, etc.
CV	Converters (electronic)	Electronic apparatus for changing the phase, frequency, or from one medium to another.
CW	Covers	Cover, bag, roll, cap, radome, nacelle, etc.
CX	Cable assemblies, Non-r-f	Non-r-f cables with terminals, test leads, also composite cables of r-f and non-r-f conductors.
CY	Cases and cabinets	Rigid and semirigid structure for enclosing or carrying equipment.
D	Dispensers	Chaff dispensers.
DA	Load, dummy	R-f and non-r-f test loads.
DT	Detecting heads	Magnetic pickup device, search coil, hydrophone, etc.
DY	Dynamotors	Dynamotor power supply.
E	Hoists	Sonar hoist assembly.
F	Filters	Bandpass, noise, telephone, wave traps, etc.
FN	Furniture	Chairs, desks, tables, etc.
FR	Frequency measuring devices.	Frequency meters, tuned cavity, etc.
G	Generators, power	Electrical power generators without prime movers. (See PU and PD.)
GO	Goniometers	Goniometers of all types.
GP	Ground rods	Ground rods, stakes, etc.
H	Head, hand, and chest sets	Includes earphone.
HC	Crystal holder	Crystal holder, less crystal.
HD	Air conditioning apparatus	Heating, cooling, dehumidifying, pressure, vacuum devices, etc.
ID	Indicators, non-cathode ray tube.	Calibrated dials and meters, indicating lights, etc. (See IP.)
IL	Insulators	Strain, standoff, feed-through, etc.
IM	Intensity measuring devices.	Includes SWR gear, field intensity and noise meters, slotted lines, etc.

Table 1-3. —Component Indicators—Continued.

Ind. ltr.	Family name	Examples of use
IP	Indicators, cathode ray tube.	Azimuth, elevation, panoramic, etc.
J	Junction devices	Junction, jack, and terminal boxes, etc.
KY	Keying devices	Mechanical, electrical, and electronic keyers, coders, interrupters, etc.
LC	Tools, line construction . .	Includes special apparatus such as cable plows.
LS	Loudspeakers	Separately housed loudspeakers, intercommunication station.
M	Microphones.	Radio, telephone, throat, hand, etc.
MA	Magazines	Magnetic tape or wire.
MD	Modulators.	Device for varying amplitude, frequency, or phase.
ME	Meters, portable	Multimeters, volt-ohm-milliammeters, vacuum tube voltmeters, power meters, etc.
MF	Magnets or magnetic field generators.	Magnetic tape or wire eraser, electromagnet, permanent magnet, etc.
MK	Miscellaneous kits	Maintenance, modification, etc., except tool and crystal. (See CK, TK.)
ML	Meteorological devices . .	Barometer, hygrometer, thermometer, scales, etc.
MT	Mountings	Mountings, racks, frames, stands, etc.
MX	Miscellaneous.	Equipment not otherwise classified. Do not use if better indicator is available.
O	Oscillators	Master frequency, blocking, multivibrators, etc. (For test oscillators, see SG.)
OA	Operating assemblies. . . .	Assembly of operating units not otherwise covered.
OC	Oceanographic devices . .	Bathythermographs.
OS	Oscilloscope, test.	Test oscilloscopes for general test purposes.
PD	Prime drivers	Gasoline engines, electric motors, diesel motors, etc.
PF	Fittings, pole	Cable hangar, clamp, protectors, etc.
PG	Pigeon articles.	Container, loft, vest, etc.
PH	Photographic articles . . .	Camera, projector, sensitometer, etc.
PP	Power supplies.	Nonrotating machine type such as vibrator pack, rectifier, thermoelectric, etc.
PT	Plotting equipment except meteorological, maps etc.	Boards, maps, plotting table, etc.
PU	Power equipment except dynamotors, motor generator etc.	Rotating power equipment; motor generator.
R	Receivers	Receivers, all types except telephone.
RC	Reels	Reel, cable. (See RL.)
RD	Recorder-reproducers. . .	Sound, graphic, tape, wire, film, disk facsimile, magnetic, mechanical, etc.
RE	Relay assemblies	Electrical, electronic, etc.
RF	Radiofrequency component	Composite component of r-f circuits. Do not use if better indicator is available.
RG	Cables, r-f, bulk	R-f cable, waveguides, transmission lines, etc., without terminals.
RL	Reeling machines	Mechanisms for dispensing and rewinding antenna or field wire, recording wire or tape, etc.
RO	Recorders.	Sound, graphic, tape, wire, film, disk, facsimile, magnetic, mechanical, etc.

Table 1-3. —Component Indicators—Continued.

Ind. ltr.	Family name	Examples of use
RP	Reproducers.	Sound, graphic, tape, wire, film, disk, facsimile, magnetic, mechanical, etc.
RR	Reflectors	Target, confusion, etc., except antenna reflectors. (See AT.)
RT	Receiver and transmitter	Radio and radar transceivers, composite transmitter and receiver, etc.
S	Shelters.	House, tent, protective shelter, etc.
SA	Switching devices	Manual, impact, motor-driven, pressure-operated, etc.
SB	Switchboards	Telephone, fire control, power, panel, etc.
SG	Generators, signal	Test oscillators, noise generators, etc. (See O)
SM	Simulators	Flight, aircraft, target, signal, etc.
SN	Synchronizers.	Equipment to coordinate two or more functions.
ST	Straps	Harness, straps, etc.
SU	Optical Device	Telescope, periscope, projectors, and boresighting scope.
T	Transmitters	Transmitters, all types except telephone.
TA	Telephone apparatus . . .	Miscellaneous telephone equipment.
TD	Timing devices	Mechanical and electronic timing devices, range device, multiplexes, electronic gates, etc.
TB	Towed Body	Towed underwater body, paravanes, etc.
TC	Towed Cable.	Faired cable, etc.
TF	Transformers	Transformers when used as separate items.
TG	Positioning devices	Tilt and/or train assemblies.
TH	Telegraph apparatus. . . .	Miscellaneous telegraph apparatus.
TK	Tool kits	Miscellaneous tool assemblies.
TL	Tools	All types except line construction. (See LC.)
TN	Tuning units	Receiver, transmitter, antenna, tuning units, etc.
TR	Transducers	Magnetic heads, phono pickups, sonar transducers, virbration pickups, etc. (See H, LS, and M.)
TS	Test items	Test and measuring equipment not otherwise included; boresighting and alignment equipment.
TT	Teletypewriter and facsimile apparatus	Miscellaneous tape, teletype, facsimile equipment, etc.
TV	Tester, tube.	Electronic tube tester.
TW	Tapes and recording wires	Recording tape and wire, splicing, electrical insulating tape, etc.
U	Connectors, audio and power.	Unions, plugs, sockets, adapters, etc.
UG	Connectors, r-f	Unions, plugs, sockets, choke couplings, adapters, elbows, flanges, etc.
V	Vehicles	Carts, dollies, trucks, trailers, etc.
VS	Signaling equipment, visual	Flag sets, aerial panels, signal lamp equipment, etc.
WD	Cables, two-conductor .	Non-r-f wire, cable and cordage in bulk. (See RG.)
WF	Cables, four-conductor .	Non-r-f wire, cable and cordage in bulk. (See RG.)
WM	Cables, multiple-conductor	Non-r-f wire, cable and cordage in bulk. (See RG.)
WS	Cables, single-conductor	Non-r-f wire, cable and cordage in bulk. (See RG.)
WT	Cables, three-conductor.	Non-r-f wire, cable and cordage in bulk. (See RG.)
ZM	Impedance measuring devices.	Used for measuring Q, C, L, R, or PF, etc.

Table 1-4. —Designation of Components.

Radar receiver	R	7	/APS-2
Item name as prescribed.	From table 1-3.	The 7th receiver to which AN designation is assigned.	The set of which it is a part or with which it is used.

should contribute to a better understanding of the information contained in this text.

ABSORPTION: The loss of energy in traveling through a medium.

ALIGN: To adjust the tuned circuits of a transmitter or receiver for proper signal response.

ALTERNATION: One-half of a complete cycle.

AMPERE: The basic unit of current flow; a current of 1 ampere will flow through a conductor having a resistance of 1 ohm when a potential of 1 volt is applied.

AMPLIFICATION: The process of increasing the magnitude of a signal (voltage or current).

AMPLIFIER: A device for increasing the signal voltage, current, or power without appreciably altering its quality, generally made up of an electron tube or transistor and associated circuit called a stage. The amplifier may contain several stages in order to obtain a desired gain.

AMPLITUDE: The maximum departure from the average value of an alternating voltage or current, measured from zero value in either the positive or negative direction.

AMPLITUDE DISTORTION: The undesired change of a waveshape so that it no longer is proportional to its original form.

AMPLITUDE MODULATION: The process of changing the amplitude of a radiofrequency (r-f) carrier wave in accordance with the variations of an audiofrequency (a-f) wave.

ANODE: A positive electrode; the plate of an electron tube.

ANTENNA: A conductor or system of conductors used to send out or pick up radio waves.

Table 1-5.—Navy Model Letters.

Model letters	Primary function of equipment
A	Airborne (used as a prefix to indicate airborne installation, as AR series) airborne radio receiving, etc.
B	IFF.
CX	Commercial experimental.
D	Radio direction finding.
E	Emergency power.
FS	Frequency shift keying.
G	Formerly aircraft transmitting. (Now superseded by A series.)
J	Sonar listening (receiving).
K	Sonar transmitting.
L	Precision calibrating.
M	Combined radio transmitting and receiving.
MARK	Fire control radar.
N	Sonar navigational aids, including echo sounding.
O	Measuring and operator training.
P	Automatic transmitting and receiving.
Q	Sonar ranging.
R	Radio receiving.
S	Search radar.
T	Radio transmitting (includes combination transmitting and receiving).
U	Remote control (includes automatic keyers).
V	Radar repeaters.
W	Combined sonar ranging and sounding.
X	Naval experimental.
Y	Navigational and landing aids.
Z	Navigational and landing aids (airborne). (Superseded by model Y series.)

ATTENUATION: The reduction in strength of a signal.

AUDIBLE: Capable of being heard; a signal or vibrational disturbance of audiofrequency of sufficient strength to be heard.

AUDIO AMPLIFIER: Any device that amplifies a-f signals.

AUDIO COMPONENT: That portion of any wave or signal whose frequencies are within the audio range.

AUDIOFREQUENCY: A frequency that can be detected as a sound by the human ear. The range of audiofrequencies extends from 20 to 20,000 cycles per second.

AUTOMATIC VOLUME CONTROL: A method of automatically regulating the gain of a receiver so that the output tends to remain constant although the incoming signal may vary in strength.

BALANCED CIRCUIT: A divided circuit in which both sides are electrically equal.

BAND OF FREQUENCIES: The frequencies existing between two definite frequency limits.

BANDPASS FILTER: A circuit designed to pass currents of frequencies within a definite frequency band with nearly equal response, and to reduce substantially the amplitude of currents of all frequencies outside that band.

BAND SPREAD: Any method of spreading tuning indications over a greater scale range to simplify tuning in a crowded band of frequencies.

BEAT FREQUENCY: One of the two additional frequencies obtained when signals of two different frequencies are combined. Their values are equal to the sum and difference, respectively, of the original frequencies.

BEAT FREQUENCY OSCILLATOR: An oscillator in which an audible beat frequency is obtained by mixing or beating together two radiofrequencies. The bfo is used for continuous wave (CW) reception in superheterodyne receivers, or as an instrument for test purposes.

BEAT NOTE: The audio frequency produced by beating together two different frequencies.

BREAKDOWN VOLTAGE: The voltage at which an insulator or dielectric ruptures; or the voltage at which ionization and conduction begin in a gas or vapor.

CAPACITANCE: The ability of a capacitor (or any two conductors) to store electrical energy.

CAPACITOR: Two electrodes or sets of electrodes in the form of plates, separated from each other by an insulating material called the dielectric.

CARRIER: See Carrier Frequency.

CARRIER FREQUENCY: The frequency of an unmodulated carrier wave. The r-f component of a transmitted wave upon which an audio signal or other form of intelligence can be impressed.

CATHODE: The electrode in a vacuum tube that provides electron emission.

CENTER FREQUENCY: See Resting Frequency.

COAXIAL CABLE: A transmission line consisting of one conductor, usually a small copper tube or wire, within and insulated from another conductor of larger diameter, usually copper tubing braid. The outer conductor may or may not be grounded. Radiation from this type of line is practically zero. Coaxial cable sometimes is called concentric line.

CONDUCTANCE: The ability of a material to conduct or carry an electric current. It is the reciprocal (opposite) of the resistance of the material and is expressed in mhos.

CONTINUOUS WAVES: Radio waves that maintain a constant amplitude and a constant frequency; abbreviated CW.

COUNTERPOISE: A conductor or system of conductors used as a substitute for ground in an antenna system.

CROSS MODULATION: A type of crosstalk in which the carrier frequency being received is interfered with by an adjacent carrier so that the modulated signals of both are heard at the same time.

CRYSTAL: A natural substance, such as quartz or tourmaline, capable of producing a voltage when under stress or pressure, or producing pressure when under an applied voltage. Under stress it has the property of responding only to a given frequency when cut to a given thickness. It is therefore a valuable medium to control the frequency of transmitters or oscillators.

CRYSTAL CONTROL: Control of the frequency of an oscillator by means of a specially designed and cut crystal.

CRYSTAL OSCILLATOR: An oscillator circuit in which a crystal is used to control the frequency and to reduce frequency instability to a minimum.

CRYSTAL OVEN: A container maintained at a constant temperature in which a crystal and its holder are enclosed to reduce frequency drift.

CURRENT: The rate of flow of electrons; expressed in amperes.

CYCLE: One complete positive alternation and one complete negative alternation of an alternating current (or voltage).

DAMPED WAVES: Waves that steadily decrease in amplitude.

DEMODULATION: The recovery of the information, from the r-f carrier, with which the carrier had been modulated. This is a much broader term than detection, but of which detection is a part. (See Detection.)

DETECTION: The process of recovering the audio component (audible signal) from a modulated r-f carrier wave.

DETECTOR CIRCUIT: The portion of a receiver that recovers the audible signal from the modulated r-f carrier wave.

DEVIATION: A term used in frequency modulation to indicate the amount (of frequency) by which the carrier or resting frequency increases or decreases when modulated. It usually is expressed in kilocycles.

DEVIATION RATIO: A term used in frequency modulation to indicate the ratio of the maximum amount of deviation of a fully modulated carrier to the highest audiofrequency being transmitted.

DIELECTRIC: An insulator. A term applied to the insulating material between the plates of a capacitor.

DISTORTION: Distortion is said to exist when an output waveform is not a true reproduction of the input waveform. Distortion may consist of irregularities in amplitude, frequency, or phase.

DRIFT FREQUENCY: Change in a frequency from its basic wavelength caused by temperature or component variations in the frequency-determining elements.

DRIVER: An amplifier used to excite the final power amplifier stage of a transmitter or receiver.

EFFICIENCY: The ratio of output to input power, generally expressed as percentage.

ELECTROMAGNETIC WAVE: A wave of electromagnetic radiation, characterized by variations of electric and magnetic fields.

ELECTRON: The most elementary charge of electricity. It is always negative.

ELECTRON EMISSION: The liberation of electrons from a body into space under the influence of heat, light, impact, chemical disintegration, or a potential difference.

FADING: Reductions in the strength of a radio signal at the point of reception.

FIDELITY: The degree of accuracy with which a system, or portion of a system, reproduces in its output the signal impressed on its input.

FILTER: A combination of resistances, inductances, and capacitances, or any one or two of these, which allows the comparatively free flow of certain frequencies or of direct current while blocking the passage of other frequencies. An example is the filter used in a power supply, which allows the direct current to pass, but filters out the a-c component.

FREE ELECTRONS: Electrons that are not bound to a particular atom, but move about continuously among the many atoms of a substance.

FREQUENCY: The number of complete cycles per second existing in any form of wave motion; the number of cycles per second of an alternating current or sound wave.

FREQUENCY DEVIATION: See Deviation.

FREQUENCY DRIFT: See Drift Frequency.

FREQUENCY METER: A meter calibrated to measure frequency.

FREQUENCY MODULATION: The process of varying the frequency of an r-f carrier wave in accordance with the amplitude and frequency of an audio signal. The amplitude of the modulated wave stays constant.

FREQUENCY MULTIPLIER: A harmonic conversion transducer in which the frequency of the output signal is an exact integral multiple of the input frequency. Also called multiplier.

FREQUENCY STABILITY: The ability of an oscillator to maintain its operation at a constant frequency.

GAIN: The ratio of the output power, voltage, or current to the input power, voltage, or current.

GANG TUNING: Simultaneous tuning of two or more circuits by a single mechanical control.

GROUND: A metallic connection with the earth to establish ground potential. Also, a common return to a point of zero r-f potential, such as the chassis of a receiver or a transmitter.

GROUNDWAVE: That portion of the transmitted radio wave that travels near the surface of the earth.

HETERODYNE: To mix two alternating currents of different frequencies in the same circuit; they are alternately additive and subtractive, thus producing two beat frequencies, which are the sum of, and difference between, the two original frequencies.

HIGH FIDELITY: The ability to reproduce all audiofrequencies between 50 and 16,000 cycles per second without serious distortion.

HIGH-LEVEL MODULATION: Modulation produced at a point in a system where the power level approximates that at the output of the system. Also called plate modulation.

IMPEDANCE: The total opposition offered to the flow of an alternating current. It may consist of any combination of resistance, inductive reactance, or capacitive reactance. It is expressed in ohms, and its symbol is Z.

IMPULSE: Any force acting over a comparatively short period of time. An example would be a momentary rise in voltage.

INSTANTANEOUS VALUE: The magnitude at any particular instant when a value is continually varying with respect to time.

INTELLIGENCE: The message or information conveyed, as by a modulated radio wave.

INTENSITY: The relative strength of electric, magnetic, or vibrational energy.

INTERMEDIATE FREQUENCY: The fixed frequency to which all r-f carrier waves are converted in a superheterodyne receiver.

ION: An atom that has lost or gained one or more electrons and is therefore positively or negatively charged.

IONIZATION: The breaking up of atoms into ions.

IONOSPHERE: Highly ionized layers of atmosphere from between 40 and 350 miles above the surface of the earth.

KEY: A special form of switch capable of rapid operation used to form the dots and dashes of code signals.

KILO: A prefix meaning one thousand.

KILOCYCLE: One thousand cycles per second. Abbreviated kc.

LAG: The amount one wave is behind in time, expressed in electrical degrees. When two waves are out of phase, the one that reaches maximum or zero amplitude after the other is said to lag.

LEAD: The opposite of lag. Also a term given to a wire or connection.

LEAKAGE: The electrical loss due to poor insulation.

LINEAR: Having on output that varies in direct proportion to its input.

LOUDSPEAKER: A device that converts a-f electrical energy to sound energy.

LOW-LEVEL MODULATION: Modulation produced at a point in a system where the power level is low compared with the power level at the output of the system.

MEG OR MEGA: A prefix indicating one million.

MEGACYCLE: One million cycles per second. Abbreviated mc.

MICROPHONE: A device for converting sound energy into a-f electrical energy.

MODULATED CARRIER: An r-f carrier whose amplitude or frequency has been varied in accordance with the intelligence to be conveyed.

MODULATION: The process of varying the amplitude or frequency of a carrier wave in accordance with other signals in order to convey intelligence. The modulating signal may be an audiofrequency signal, video signal (as in television), or even electrical pulses or tones to operate relays.

MODULATOR: That part of a transmitter that supplies the modulating signal to the modulated circuit, where it can act upon the carrier wave.

NONLINEAR: Having an output that does not vary in direct proportion to its input.

OHM: The unit of electrical resistance.

OHM'S LAW: A fundamental law of electricity. It expresses the definite relationship existing between the voltage E, the current I, and the resistance R, the common form for which is $E = IR$.

OPEN CIRCUIT: A circuit that does not provide a complete path for the flow of current.

OSCILLOGRAPH: See Oscilloscope.

OSCILLOSCOPE: An instrument for showing visually on a cathode ray tube representations of the waveforms encountered in electrical circuits.

OUTPUT: The energy delivered by a device or circuit such as a radio receiver or transmitter.

OVERMODULATION: More than 100 percent modulation. In amplitude modulation, over modulation produces positive peaks of more than twice the carrier's original amplitude, and brings about complete stoppage of the carrier on negative peaks, thus causing distortion.

PERCENTAGE MODULATION: A measure of the degree of change in a carrier wave caused by the modulating signal, expressed as a percentage.

PIEZOELECTRIC EFFECT: Effect of producing a voltage by placing a stress, either by compression, expansion, or twisting, on a crystal and, conversely, producing a stress in a crystal by applying a voltage to it.

POTENTIOMETER: A variable voltage divider. A resistor that has a variable contact arm so that any portion of the potential applied between its ends may be obtained.

PULSATING CURRENT: A direct current, which periodically increases and decreases in value.

RADAR: An electronic radio detection and ranging system employing microwaves and ultrahigh frequencies for detecting and tracking ships and aircraft and other material targets.

RADIATE: To send out energy into space, as r-f waves.

RADIO: The science of communication in which r-f waves are used to carry intelligence through space.

RADIO CHANNEL: A band of adjacent frequencies of a width sufficient to permit its use for radio communication.

RADIOFREQUENCY: Any frequency of electrical energy capable of propagation into space. Frequencies normally are much higher than those associated with sound waves.

REFLECTION: The turning back of a radio wave from the surface of the earth or the ionosphere.

REFRACTION: The bending or change in the direction of a wave in passing from one medium into another. This effect will turn a radio wave back to earth if the angle of attack is not too great, and it will bend a sound wave in sonar ranging as the wave passes from one layer of water to another.

RESONANCE: The condition existing in a circuit when the values of inductance, capacitance, and the applied frequency are such that the inductive reactance and capacitive reactance cancel each other.

RESTING FREQUENCY: The initial frequency of the carrier wave of an f-m transmitter before modulation. Also called the center frequency.

RHEOSTAT: A variable resistor, usually associated with power devices.

SELECTIVITY: The degree to which a receiver is capable of discriminating between signals of different carrier frequencies.

SENSITIVITY: The degree to which a radio circuit responds to signals when that circuit is tuned.

SHARP TUNING: Very high selectivity.

SHORT WAVE: Refers to radio operation on frequencies higher than those used at the present time for commercial broadcasting. The range of frequencies extend from 1500 kilocycles to 30,000 kilocycles.

SIDEBAND: The frequency band, both above and below the carrier frequency, produced as a result of modulation of a carrier.

SIDEBAND POWER: The power contained in the sidebands. It is to this power that a receiver responds, not to the carrier power, when receiving a modulated wave.

SKIP DISTANCE: The distances on the earth's surface between the points where a radio skywave is reflected successively between the earth and the ionosphere.

SKYWAVE: That portion of a radiated wave that travels in space and is returned to earth by refraction in the ionosphere.

SPEECH AMPLIFIER: An a-f voltage amplifier for amplifying signals from a microphone.

STATIC: Any electrical disturbance caused by atmospheric conditions. Also a fixed, non varying condition, without motion.

SYNCHRONOUS: Happening at the same time; having the same period and phase.

TONE CONTROL: A method of emphasizing either low or high tones at will in an a-f amplifier.

TONE MODULATION: A type of code-signal transmission obtained by causing the r-f carrier amplitude to vary at a fixed audiofrequency.

TUNING: The process of adjusting a radio circuit to resonance with the desired frequency.

UNDERMODULATION: Insufficient modulation.

UNIDIRECTIONAL: Flowing in one direction only. (Direct current is unidirectional.)

VOLT: The basic unit of electrical pressure.

VOLUME: A term used to denote the sound intensity (amount of radio output) of a receiver or audio amplifier.

VOLUME CONTROL: A device for controlling the output volume.

WATT: The basic unit of electrical power.

WAVE: The progressive movement (propagation) either of sound or electromagnetic waves through a conducting medium, as rhythmical disturbances.

WAVEFORM: The shape of the wave obtained when instantaneous values of a-c quantities are plotted against time in rectangular coordinates.

WAVELENGTH: The distance in meters traveled by a wave during the time interval of one complete cycle. It is equal to the velocity divided by the frequency.

WAVE PROPAGATION: The radiation, as from an antenna, of r-f energy into space, or of sound energy into a conducting medium.

ZERO BEAT: The condition wherein two frequencies are exactly the same, and therefore produce no beat note.

CHAPTER 2

RADIO

The word "radio" can be defined briefly as the transmission of signals through space by means of electromagnetic waves. Usually, the term is used in referring to the transmission of code and sound signals, although television (picture signals) and radar (pulse signals) also depend on electromagnetic waves.

Of the several methods of radio communicatuons available, those utilized most commonly by the Navy are radiotelegraphy, radiotelephony, radioteletype, and radiofacsimile. These four modes are defined as follows:

1. RADIOTELEGRAPHY: The transmission of intelligence coded radiofrequency waves in the form of short transmissions (dots) and long transmissions (dashes).
2. RADIOTELEPHONY: The transmission of sound intelligence (voice, music, or tones) by means of radiofrequency waves.
3. RADIOTELETYPE: The transmission of messages from a teletypewriter or coded tape over a radiofrequency channel by means of coded combinations of mark and space impulses.
4. RADIOFACSIMILE: The transmission of still images (weather maps, photographs, sketches, typewritten pages, and the like) over a radiofrequency channel.

Radio equipment can be divided into two broad categories: transmitting equipment and receiving equipment. Both transmitting and receiving equipments consist basically of electronic power supplies, amplifiers, and oscillators.

A basic radio communication system may consist of only a transmitter and a receiver, which are connected by the medium through which the electromagnetic waves travel (fig. 2-1). The transmitter comprises an oscillator (which generates a basic radiofrequency), radiofrequency (r-f) amplifiers, and the stages (if any) required to place the audio intelligence on the r-f signal (modulator).

The medium (atmosphere) conducts the electromagnetic variations from the transmitting antenna to the receiving antenna.

The receiving antenna converts that portion of the transmitted electromagnetic energy received by the antenna into a flow of alternating radiofrequency currents. The receiver converts these current changes into the intelligence that is contained in the transmission.

FREQUENCY SPECTRUM

Radio transmitters operate on frequencies ranging from 10,000 cycles per second (cps) to several thousand megacycles. These frequencies are divided into eight bands as shown in table 2-1.

Because the VLF and LF bands require great power and long antennas for efficient

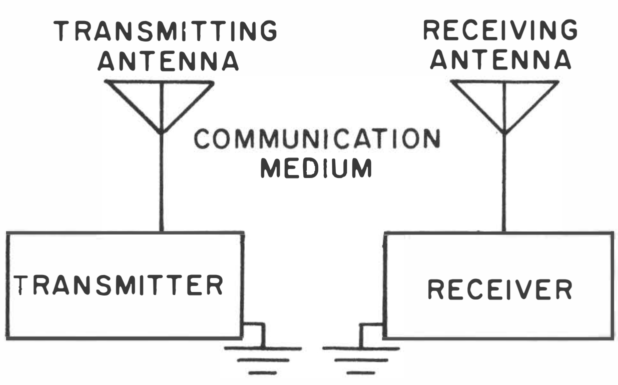

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Figure 2-1.—Basic radio communication system.

Table 2-1. —Bands of Frequencies.

Abbreviation	Frequency band	Frequency range
VLF	Very low frequency	below 30 kc
LF	Low frequency	30-300 kc
MF	Medium frequency	300-3000 kc
HF	High frequency	3000-30, 000 kc
VHF	Very high frequency	30-300 mc
UHF	Ultrahigh frequency	300-3000 mc
SHF	Superhigh frequency	3000-30, 000 mc
EHF	Extremely high frequency	30, 000-300, 000 mc

transmission, the Navy uses these bands only for shore station transmissions. (The antenna length varies inversely with frequency.)

Only the upper and lower ends of the MF band have naval use because of the commercial broadcast band extending from about 550 kc to 1700 kc.

Most shipboard radio communications are conducted in the HF band. Consequently, a large percentage of shipboard transmitters and receivers are designed to operate in this band. The HF band lends itself well for long-range communications.

A large portion of the lower end of the VHF band is assigned to the commercial television industry. Hence, it is lost to Armed Forces use except in special instances. The upper portion of this band (225 mc to 300 mc) is the lower operating frequency end of naval UHF radio transmitters and receivers.

The lower end of the UHF band (300 mc to 400 mc) is the upper end of the naval UHF radio communication equipment range, and is used extensively. Above 400 mc are the radar and other special equipment frequencies.

The SHF and EHF bands are used for radar and special equipment.

ANTENNAS AND PROPAGATION

An antenna is a conductor or system of conductors that radiates or intercepts energy in the form of electromagnetic waves. In its elementary form, an antenna may be simply a length of elevated wire similar to the common receiving antenna for an ordinary commercial broadcast receiver. For communication and radar work, however, other considerations make the design of an antenna system a more complex problem. For instance, the height of the radiator above ground, the conductivity of the earth below the radiator, and the shape and dimensions of an antenna all affect the radiated field pattern in space.

When r-f current flows through a transmitting antenna, radio waves are radiated from the antenna in much the same way that waves travel on the surface of a pond into which a rock is thrown. Part of each radio wave moves outward in contact with the ground to form the groundwave, and the rest of the wave moves upward and outward to form the skywave. The ground and sky portions of the radio wave are responsible for two different methods of carrying signals from transmitter to receiver.

Commonly, the groundwave is considered to be made up of two parts: a surface wave and a direct wave. The surface wave travels along the surface of the earth, whereas the direct wave travels in the space immediately above the surface of the earth. The groundwave is used both for short-range communications at high frequencies with low power and for long-range communications at low frequencies with very high power.

That part of the radio wave that moves upward and outward, but is not in contact with the ground, is called the skywave. An ionized belt, found in the rarefied atmosphere approximately 40 to 350 miles above the earth, is known as the ionosphere. It refracts (bends) some of the energy of the skywave back toward the earth. A receiver in the vicinity of the returning

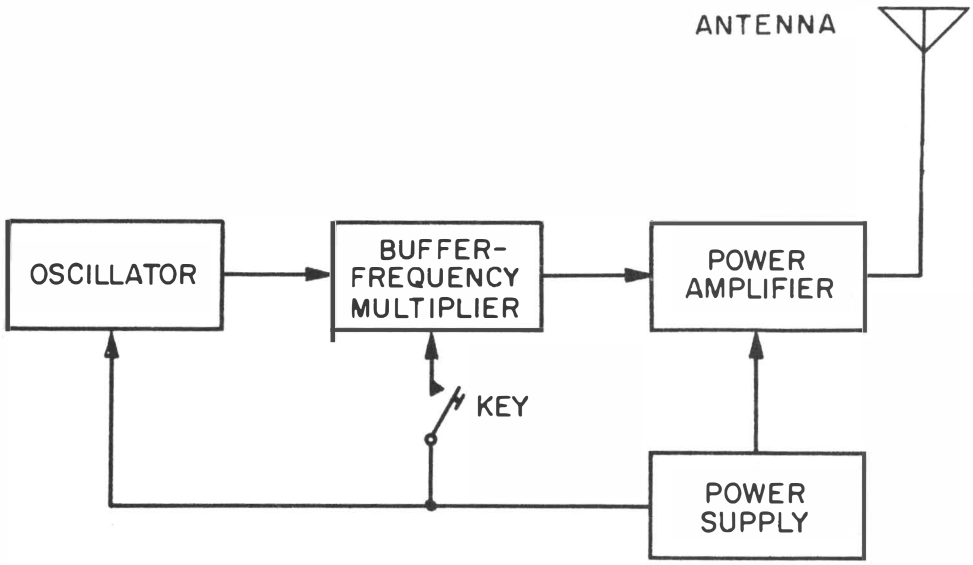

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Figure 2-2.—Continuous-wave transmitter.

skywave receives strong signals even though the receiver is several hundred miles beyond the range of the groundwave. The skywave is used for long-range, high-frequency, daylight communications. It also provides a means for long-range contacts at somewhat lower frequencies at night.

CONTINUOUS-WAVE TRANSMITTER

One of the simplest types of radio transmitters is the continuous-wave (CW) transmitter. (See fig. 2-2.) This CW transmitter is designed to send short or long pulses of r-f energy to form the dots and dashes of the Morse code characters.

A CW transmitter has four essential components. They are: (1) a generator of r-f oscillations, (2) a means of amplifying these oscillations, (3) a method of turning the r-f output on and off (keying) in accordance with the code to be transmitted, and (4) a power supply to provide the operating potential to the various electron tubes and transistors. Although not actually a part of the transmitter, an antenna is required to radiate the keyed output of the transmitter.

OSCILLATOR

The oscillator is the basic circuit of the transmitter. It is here that the r-f signal is generated. If the oscillator fails to function, the transmitter will not operate.

Frequently, the oscillator operates on a submultiple of the transmitter output frequency. When this occurs, a process called frequency multiplication is used to increase the transmitter frequency as desired. This action is particularly desirable when the output frequency is so high that stable oscillations are difficult to obtain.

Present-day transmitters may contain several oscillators to perform various functions. In general, only one exceptionally stable, oscillator stage is used to generate the basic transmitter radiofrequency. This oscillator usually is called the master oscillator (MO) to distinguish it from any other oscillator circuit in the transmitter.

Transmitters capable of transmitting over a wide frequency range normally have the total frequency coverage divided into separate bands. In such instances, the frequency-determining components in the oscillator (and other stages as necessary) are selected by means of a band switch.

BUFFER—FREQUENCY MULTIPLIER

When the transmitter is keyed, the associated changes in the condition of the transmitter stages may cause undesired voltage or current reflections. If permitted to reach the oscillator, these reflections would cause the oscillator frequency to change. The buffer stage is situated between the oscillator and subsequent stages to isolate the oscillator from these load reflections.

As stated previously, the oscillator may be operated at a submultiple of the transmitter output frequency. With this mode of operation, the buffer stage usually performs the additional function of frequency multiplication.

POWER AMPLIFIER

The power amplifier (PA) is operated in such a manner that it greatly increases the magnitude of the r-f current and voltage. The output from the PA is fed to the antenna via r-f transformers and transmission lines.

POWER SUPPLY

Transmitters (and many other types of electronic equipment) require d-c voltages ranging from a minus hundreds of volts to plus thousands of volts. Additionally, they need a-c voltages at smaller values than those available from the ship's normal power source. It is the function of the power supply to furnish these voltages at the necessary current ratings. Usually, this is accomplished through transformer-rectifier-filter action, with the ship's power as the source of supply.

MODULATION

Because it is impractical to transmit electromagnetic waves at sound frequencies (15 cps to 20,000 cps), the intelligence, by means of modulation, is impressed upon a higher frequency for transmission. Modulation is the process of varying the amplitude or the frequency of a carrier signal (r-f output of the transmitter) at the rate of an audio signal. The composite wave thus contains radiofrequency and audiofrequency components. A receiver that is within reception range and tuned to the carrier frequency accepts the transmitter signal and removes the audio component from the carrier. This process is called demodulation or detection. The audio signal then is fed to a loudspeaker or headset that reproduces the original sound frequencies.

AMPLITUDE MODULATION

Amplitude modulation (a-m) is the result of causing the amplitude of a carrier wave to vary in accordance with the amplitude of an audio signal. This process can be accomplished by modifying the continuous-wave transmitter (fig. 2-2) so that the audio output from a microphone (and necessary amplifiers) is impressed on the carrier frequency. The required changes are incorporated in the block diagram of a basic a-m radiotelephone transmitter, as shown in figure 2-3. The top row of blocks produces and amplifies the r-f carrier frequency; the lower row produces and amplifies the audiofrequency. The speech amplifier, driver, and modulator stages provide the power amplification required in the modulation process.

Assume that the modulating audio signal is of constant frequency. The audio voltage is fed into the r-f power amplifier stage so that it alternately adds to and subtracts from the d-c supply voltage in the amplifier. An increase in voltage in the PA increases the r-f power output. Conversely, a decrease in voltage decreases the r-f power. The presence of the audio voltage in series with the supply voltage causes the overall amplitude of the r-f field at the antenna to increase gradually in strength during the time the audio voltage is increasing (from 1 to 2 on the waveforms). It also results in a decrease in strength during the time the audio output is decreasing (from 2 to 3). Similar variations in r-f power output occur throughout each audio cycle. The waveform produced at the antenna thus contains radiofrequency and audiofrequency components, and normally is referred to as an r-f voltage that varies at an audio rate.

Actually, the two frequencies introduced in the PA during the modulation process combine to produce two additional frequencies called sideband frequencies. The sideband frequencies are always related to the original two frequencies

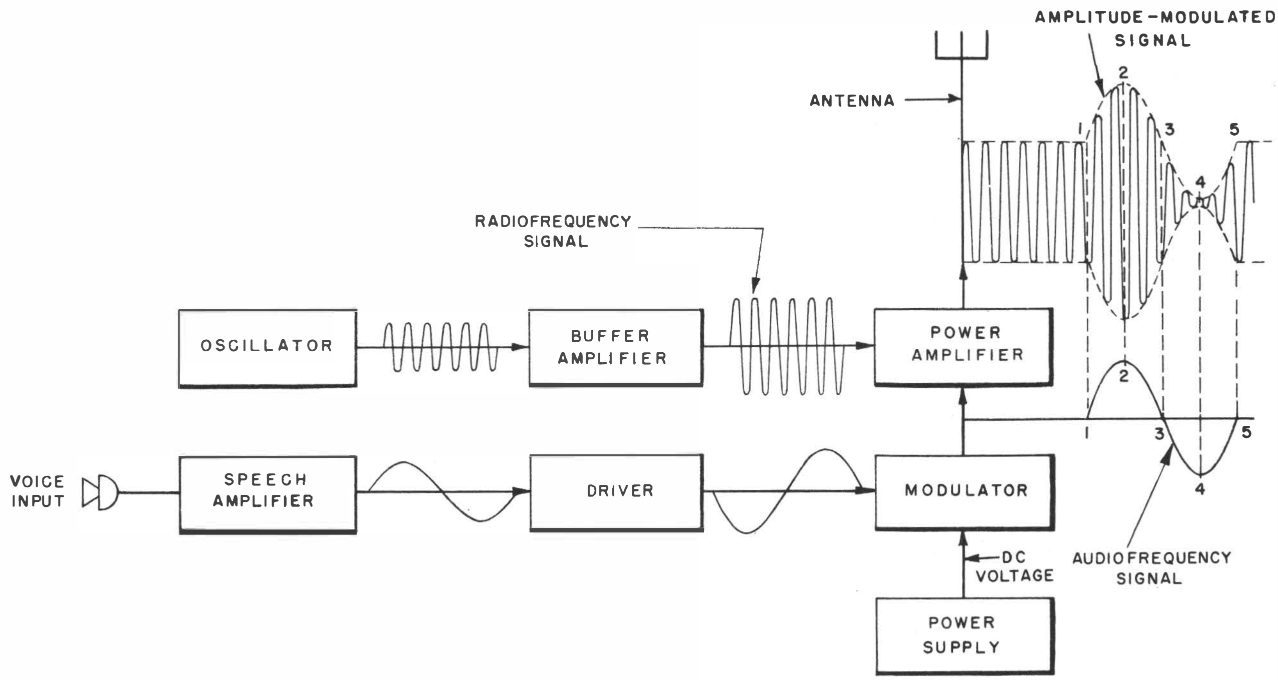

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Figure 2-3.—An a-m radiotelephone transmitter.

as sum and difference frequencies, respectively. The sum frequency, i.e., the sum of the r-f carrier and audio-modulating frequencies, is called the upper sideband; the difference frequency is the lower sideband. At 100 percent modulation, one-sixth of the total power (r-f plus audio power) appears in each of the sidebands.

The relationship of the carrier, audio, and sideband frequencies is illustrated in figure 2-4. Assume that the carrier frequency is 1000 kc at 100 watts, and that the audio-modulating frequency is a single 1-kc tone at 50 watts. Then, each of the sidebands is displaced 1000 cps from the carrier frequency. The lower sideband is 1,000,000 cps − 1000 cps = 999,000 cps (or 999 kc). The upper sideband is 1,000,000 cps + 1000 cps = 1,001,000 cps (or 1001 kc). The power in each sideband (25 watts) is one-sixth the total transmitter output power (150 watts).

Note that the amplitude of each of the three frequencies is constant when considered alone. But, because these frequencies appear simultaneously at the output, they add to form one composite envelope (signal). This envelope is in the shape of the output waveform shown in figure 2-3.

During modulation, the peak voltages and currents on the r-f power amplifier stage are greater than values that occur when the stage is not modulated. To prevent damage to the equipment, a transmitter, designed to transmit both CW and radiotelephone signals, is provided with controls that reduce the transmitter power output for radiotelephone operation.

FREQUENCY MODULATION

Intelligence can be transmitted by varying the frequency of a carrier signal of constant amplitude. The carrier frequency can be varied a small amount on either side of its average or assigned frequency by means of the a-f modulating signal. The amount the carrier is varied depends on the magnitude of the modulating signal; the frequency with which the carrier is varied depends on the frequency of the modulating signal. With or without modulation, the amplitude of the r-f carrier remains constant.

A block diagram of a representative f-m transmitter, in which frequency modulation is accomplished by a phase-shift system, is shown in figure 2-5. The transmitter oscillator is maintained at a constant frequency by means of a quartz crystal. This constant-frequency signal passes through an amplifier that increases the amplitude of the r-f carrier. The audio signal is applied to the carrier in a combining network in such a manner as to cause the frequency of the carrier to shift according to the variations of the audio signal. The f-m output of the combining network is fed into a series of frequency multipliers that raise the signal to the desired output frequency. Then the signal is amplified in the power amplifier and coupled to the antenna for radiation.

RECEIVERS

The modulated r-f carrier wave produced at the transmitter travels through space as an electromagnetic wave. When the wave passes across a receiving antenna, it induces small r-f voltages (and associated currents) in the antenna wire at the frequency of the transmitted signal. The signal voltage is coupled to the receiver input via an antenna coil or antenna transformer.

Electromagnetic energy is received from several transmitters simultaneously by the receiving antenna. The receiving circuits must select the desired transmitter signal from those present at the antenna and amplify this signal. Further, the receiver must remove the audio component from the carrier frequency by a process called demodulation, or detection, and amplify the audio component to the proper magnitude to operate a loudspeaker or earphones.

TUNED RADIOFREQUENCY RECEIVER

Although not used extensively in the Navy, the tuned radiofrequency (t-r-f) receiver is the forerunner of the modern military receiver. It is of the simplest design, and lends itself well for the purpose of explaining basic receiver principles.

The t-r-f receiver (fig. 2-6) consists of one or more r-f amplifier stages, a detector (demodulator) stage, one or more stages of audio amplification, a power supply, and a reproducer (usually loudspeaker or earphones). Waveforms that appear at the input and output of each stage are shown in the illustration.

Radiofrequency Stages

Radiofrequency stages of the receiver are designed to select and amplify the desired signal. The relative ability of a receiver to select a

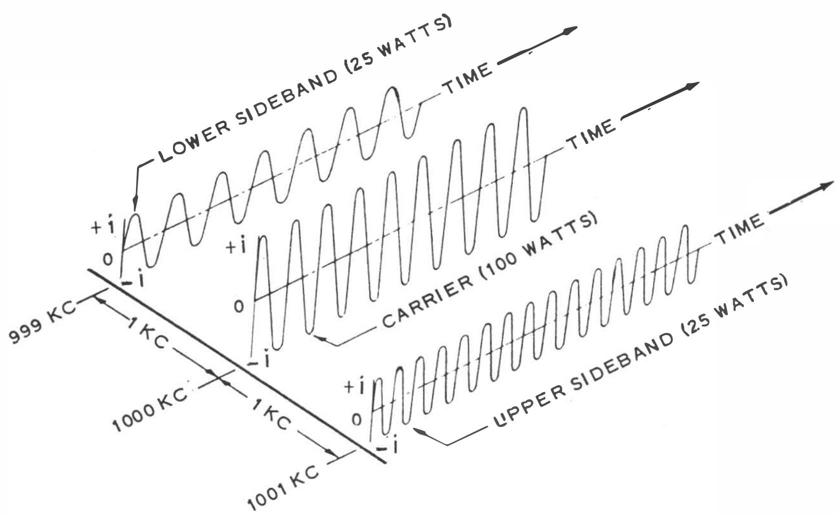

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Figure 2-4.—Carrier wave and its sideband frequencies.

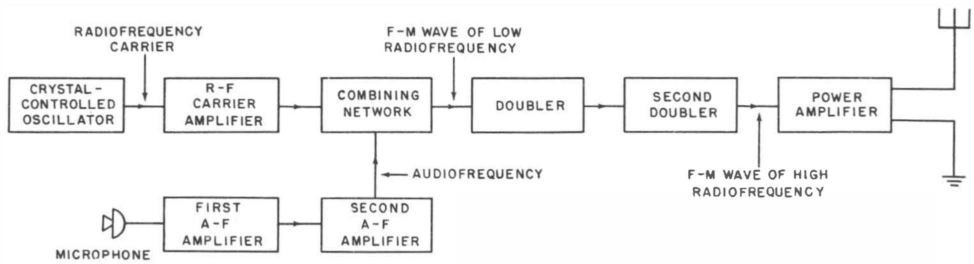

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Figure 2-5.—Block diagram of f-m transmitter.

particular frequency and to reject all others is called the selectivity of the receiver. The relative ability of the receiver to amplify small signal voltages is called the sensitivity of the receiver. Both of these values can be improved by increasing the number of r-f stages.

Detector

In the detector stage, the intelligence component of the modulated wave is separated from the r-f carrier. The separation process, called detection or demodulation, consists of rectifying the a-m envelope and removing (filtering out) the r-f carrier.

As seen earlier, amplitude modulation of an r-f carrier with audio intelligence causes both the positive and the negative half cycles of successive r-f cycles to vary in amplitude. The resultant amplitude variations are a replica of the modulating audio signal. The detector stage accepts the r-f amplitude variations at its input, and produces audio variations at its output.

Audio Amplifier

The function of the audiofrequency section of the receiver is to amplify the audio signal from the detector. In most instances, the amount of audio amplification necessary depends on the type of reproducer. If the reproducer is earphones, only one stage of amplification may be required.

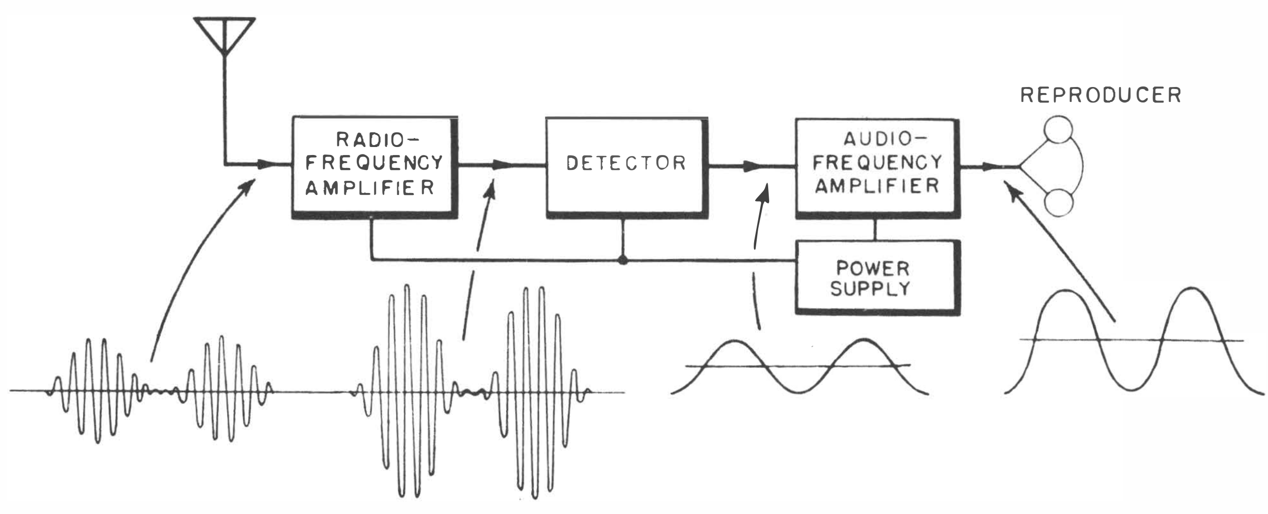

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Figure 2-6.—Block diagram of t-r-f receiver and waveforms.

Disadvantages of T-R-F Receiver

The principal disadvantages of the t-r-f receiver are its inability to reject unwanted frequencies, and its inability to amplify desired frequencies uniformly. In other words, the selectivity and the sensitivity of the receiver are not uniform over its frequency range.

The selectivity of the t-r-f receiver decreases as it is tuned from the low-frequency end of its range to the high-frequency end. Conversely, the sensitivity of the receiver increases as it is tuned from the low-frequency end to the high-frequency end.

SUPERHETERODYNE RECEIVER

To overcome the disadvantages of t-r-f receivers, the superheterodyne receiver was developed. The essential difference between the two types of receivers is in the amplifier stage(s) preceding the detector. Whereas the r-f amplifier preceding the detector in the t-r-f receiver is tunable, the corresponding amplifier in the superheterodyne receiver is pretuned to one fixed frequency called the intermediate frequency (i-f).

The intermediate frequency is obtained through the principle of frequency conversion by heterodyning a signal generated in a local oscillator of the receiver with the incoming signal in a mixer stage. (Heterodyning is discussed in our next topic.) Thus, an incoming signal is converted to the fixed intermediate frequency, and the i-f amplifier operates with uniform selectivity and sensitivity over the entire tuning range of the receiver.

A block diagram of a representative superheterodyne receiver is shown in figure 2-7. Although not illustrated, a superheterodyne receiver may have more than one frequency-converting stage and as many amplifiers as needed to obtain the desired power output.

Heterodyning

The intermediate frequency is produced by a process called heterodyning. This action takes place in the mixer, so called because it receives and combines two frequencies. These two frequencies are the incoming signal from the r-f amplifier, and a locally generated, unmodulated r-f signal of constant amplitude from the local oscillator.

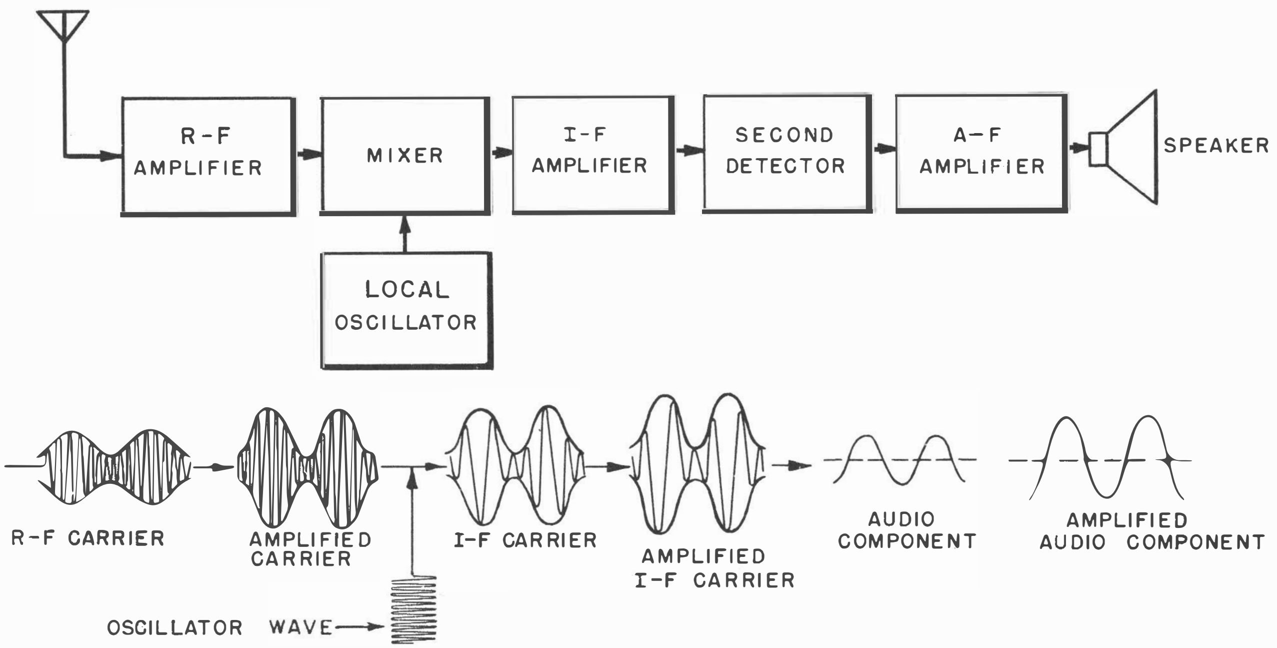

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Figure 2-7.—Block diagram of a superheterodyne receiver and waveforms.

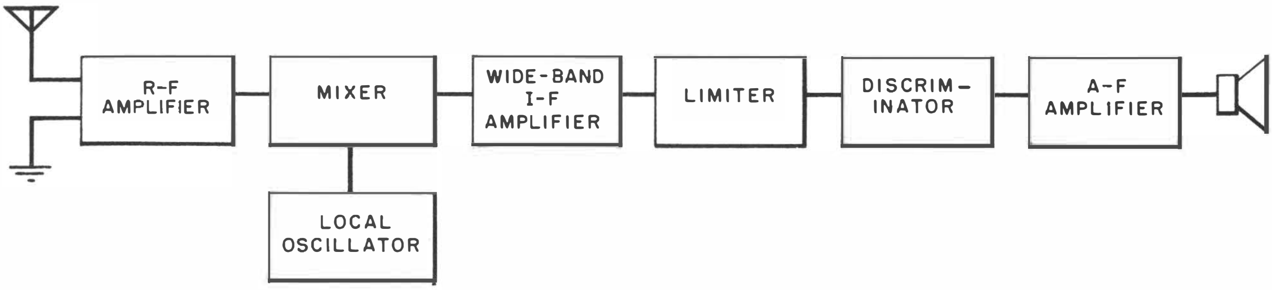

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Figure 2-8.—Block diagram of f-m receiver.

The heterodyning action in the mixer (also called the first detector) produces four frequencies at the mixer output. These frequencies are (1) the incoming r-f signal, (2) the local oscillator signal, (3) the sum of the incoming r-f and local oscillator signals, and (4) the difference of these signals. Both the sum and difference frequencies contain the amplitude modulation. Usually, the difference frequency is used as the intermediate frequency, although the sum frequency can be used equally as well. A common intermediate frequency for communication receivers is 455 kc.

FREQUENCY-MODULATED RECEIVER

A frequency-modulated (f-m) receiver is basically the same as an a-m superheterodyne receiver. Figure 2-8 is a block diagram of an f-m receiver. The amplitude of the incoming signal is increased in the r-f stages. The mixer combines the incoming r-f and local oscillator signals to produce the intermediate frequency that is amplified by one or more i-f amplifier stages. In an f-m receiver, the amplitude of the i-f output is clipped in a limiter stage before the modulation is removed by the second detector (or discriminator as it is called in the f-m receiver) in order to eliminate any noise peaks.

SINGLE-SIDEBAND COMMUNICATIONS

As explained earlier, the intelligence of amplitude-modulated signals is contained in the sidebands, and, for normal amplitude modulation, the intelligence in both sidebands is the same. If some method of carrier reinsertion is used at each receiving station, radio intelligence can be conveyed by removing the carrier and one sideband, and transmitting only the remaining sideband. This type of communications is called single-sideband (SSB) communications—all transmitting power is concentrated in the one sideband. The carrier, which has been either partially or entirely suppressed at the transmitter, is returned to mix with the received sideband by the receiver. The result is a waveform identical to the one produced in the transmitter before suppression of the carrier and one sideband.

Single-sideband communications has several advantages over the conventional a-m system. One of the major advantages is that all of the radiated power is utilized in conveying the intelligence, and no power is lost in transmitting the carrier or duplicate sideband. A second advantage is seen when comparing the bandwidths necessary to receive single sideband to that required to receive both sidebands. Because the bandwidth necessary for single-sideband reception is obviously narrower, more single-sideband channels can be fitted into a given band of frequencies.

CHAPTER 3

RADIO EQUIPMENT

The radio equipment described and illustrated in this chapter is selected as representative of the many models and types of radio transmitters, receivers, and auxiliary equipment used in the fleet today. No attempt is made to cover all equipment in use, and, in consonance with the security classification of this text, any discussion of classified equipment is avoided.

TRANSMITTERS AND TRANSCEIVERS

Modern shipboard transmitters must be of rugged construction for long service life. They must be capable of transmitting over a wide range of frequencies and distances. Moreover, they must provide various modes of operation. Transmitters that meet these requirements are quite complex and, because of the limited space available for radio installations in naval vessels, are of compact construction.

One method of obtaining equipment compactness is to combine a transmitter and a receiver into one unit called a transceiver. A transceiver used part of the same electronic circuitry for both transmitting and receiving, hence cannot transmit and receive simultaneously. A transmitter-receiver, however, is a separate transmitter and receiver mounted in the same rack or cabinet. The same antenna may be utilized for the transmitter-receiver arrangement, but the capability for independent operation of the equipment still exists. Both terms are commonly used when discussing radio equipment.

In the following descriptions of specific equipment capabilities, the term "short range" (or "distance") means a measurement less than 200 miles; "medium range" is between 200 and 1500 miles; and "long range" exceeds 1500 miles. These values are approximations, because the range of a given equipment varies considerably according to terrain, atmospheric conditions, frequencies, and time of day, month, and year.

LF, MF, AND HF TRANSMITTERS

Transmitters operating in the low-, medium-, and high-frequency bands of the frequency spectrum are used chiefly for communication at medium and long ranges. Some transmitters in these bands, however, are designed for short-range communication. In most instances, short-range transmitters have a lower output power than those designed for communication at medium and long ranges.

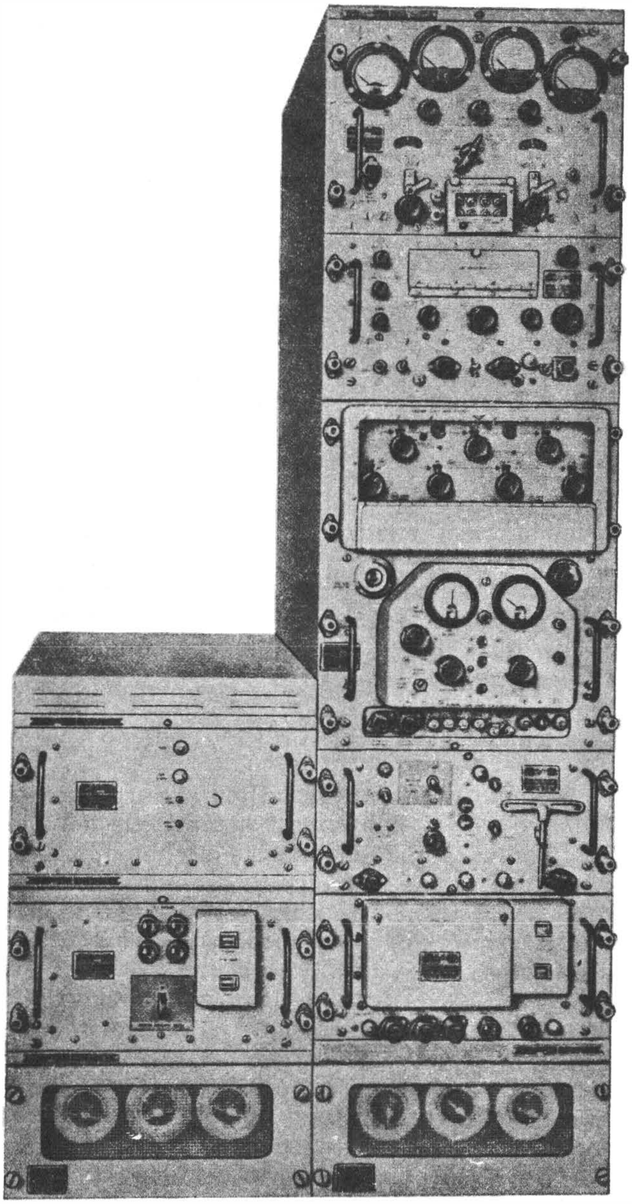
Transmitters AN/SRT-14, -15, and -16

Transmitting sets AN/SRT-14, -15, and -16 are a series of shipboard transmitters designed for medium- and long-range communications. The AN/SRT-14 is the basic transmitter in the series, with a power output of 100 watts. By adding a power booster to the basic transmitter, it becomes the AN/SRT-15 (fig. 3-1). The AN/SRT-15 has an optional output power of either 100 or 500 watts. Transmitter set AN/SRT-16 consists of two AN/SRT-14 equipments plus the booster, furnishing two entirely independent transmitting channels of 100-watt output, with the 500-watt booster available for use with either channel when desired.

All three transmitters cover the frequency range 0.3 to 26 mc, and may be used for CW, radiotelephone, radioteletype, and facsimile transmissions. The 500-watt output power, however, is available only when the AN/SRT-15 or the AN/SRT-16 is operating in the frequency range of 2 to 26 mc; at frequencies below 2 mc, output is limited to 100 watts.

Transmitter-Receiver AN/URC-7

The AN/URC-7 is an amplitude-modulated transmitter-receiver for short-distance radio-



1.144
Figure 3-1.—Transmitter AN/SRT-15.

telephone communication. Both transmitter and receiver have six pretuned crystal-controlled channels in the frequency range 2000 to 7000 kc. The transmitter has an output power of 25 watts. The transmitter, receiver, and the modulator-power supply are contained in a single cabinet (fig. 3-2).

The AN/URC-7 is used principally in service craft and auxiliary-type ships, such as tugs, transports, tankers, and ships of the amphibious force.

Transceiver AN/URC-32

Radio transceiver AN/URC-32 (fig. 3-3) is a manually operated radio communication equipment for operation in the 2- to 30-mc (high-frequency) range. With a power output of 500 watts, this transceiver is capable of transmitting signals over long distances. It is designed for single-sideband transmission and reception on upper sideband, lower sideband, or the two independent sidebands simultaneously, with separate a-f and i-f channels for each sideband. In addition to SSB operation, provisions are included for compatible a-m (carrier plus upper sideband), CW, or frequency shift keying (fsk). The fsk mode of operation is used for sending radioteletype (RATT) and facsimile (FAX) signals.

The frequency range of 2 to 30 mc is covered in four bands. The desired operating

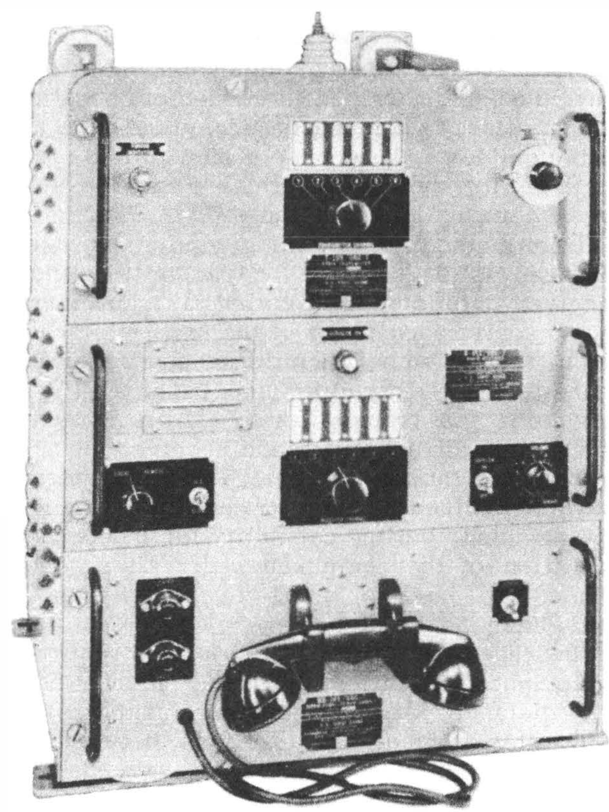


Figure 3-2.—Transmitter-receiver AN/URC-7. 76.19

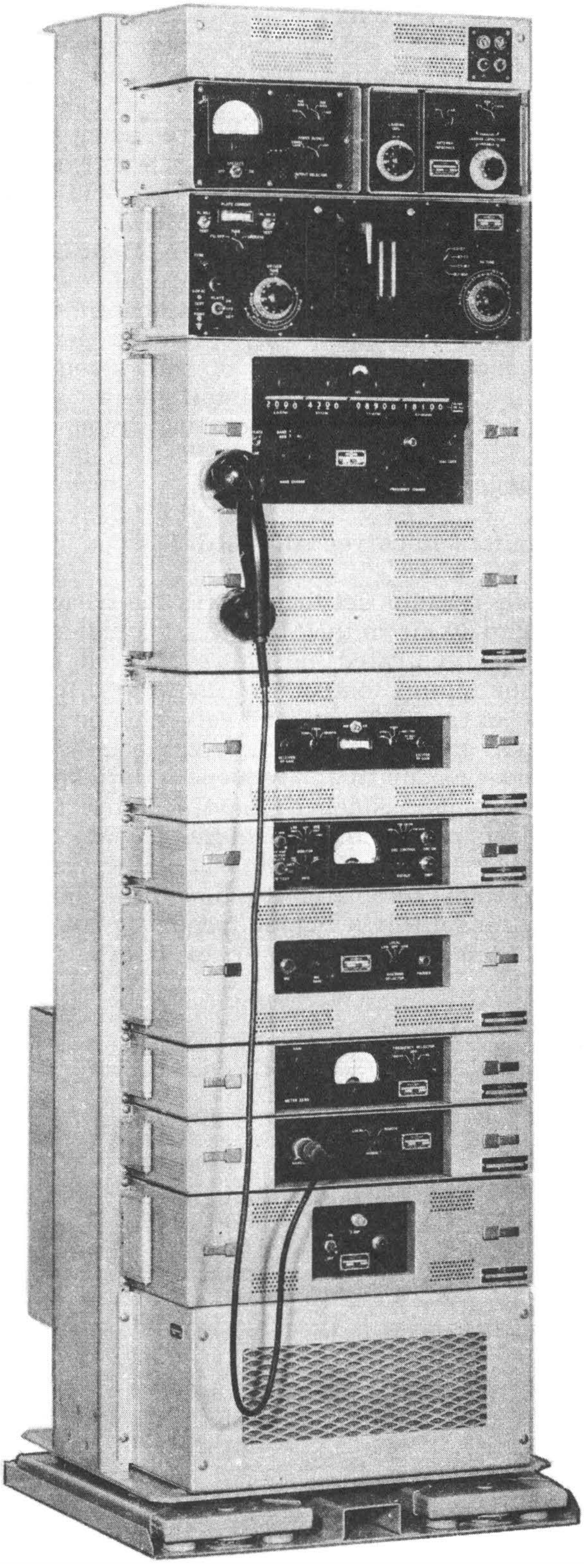


Figure 3-3.—Radio set AN/URC-32. 32.135

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. Provisions also are made for using an external frequency standard.

Because of its versatility and power, the AN/URC-32 is installed on most Navy ships having a requirement for communicating at long distances.

Transceiver AN/URC-35

Radio set AN/URC-35, shown in figure 3-4, is a recently developed, single-sideband transceiver. It is a compact equipment that operates over a frequency range of 2 to 30 mc while providing three modes of operation: upper sideband, lower sideband, and amplitude modulation (compatible). For single-sideband operation, the transmitter power output is 100 watts; for amplitude-modulated operation, the available carrier power is 25 watts.

Although capable of transmitting CW and fsk signals, the AN/URC-35 is used chiefly for voice communications over short and medium distances. It is replacing the TCS series transmitter-receiver (discussed later) aboard Navy ships.

Transmitter AN/WRT-1

The AN/WRT-1 (fig. 3-5) is a shipboard transmitter designed for operation in the

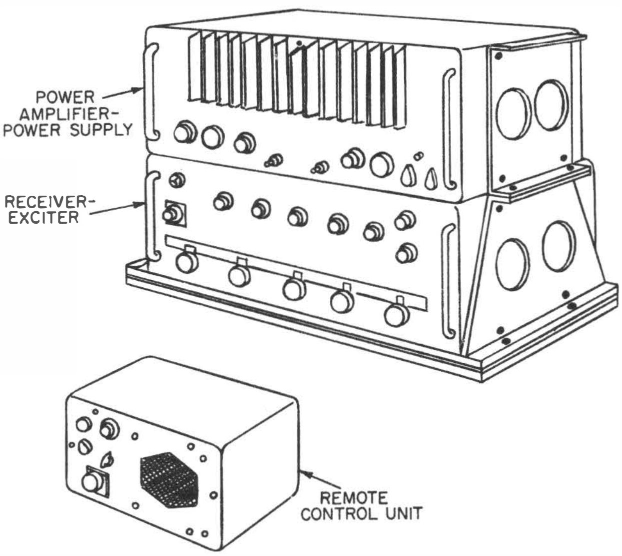
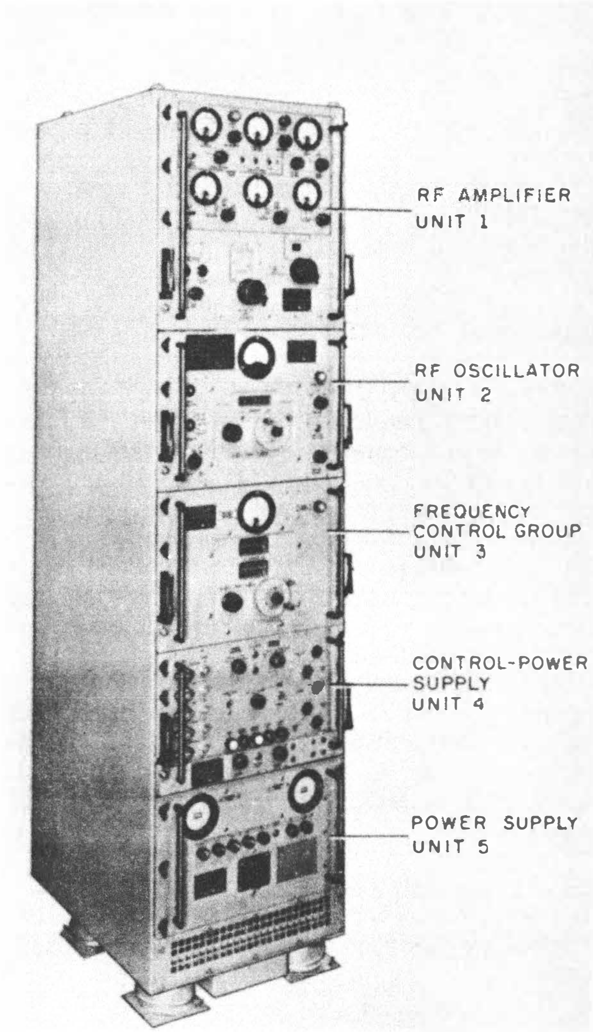


Figure 3-4.—Radio set AN/URC-35. 120.1



32.278
Figure 3-5.—Radio transmitter AN/WRT-1.

frequency range 300 to 1500 kc. This equipment can transmit CW, fsk, and voice signals, but it has no SSB capability. When used for CW and fsk transmissions, the transmitter has a power output of 500 watts. Voice operation, however, reduces the available power to approximately 125 watts.

Because of operating in the medium frequencies with a substantial power output, the AN/WRT-1 lends itself well for communicating over long distances during the hours of darkness. Its range is reduced to medium distances during daylight hours.

Transmitter AN/WRT-2

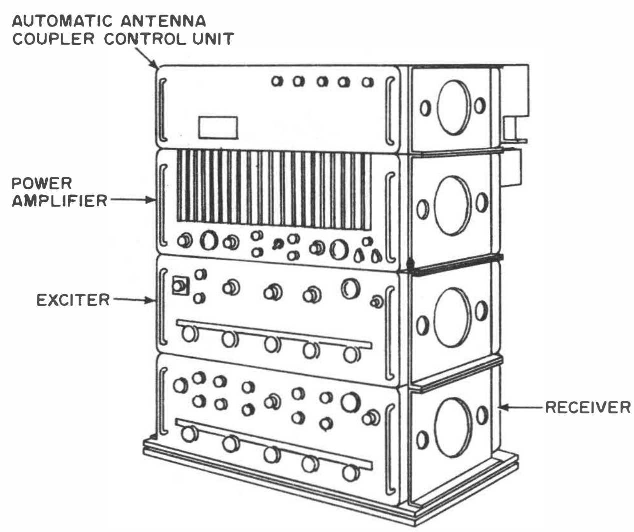
Radio transmitter AN/WRT-2 (not illustrated) is similar in size and appearance to the AN/WRT-1. It covers the frequency spectrum between 2 and 30 mc, and has an average power output of 500 watts for CW, fsk, and compatible a-m modes of operation. When operating as a single-sideband transmitter, it produces 1000 watts. An additional feature of the AN/WRT-2 is that it provides independent sideband operation. This mode of operation permits simultaneous transmission of both sidebands, each one carrying separate intelligence.

As indicated by its operating frequencies and power outputs, the AN/WRT-2 is used for long-range communications.

Transmitter-Receiver AN/WRC-1

Another radio set that covers the frequency range 2 to 30 mc is the AN/WRC-1 transmitter-receiver, illustrated in figure 3-6. It has a maximum power output of 100 watts, and is capable of transmission and reception on upper sideband, lower sideband, continuous wave, amplitude modulation, frequency shift keying, and independent sideband modes of operation.

An outstanding feature of the AN/WRC-1 is that it has an automatic antenna tuning system. This system automatically tunes the antenna to the transmitter's output frequency, thereby assuring maximum transfer of power at all times.



76.20
Figure 3-6.—Radio set AN/WRC-1.

Because the AN/WRC-1 is a recently developed equipment, only a limited number of these sets presently are installed aboard ships. They are being procured for installation throughout the fleet, however.

Transceiver AN/SRC-10( )

Although originally designed as an Army equipment, radio transceiver AN/SRC-10( ) (fig. 3-7) is installed aboard Navy ships for short-distance amphibious communication in the frequency range 2 to 27.9 mc. Its only mode of operation is radiotelephone, which is delivered at a selectable power output of either 2 or 16 watts. When supplemented with certain accessories, the AN/SRC-10( ) becomes a portable radio set for use ashore and in boats.

One major difference between this set and the equipment discussed previously is that it uses the frequency-modulation (f-m) principle for voice transmission. The others, when used for radiotelephone, are amplitude-modified.

Transmitter Model TBL-( )

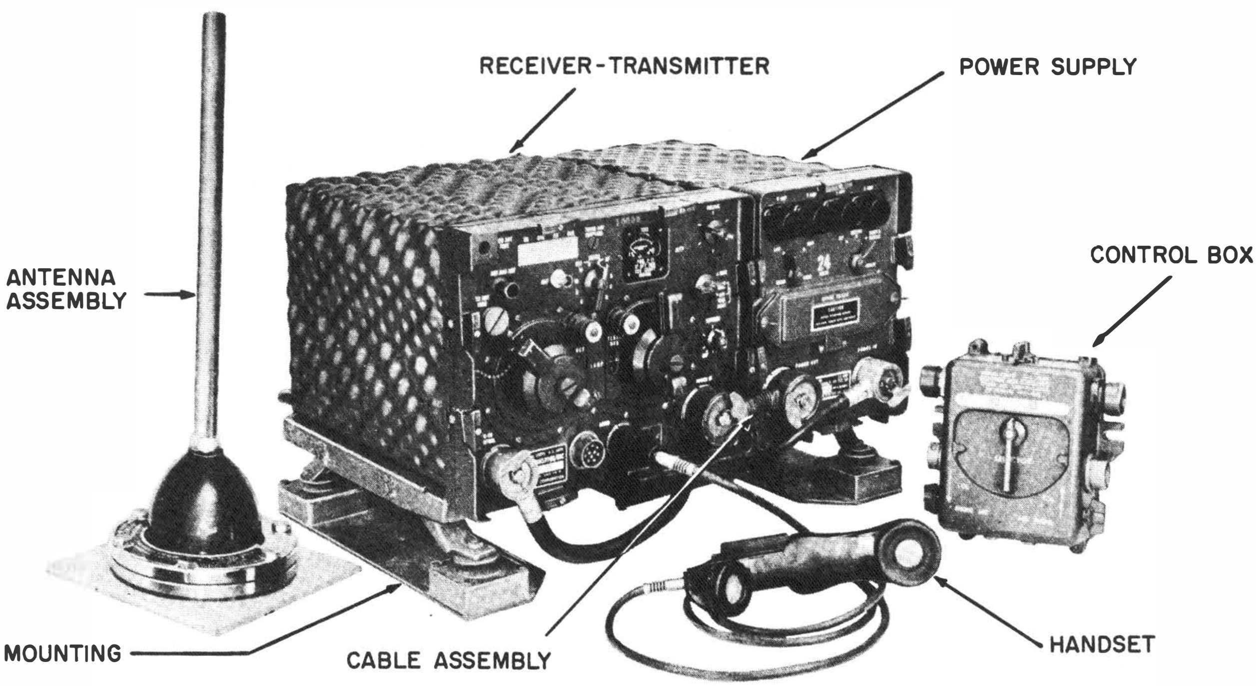
The TBL-( ) transmitter, illustrated in figure 3-8, has been used extensively for many years. It has a power output of 200 watts on CW and 50 watts on voice mode. In addition, it provides a modulated continuous-wave (MCW) mode of operation at an output of 100 watts. The MCW mode is similar to regular CW, except that an audio tone is used to modulate the carrier. Because this mode is less efficient than regular CW, it seldom is used.

The TBL-( ) operates in two frequency ranges. The low-frequency side of the transmitter covers the range 175 to 600 kc; the high side, from 2 to 18 mc. Both sides cannot be keyed simultaneously. To shift from one frequency range to the other, however, is simply a matter of throwing a switch.

Because the original design of the TBL-( ) made no provision for radiotelephone operation, a separate speech amplifier (not illustrated) must be used with the transmitter when transmitting voice signals. The most recent improvement to the transmitter is field change AN/WRA-1, which gives it the single-sideband capability.

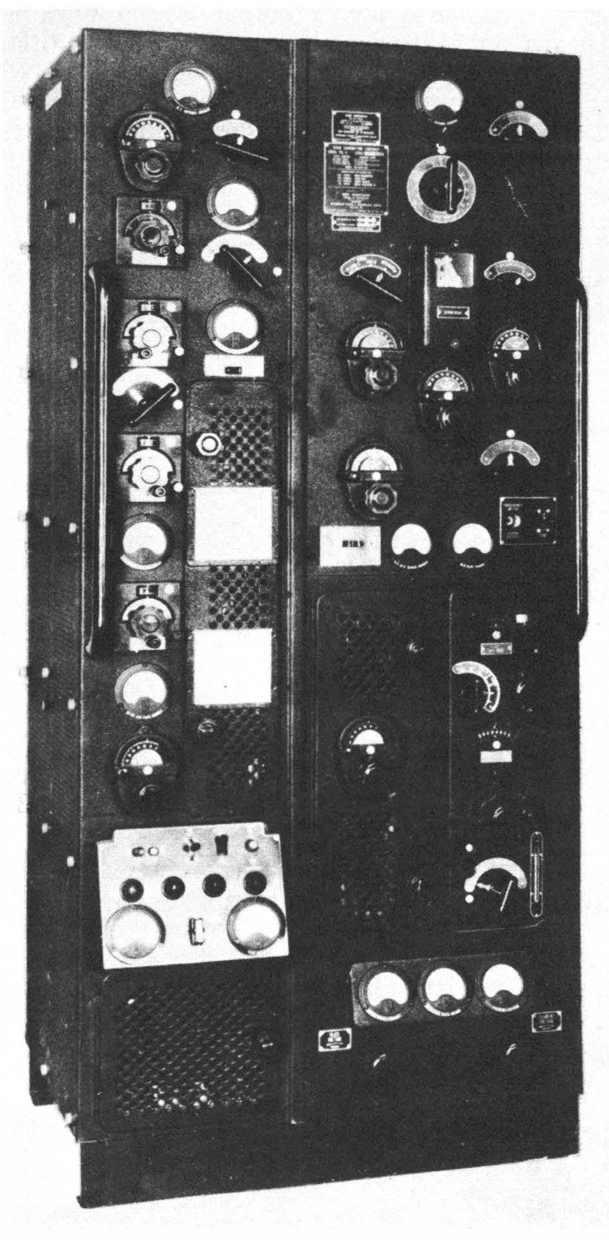
Transmitter-Receiver Model TCS-( )

The model TCS-( ), shown in figure 3-9, is a small transmitter-receiver that has been



120.2

Figure 3-7.—Radio transceiver AN/SRC-10( ).



76.21
Figure 3-8.—Model TBL-( ) transmitter.

in use for many years for short-range communications. It has an output power of 10 watts for radiotelephone and 25 watts for CW. The TCS-( ) has a frequency range of 1.5 to 12 mc. Its frequency-determining section may be either crystal-controlled or a continuously variable oscillator, whichever is more desirable. Transmitter and receiver use the same antenna, which is switched from receiver to transmitter by a relay when the transmitter is keyed. Although it is being replaced by the AN/URC-35, the TCS-( ) still is used aboard ships of all types.

VHF TRANSMITTERS

Except for special applications, equipments in the VHF range no longer are used extensively by the Navy. Most tactical voice communications now are conducted in the UHF band. Limited shipboard installations of VHF equipments are retained, however, for emergency communications and for communication with allied forces that have not yet converted to UHF equipments.

Transmissions in the VHF range normally are restricted to line-of-sight distances (less than 30 miles). Under certain atmospheric conditions, they have been received at considerably longer distances—500 miles or more. Obviously, this sometimes unpredictable behavior of VHF signals jeopardizes the security of tactical communications. It is for this reason that the Navy shifted to the UHF band.

Transmitter AN/URT-7( )

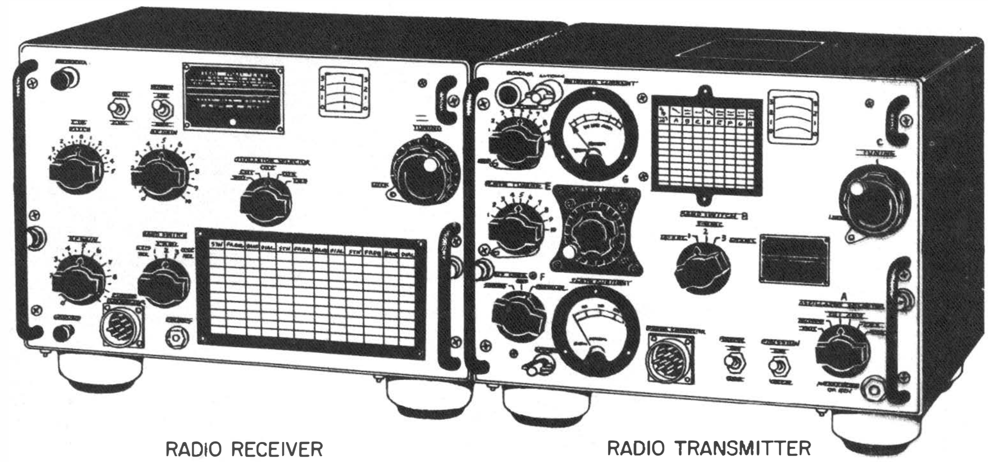
The AN/URT-7( ) (fig. 3-10) is a crystal-controlled VHF transmitter that operates in the frequency range 115 to 156 mc. Although mountings for four crystals are provided, permitting rapid selection of any one of four frequencies, the transmitter must be returned each time the frequency is changed. With a power output of 30 watts, this equipment provides two modes of operation: radiotelephone and MCW.

Transceivers AN/SRC-11( ) and -12( )

Except for the frequencies covered, radio transmitting and receiving sets AN/SRC-11( ) and AN/SRC-12( ) are identical to the AN/SRC-10( ) discussed under high-frequency transmitters. All three sets are f-m transceivers used for amphibious communication. They afford a total frequency coverage of 20 to 54.9 mc, with the AN/SRC-11( ) operating in the frequency range 27 to 38.9 mc, and the AN/SRC-12( ) covering between 38 and 54.9 mc.

Transmitter Model TDQ

The model TDQ transmitter (fig. 3-11), although being replaced by the newer AN/URT-7,



76.22

Figure 3-9.—Model TCS-( ) transmitter-receiver.

still is installed aboard all types of ships. Like the AN/URT-7, it is crystal-controlled and operates in the VHF range between 115 and 156 mc. Modes of operation are radiotelephone and MCW. Power output is 45 watts.

Transmitter-Receiver AN/ARC-1( )

Radio transmitter-receiver AN/ARC-1( ), illustrated in figure 3-12, is a low-power (8

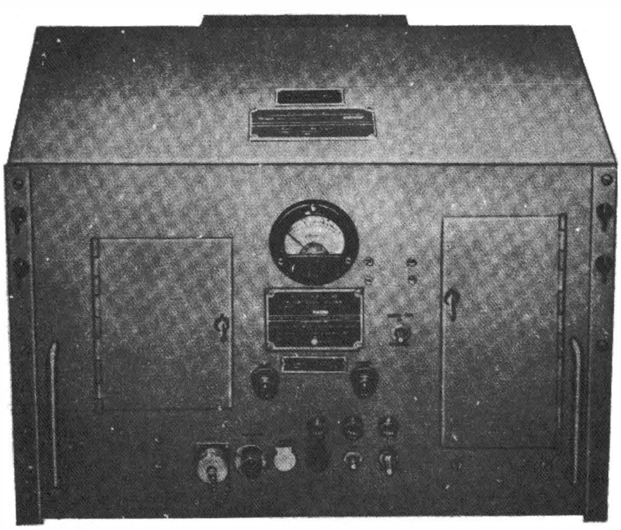


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Figure 3-10.—VHF transmitter AN/URT-7( ).

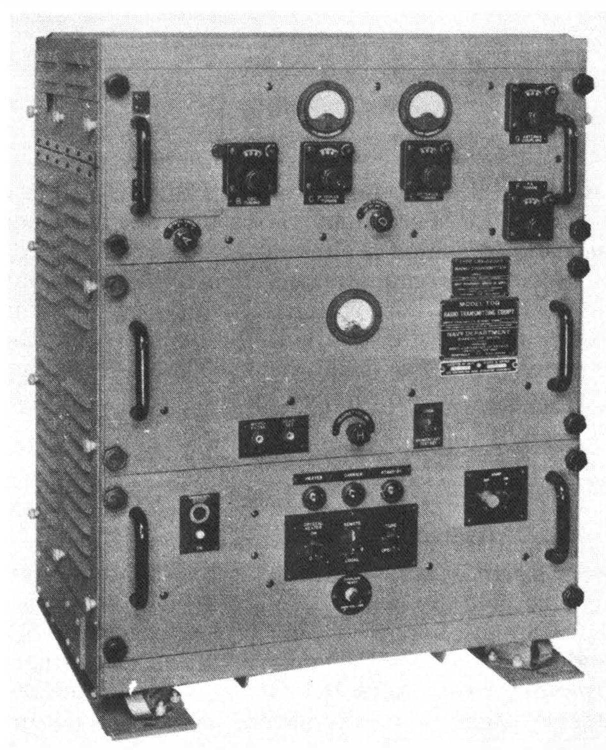

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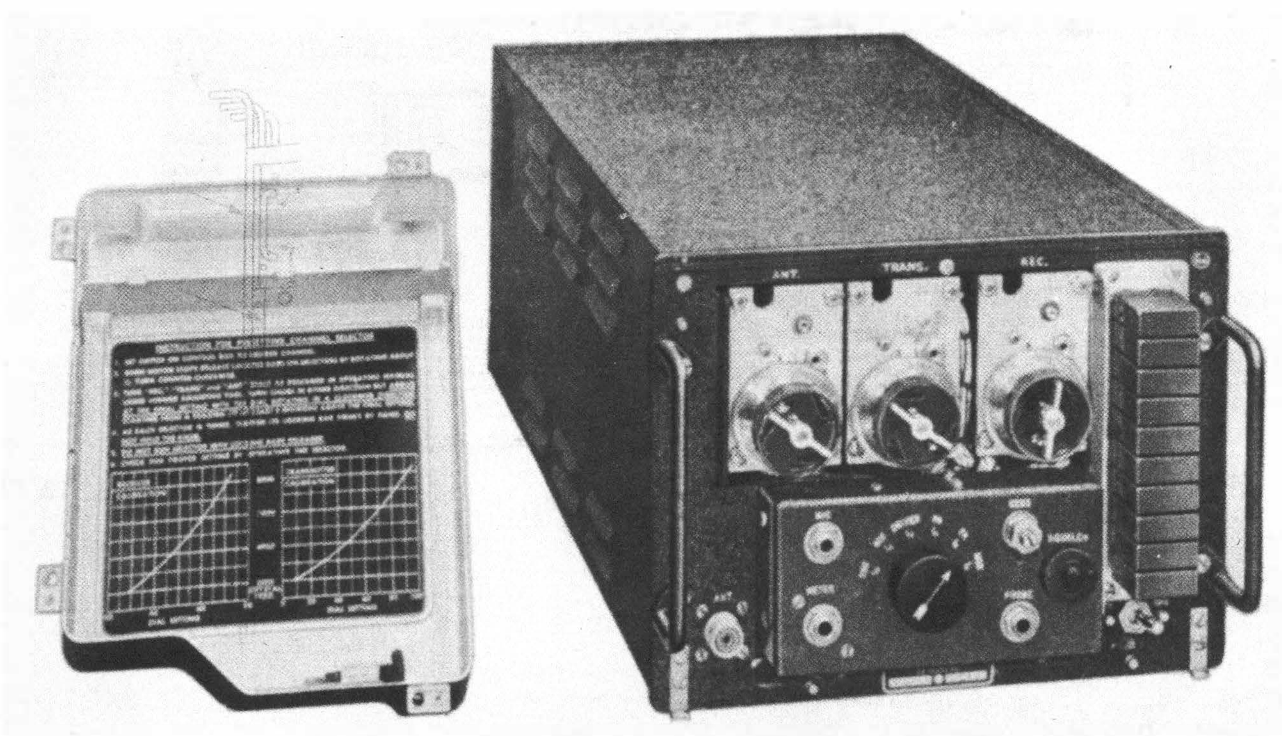
Figure 3-11.—VHF transmitter model TDQ.



120.3

Figure 3-12.—VHF transmitter-receiver AN/ARC-1( ).

watts) VHF equipment designed for installation in aircraft. For many years this set has been used aboard ship for surface-to-air and surface-to-surface communication. It provides two-way radiotelephone operation on any one of ten pretuned, crystal-controlled channels in the frequency range 100 to 156 mc. Channel selection is accomplished by means of a remote control unit (not illustrated).

UHF TRANSMITTERS

Most UHF radio transmitters (and receivers) used by the Navy operate in the 225- to 400-mc frequency range. Actually, this range of frequencies covers portions of both the VHF band and the UHF band. For convenience, however, radio sets operating within this frequency range are considered to be UHF equipment.

The effective distance range of UHF normally is limited to line-of-sight distances, making it ideally suited for low-power tactical voice communications.

Transmitter-Receiver AN/GRC-27( )

The AN/GRC-27( ), shown in figure 3-13, is a UHF transmitter-receiver set covering frequencies from 225 to 400 mc. This equipment is used for radiotelephone and MCW communications from ship-to-ship, ship-to-shore, or with aircraft. The AN/GRC-27( ) is installed principally in carriers and antisubmarine warfare ships, whose primary missions involve the control of aircraft.

The transmitter has a power output of 100 watts. It has three crystal-controlled oscillators, using a total of 38 crystals. These crystals, located within the transmitter, do not require handling by the operator. From the combination and multiplication of these 38 crystal frequencies are produced 1750 frequencies spaced at 100-kc intervals throughout the transmitter's frequency range. Any 10 of these 1750 frequencies can be preset manually with selector switch dials. Of the 10 preset frequencies, one then can be selected automatically by a telephone-type dial. The automatic selection can be made either locally at the transmitter or from a remote unit at other locations, such as CIC and the bridge. Only 2 to 7 seconds are required to shift automatically from one channel to another in any of the 10 preset channels.

The receiver also operates on any of the 1750 channels. It is a triple-conversion superheterodyne and has crystal oscillators using 38 crystals in a system separate from but similar to that used in the transmitter. Here, again, automatic shifting of channels is done in about 2 to 7 seconds.

Both transmitter and receiver use the same antenna. A relay switches the antenna from one to the other.

Radio Sets AN/URC-9( ), AN/SRC-20( ), and AN/SRC-21( )

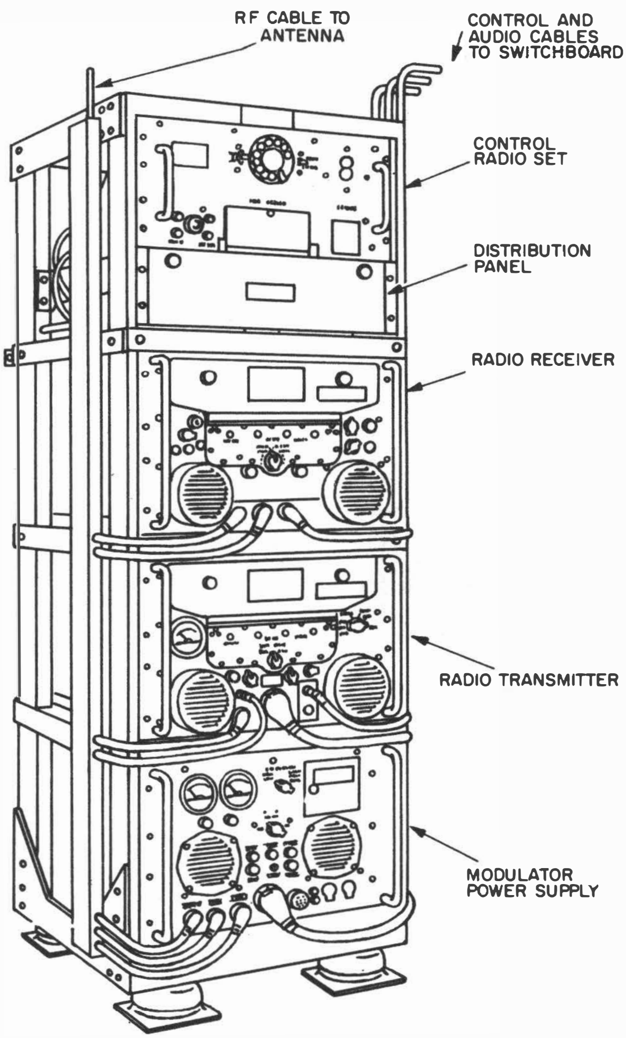
Radio set AN/URC-9( ) is a UHF transmitter-receiver that provides facilities for a-m radiotelephone communication in the frequency range 225 to 399.9 mc. The equipment is crystal-controlled and produces 1750 frequencies at 100-kc intervals within its frequency range. Although it is capable of operating on only one frequency at a time, any 20 of the 1750 available frequencies can be preset for immediate selection from remote positions. Channel selection requires a maximum of 8 seconds. This set has a power output of approximately 20 watts.

When modified by the addition of certain units, the AN/URC-9( ) is redesignated either AN/SRC-20( ), illustrated in figure 3-14, or AN/SRC-21( ). These modified sets can be connected to similar sets so that received signals are retransmitted automatically. This feature is useful when a ship (or aircraft) is serving as a relay station between two stations that cannot communicate with each other directly.

The difference between the AN/SRC-20( ) and the AN/SRC-21( ) is that the AN/SRC-20( ) has a power amplifier unit that increases the 20-watt power output from the AN/URC-9( ) to a 100-watt output.

Transmitter Model TED-( )

The model TED-( ) is a crystal-controlled, single-channel, UHF transmitter that operates in the frequency range 225 to 400 mc. Except for operating in a different frequency range and having a lower output power, this transmitter



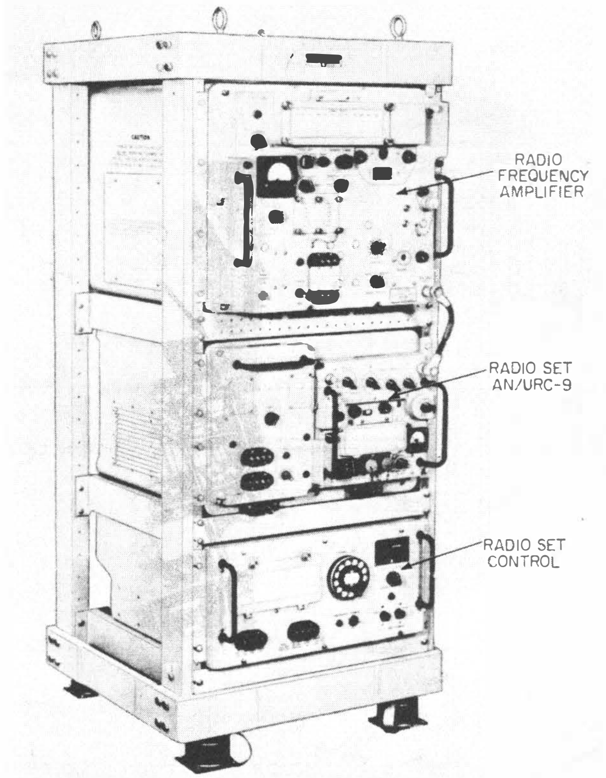
32.109.2
Figure 3-13.—Transmitter-receiver AN/GRC-27( ).

is identical to the VHF transmitter AN/URT-7 described earlier and illustrated in figure 3-10.

The TED-( ) has an output power of 15 watts. An r-f power amplifier (AM-1365/URT), designed for use with this transmitter, currently is being installed in the fleet. The amplifier boosts the output power to 100 watts.

PORTABLE AND PACK RADIO EQUIPMENT

Because portable and pack radio sets must be lightweight, compact, and self-contained,



120.4
Figure 3-14.—Radio set AN/SRC-20( ), with AN/URC-9( ) exciter.

they usually are powered by battery or hand generator, have low output power, and are either transceivers or transmitter-receivers. Navy ships carry a variety of these radio sets for emergency and amphibious communications. The numbers and types of this equipment vary according to the individual ship.

Transmitter-Receiver AN/GRC-9( )

Radio set AN/GRC-9( ) is a low-power radio transmitter and receiver. (See fig. 3-15.) It can be used in either vehicular or ground installations. It is carried aboard ship for use by landing parties for communicating with the ship.

The AN/GRC-9( ) receives and transmits CW, MCW, and a-m radiotelephone signals in the 2- to 12-mc frequency range. Provision is made for six crystal-controlled channels. Master oscillator tuning is also available for any frequency within the band.

For different kinds of installations, the radio set can be operated with batteries, dynamotors, gasoline-driven generators, or hand-driven generators.

The output power of the transmitter varies somewhat, depending on the type of power supply used. When powered by the hand generator, the output is approximately 10 watts CW and 4 watts on phone. Reliable communication range is usually about 30 miles for CW and 10 miles for phone.

The receiver and transmitter are contained in a metal case that has a tight-fitting removable cover. These components are dirtproofed and waterproofed for complete protection while transporting the equipment and when operating under extremely adverse weather conditions.

Transceivers AN/PRC-8, -9( ), -10( )

The AN/PRC-8, -9( ), and -10( ) series of portable radio sets provide voice communications for amphibious operations. These are man-pack sets, and, except for their operating frequencies and the components that determine these frequencies, they are similar electrically and mechanically. They are f-m equipments that are designed for use with their shipboard counterparts AN/SRC-10, -11, and -12, described earlier in this chapter.

Total frequency coverage of the three sets is 20 to 54.9 mc. The AN/PRC-8 covers frequencies between 20 and 27.9 mc; the AN/PRC-9( ), between 27.0 and 38.9 mc; and the AN/PRC-10( ), between 38 and 54.9 mc. With an output power of approximately 1 watt, these portable sets have an effective range of approximately 5 miles.

Figure 3-16 illustrates radio set AN/PRC-41 (discussed in the next topic), but the AN/PRC-8, -9( ), and -10( ) series closely resemble this set when they are assembled for man-pack operation.

Transceiver AN/PRC-41

Radio set AN/PRC-41 is a watertight, lightweight, portable UHF equipment that may be operated on any of 1750 channels, spaced 100 kc apart in the 225- to 399.9-mc range. Its only mode of operation is a-m voice, which it supplies at an average output power of 3 watts. Although designed principally for man-pack

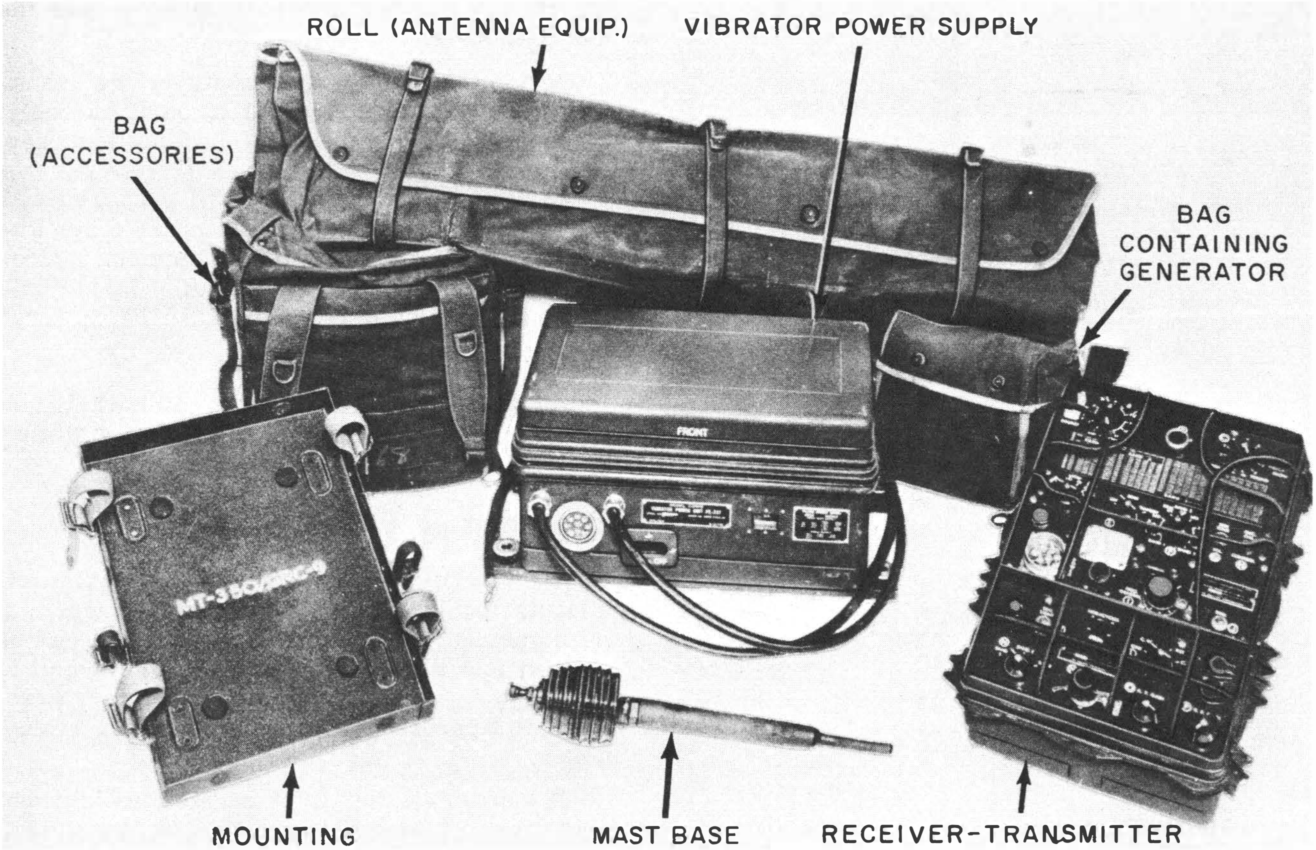


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Figure 3-15.—Radio set AN/SRC-9( ).

operation, the set also may be used for fixed station and vehicular operation when complemented by certain accessories. When not in use, the equipment is disassembled and stowed in a compartmentized aluminum transit case similar to an ordinary suitcase.

Transmitter AN/CRT-3

Radio transmitter AN/CRT-3, popularly known as the "Gibson girl," is a rugged emergency transmitter carried aboard ships and aircraft for use in lifeboats and liferafts. It is shown in figure 3-17. No receiving equipment is included.

The transmitter operates on the international distress frequency (500 kc) and the survival craft communication frequency (8364 kc).

The complete radio transmitter, including the power supply, is contained in an aluminum cabinet that is airtight and waterproof. The cabinet is shaped to fit between the operator's legs, and has a strap for securing it in the operating position.

The only operating controls are a three-position selector switch and a pushbutton telegraph key. A handcrank screws into a socket in the top of the cabinet. The generator, automatic keying, and automatic frequency changing are all operated by turning the handcrank. While the handcrank is being turned, the set automatically transmits the distress signal SOS in Morse code. The code sequence consists of six groups of SOS followed by a 20-second dash, transmitted alternately on 500 kc and 8364 kc. The frequency automatically changes every 50 seconds. These signals are intended for reception by two groups of stations, each having distinct rescue functions. Direction-finding stations cooperating in long-range rescue operations normally make use of 8364 kc, whereas aircraft or ships locally engaged in

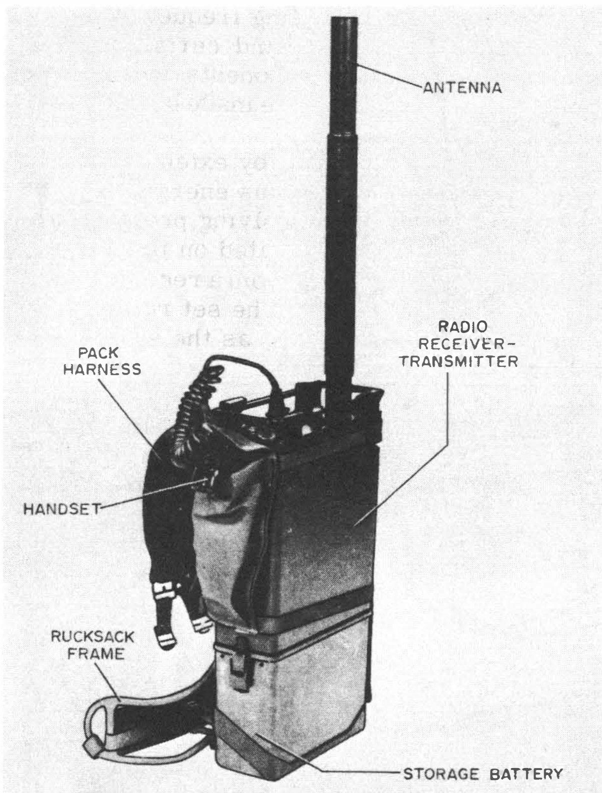

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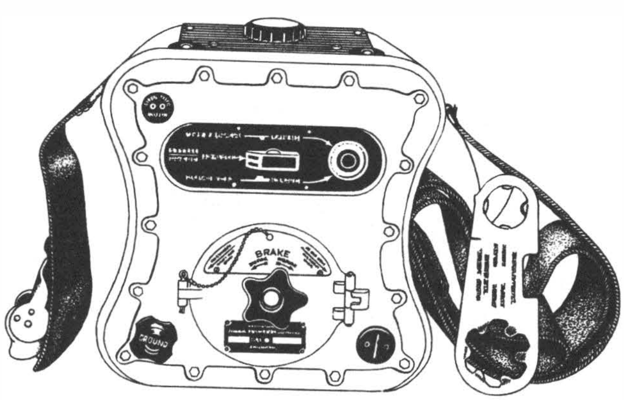
Figure 3-16.—Radio set AN/PRC-41.



76.32
Figure 3-17.—Emergency lifeboat transmitter AN/CRT-3.

search and rescue missions make use of the 500-kc signals.

Besides the automatic feature, the transmitter can be keyed manually, on 500 kc only, by means of the pushbutton telegraph key.

Additional items (not shown) packaged with the transmitter include the antenna, a box kite and balloons for supporting the antenna, hydrogen-generating chemicals for inflating the balloons, and a signal lamp that can be powered by the handcrank generator.

The equipment floats, and is painted brilliant orange-yellow to provide greatest visibility against dark backgrounds.

Transceiver AN/URC-4( )

The AN/URC-4( ) (fig. 3-18) is a compact, portable transceiver. It is small enough that the combined transmitter and receiver can be grasped and held with one hand. This unit is connected by a short cable to its battery case, which is approximately the size of the transceiver.

The complete set is intended to be carried in a special vest-type garment worn by airmen while they are on flight missions. It also may be dropped by parachute to personnel in distress. But, the principal use of this set in the Navy is for extremely short-distance distress communication between lifeboats (or liferafts) and searching rescue aircraft or ships.

This transceiver is a crystal-controlled equipment that provides voice and MCW transmissions over two frequency ranges within the VHF band. Frequencies covered are between 120 and 130 mc and between 240 and 260 mc. The operating frequency of the set is determined by a single crystal, which must be changed each time the frequency is changed. The set is pretuned, and can be operated by anyone familiar with its purpose.

Transceivers AN/URC-16( ), -17( ), -18( )

Except for the difference in power supplies and accessories, the AN/URC-16( ), -17( ), -18( ) series of portable radio sets essentially are the same as the shipboard-installed AN/SRC-10, -11, -12 series described earlier in this chapter.

120.6

Figure 3-18.—Transceiver AN/URC-4( ).

Transceiver SCR-536( )

Radio transceiver SCR-536( ), shown in figure 3-19, is a low-power, battery-operated transceiver used for voice communication over very short distances (1 to 3 miles). The equipment is crystal-controlled, and it operates on a preset frequency in the range of 3.5 to 6 megacycles. The operating frequency is varied by changing the crystal and certain other frequency-determining components within the set. Usually, these changes are made by a technician.

The set is energized by extending the telescopic antenna. When thus energized, it functions as a receiver. Applying pressure on the press-to-talk switch (located on the side of the set) shifts the equipment from a receive condition to a transmit condition. The set remains in the transmit condition as long as the switch is held depressed.

Weighing only 5-1/2 pounds, this portable set comes equipped with a carrying strap. Often the set is used as a means of communication by personnel moving about on foot, as while on shore patrol. Also, it serves as a means of communication between small boats and their parent ships.

RECEIVERS

Modern Navy radio receivers are easy to operate and maintain. They are capable of receiving several types of signals and can be tuned accurately over a wide range of frequencies. Because they are not required to

120.7

Figure 3-19.—Transceiver SCR-536( ).

produce or handle large currents and voltages, their size is relatively small when compared to the size of most transmitters.

Unlike the receiving units of the transceivers described earlier, the radio receivers discussed in this section are separate equipments that are capable of independent operation.

VLF, LF, MF, AND HF RECEIVERS

Most radio receivers operating in the VLF, LF, MF, and HF bands of the frequency spectrum are of the continuous tuning type. They are tunable to any frequency within their frequency range, and they usually cover this range in several tuning bands. Switching from one band to another changes the receiver's frequency-determining components, permitting more accurate tuning than is possible if the entire frequency range were covered by a single set of components.

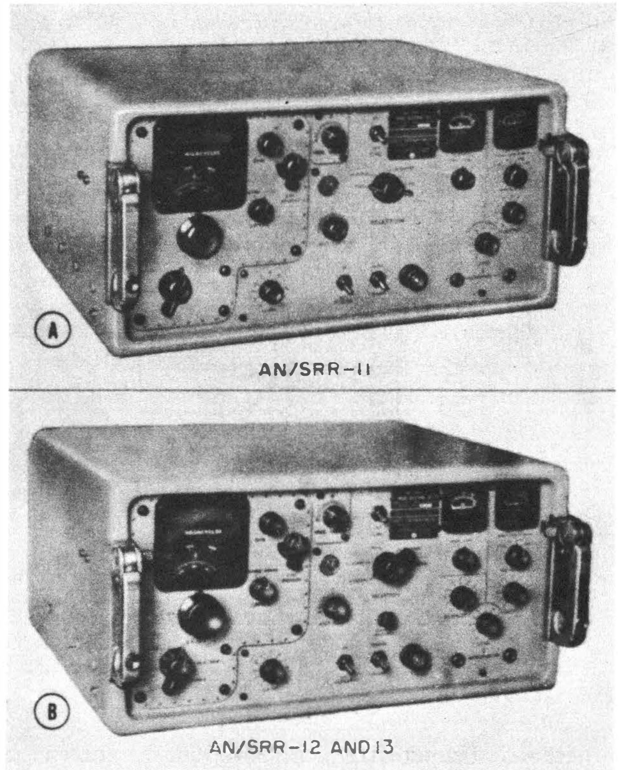
Radio Receivers AN/SRR-11, -12, -13

Radio receivers AN/SRR-11, -12, and -13 (fig. 3-20) are modern communication receivers used in all types of Navy vessels. They are companion receivers to the previously described transmitters AN/SRT-14, -15, and -16. Frequencies covered are between 14 kc and 32 mc.

The frequency range of each receiver is divided into five bands. The frequency range of the AN/SRR-11 is from 14 to 600 kc; the AN/SRR-12, from 0.25 to 8 mc; and that of the AN/SRR-13 is from 2 to 32 mc. The frequency range of AN/SRR-12 includes the standard broadcast band, and overlaps part of the frequencies covered by the other models. It is unlikely that you will encounter this model in the fleet, because the Navy procured very few AN/SRR-12 receivers.

The AN/SRR-11 receiver is used for guarding low and medium frequencies, such as the international distress frequency (500 kc). Its most general use, however, is for receiving the VLF and LF transmissions of the fleet broadcasts. This receiver can be used for CW, MCW, and frequency shift RATT and FAX reception.

The AN/SRR-13 covers all of the HF band. In addition to receiving CW, MCW, RATT, and FAX, it is an exceptionally good radiotelephone receiver.



1.157

Figure 3-20.—Radio receivers AN/SRR-11, -12, and -13.

Both the AN/SRR-11 and -13 models are double superheterodyne receivers. A crystal-controlled calibrator in each receiver provides crystal checkpoints for ensuring that the frequency dial is calibrated properly with the frequency-determining components of the receiver. The checkpoints, which are spread uniformly over the tuning range of the receivers, occur at 10-kc intervals for the AN/SRR-11 and at 200-kc intervals for AN/SRR-13.

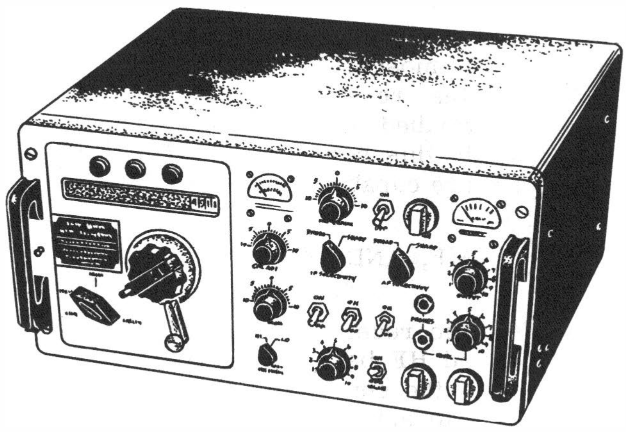
The frequency to which the receiver is tuned appears projected on a translucent screen (tuning dial) located at the upper left of the front panel. On the AN/SRR-11 the dial is calibrated in kilocycles; on the AN/SRR-13, in megacycles.

Radio Receiver AN/WRR-2

One of the latest shipboard radio receivers for the medium- and high-frequency bands is the AN/WRR-2. (See fig. 3-21.) This modern receiver is of the triple-conversion superheterodyne type, and it covers the frequency range 2 to 32 mc. Although intended chiefly for the reception of SSB transmissions, it can be used also to receive 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. The frequency to which the receiver is tuned is indicated on counter-type dials that resemble the mileage counter on an automobile dashboard.

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.



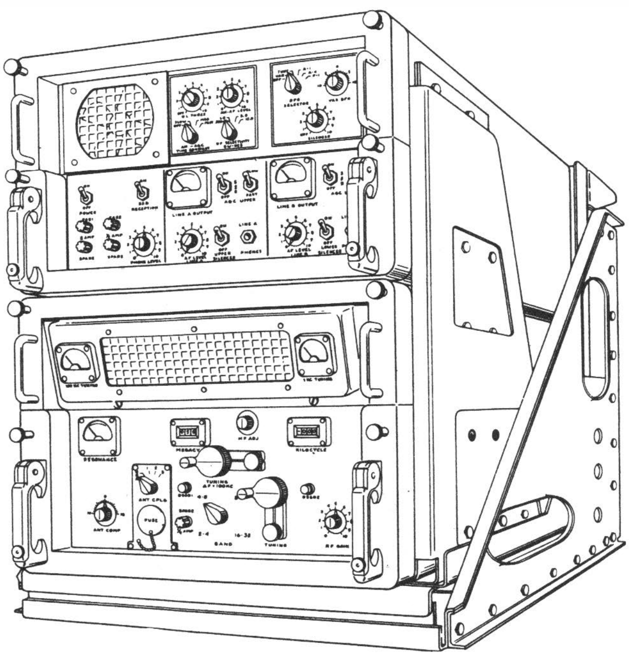
76.26*
Figure 3-22.—Radio receiver AN/WRR-3.

Radio Receiver AN/WRR-3

Radio receiver AN/WRR-3 (fig. 3-22) is a dual-conversion superheterodyne receiver for surface craft and submarine installations. It receives CW, MCW, and frequency shift keying signals.

The receiver covers the frequency range of 14 to 600 kilocycles in five bands. They are—

Band 1, 14 to 30 kc.
Band 2, 30 to 63 kc.
Band 3, 63 to 133 kc.
Band 4, 133 to 283 kc.
Band 5, 283 to 600 kc.



50.40
Figure 3-21.—Radio receiver AN/WRR-2.

The frequency to which the receiver is tuned is read directly on drum-type dials.

An internal calibration circuit provides calibration points at each 10-kc tuning point within the tuning range of the receiver.

Radio Receiver R-390( )/URR

Operating in the frequency range 500 kc to 32 mc, radio receiver R-390( )/URR (fig. 3-23) is a modern, high-performance, exceptionally stable receiver for both shipboard and shore station use. It can receive CW, MCW, a-m radiotelephone, and frequency shift radioteletype and facsimile signals. When used in conjunction with single-sideband converter CV-591( )/URR, it also is an excellent SSB receiver.

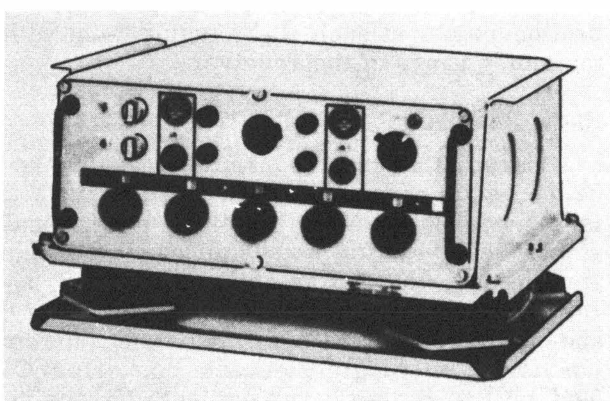
The receiver is a superheterodyne type, with multiple-frequency conversion. In the frequency range from 500 kc to 8 mc, it uses triple conversion. Double conversion is used in the range from 8 to 32 mc.

The tuning knob turns a complex arrangement of gears and shafts to indicate the frequency to which the receiver is tuned on a very accurate counter-type dial. The dial is calibrated in kilocycles, and the frequency reading accuracy of this tuning dial permits use of the receiver as an accurate frequency meter.

Radio Receiver R-1051/URR

The R-1051/URR (fig. 3-24) is one of the newest radio receivers. It is a versatile

34.15
Figure 3-23.—Radio receiver R-390( )/URR.



120.8
Figure 3-24.—Radio receiver R-1051/URR.

superheterodyne receiver capable of receiving any type of radio signal in the frequency range 2 to 30 mc. It can be used as an independent receiver. Or, in conjunction with a transmitter, it can be used to form a transmitter-receiver combination, such as radio set AN/WRC-1 described already.

Basically a crystal-controlled equipment, the R-1051/URR employs a digital tuning scheme for automatic tuning to any one of 56,000 operating channels. An additional fine tuning control provides continuous tuning throughout the receiver's frequency range.

This receiver is designated as standard equipment for use aboard all ships. Although presently available in limited numbers only, it is being procured for distribution throughout the fleet.

Radio Receiver AN/URR-22

Radio receiver AN/URR-22 (fig. 3-25) is designed chiefly for reception of voice transmissions on the standard broadcast and international shortwave broadcast bands. Additionally, it can be used as an emergency communication receiver for CW and MCW signals.

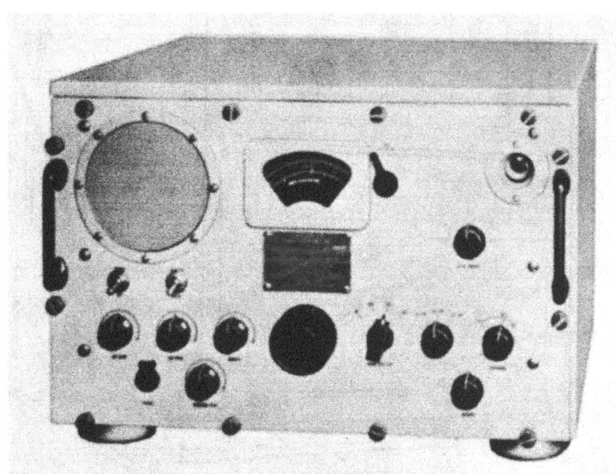
It is a superheterodyne receiver covering the frequency range of 540 kc to 18.6 mc in four frequency bands.

This receiver (and the similar AN/URR-44) is intended as a replacement for the older model RBO entertainment receiver (discussed later).

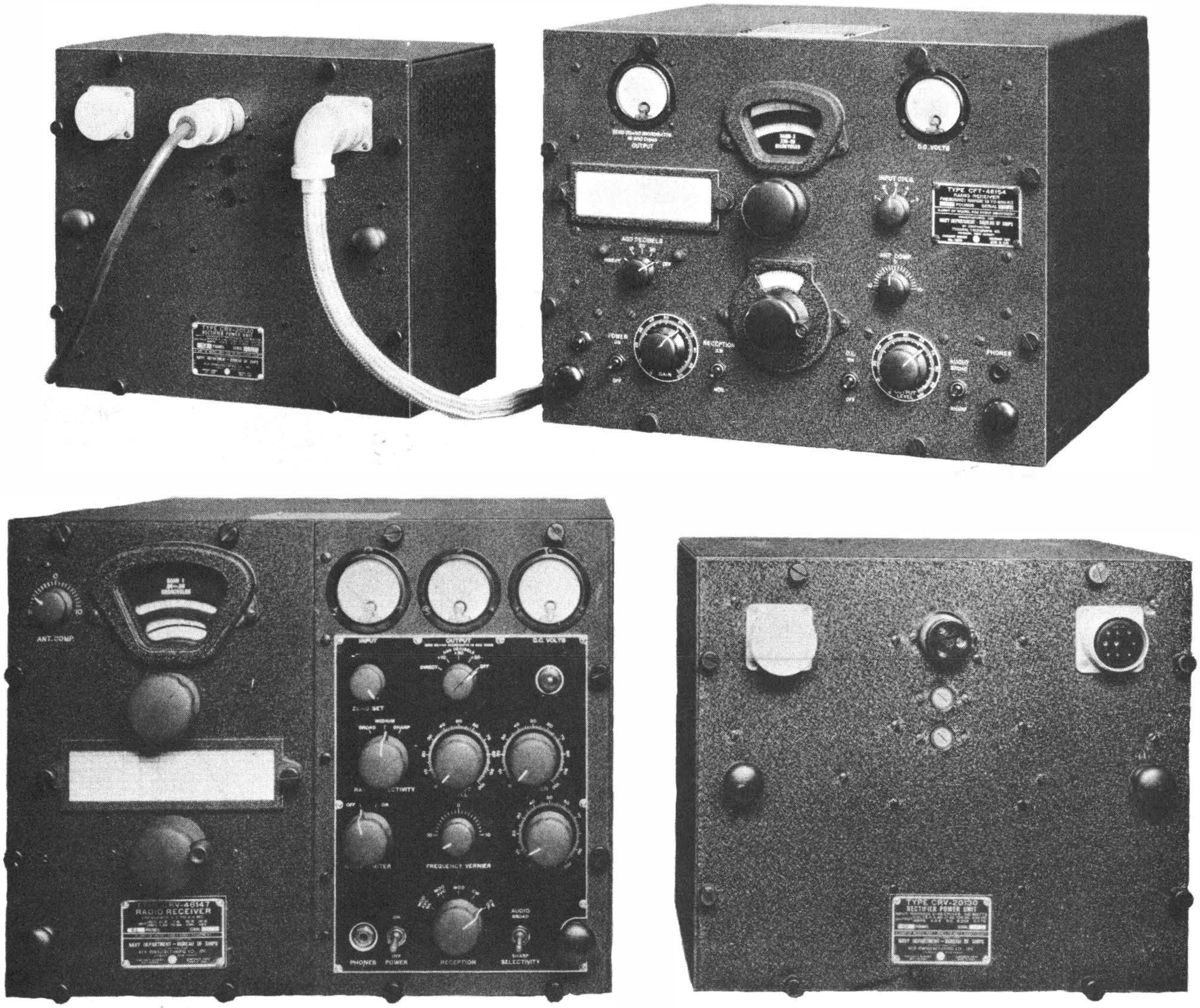
Radio Receivers RBA, RBB, and RBC

The RBA, RBB, and RBC receivers (fig. 3-26) have been used for many years aboard ship. Although they are being replaced by the AN/SRR-11, -12, and -13 series, many of these older receivers still are in service.

The total frequency coverage of these receivers is 15 kc to 27 mc—the RBA from 15 to 600 kc, the RBB from 0.5 to 4 mc, and the RBC from 4 to 27 mc.



76.28
Figure 3-25.—Radio receiver AN/URR-22.



34.17

Figure 3-26.—Receivers with power supply; top, model RBA; bottom, models RBB/RBC.

The RBA is a TRF (tuned radiofrequency) receiver, whereas the RBB and RBC are superheterodynes. All three receivers may be used for CW, MCW, and voice signals. But, because of its high selectivity, the RBA is not recommended for radiotelephone use. Most RBA and RBC receivers can receive frequency shift RATT and FAX signals also. All three receivers have high sensitivity and good selectivity. As shown in figure 3-26, the power supplies are separate units from the receivers.

Radio Receiver RBS-( )

Although being replaced by newer and more efficient equipment, the model RBS-( ) radio receiver (fig. 3-27) still is installed aboard many ships. It has a frequency range of 2 to 20 megacycles, which it covers in four tuning bands. A single tuning control provides variable tuning throughout the frequency range.

The model RBS-( ) radio receiver is capable of receiving CW, MCW, and voice signals.

When used in conjunction with a frequency shift converter, it also can be used for receiving RATT and FAX transmissions. The receiver does not perform well in the reception of fsk signals, however. The reason is that an unstable oscillator has a tendency to drift off frequency each time the ship rolls.

Radio Receiver RBO

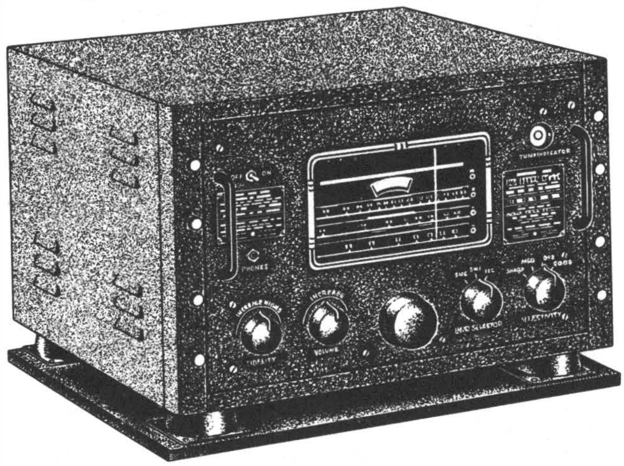
The model RBO receiver (fig. 3-28) has been the standard shipboard entertainment receiver for many years. It is installed in ships of all types. The RBO is a superheterodyne receiver. It provides high-quality reception of voice and music. Frequency bands of this receiver are (1) the standard broadcast band, 530 to 1600 kc; (2) a shortwave band from 5.55 to 9.55 mc; and (3) another shortwave band from 9.20 to 15.60 mc.

VHF RECEIVERS

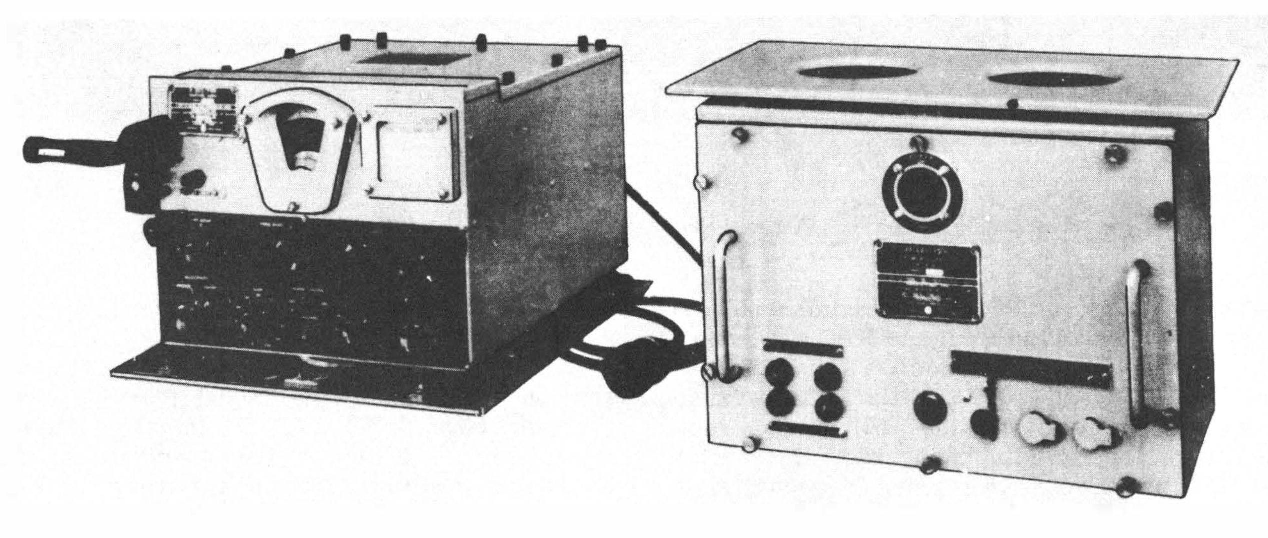
In most instances, radio receivers covering the VHF (and UHF) range are operated as crystal-controlled equipments. They are tuned easily and quickly. Once tuned, they operate efficiently for long periods of time without further attention.

As mentioned earlier in this chapter, the VHF range seldom is used for shipboard communications. Consequently, most ships carry only one or two VHF receivers.

Two models of VHF receivers currently used aboard ship are the AN/URR-21( ) and the AN/URR-27( ). Of these two, the AN/URR-27( ) is installed in greater quantity. For this reason, it is described first.



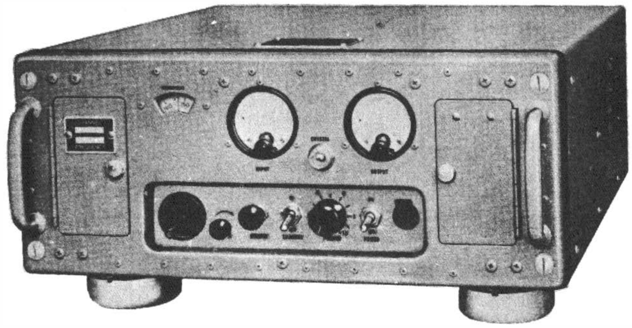
76.27
Figure 3-28.—Radio receiver model RBO.



120.9
Figure 3-27.—Radio receiver model RBS-( ), with power supply.

Radio Receiver AN/URR-27( )

Radio receiving set AN/URR-27 (fig. 3-29) provides for reception of amplitude-modulated voice and MCW transmission in the 105- to 190-mc frequency range. You will 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. It is, in effect, wasted.

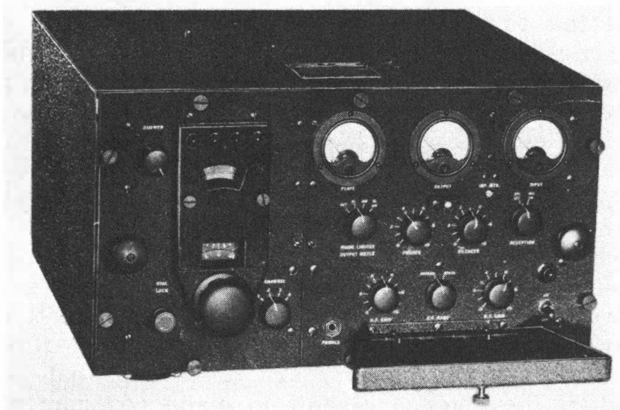


32.42
Figure 3-29.—Radio receiver AN/URR-27( ).

The AN/URR-27( ) is a superheterodyne receiver, designed chiefly for operation as a pre-tuned, 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.

Radio Receiver AN/URR-21( )

The AN/URR-21( ) receiver (fig. 3-30) is used for receiving amplitude-modulated radio-telephone signals, in a portion of the VHF band, from 115 to 156 mc. It is a crystal-controlled superheterodyne receiver. Although the receiver dial is calibrated continuously, only four channels can be tuned within the frequency range at any one time because the frequency of the oscillator is controlled by four individually selectable crystals. The four crystals are plugged into a crystal holder on the receiver chassis inside the cabinet. Special features include a front panel dial detent mechanism for rapid selection of channels, and continuous tuning of all r-f circuits by means of a single tuning control.



32.56
Figure 3-30.—Radio receiver AN/URR-21( ).

This receiver is an improved version of the old model RCK, still installed aboard many ships.

UHF RECEIVERS

Because of the extensive use of the UHF band for tactical communications, the number of UHF receivers installed in the fleet far exceeds other types of receivers. The majority of UHF receivers are models AN/URR-13( ) and AN/URR-35( ). Like the VHF receivers, these UHF receivers are crystal-controlled for stable operation over long periods of time.

Radio Receivers AN/URR-13( ) and AN/URR-35( )

Radio receivers AN/URR-13( ) and AN/URR-35( ) are used for radiotelephone and MCW reception in the range of 225 to 400 mc. Although the frequency range includes the upper portion of the VHF band, both receivers commonly are called UHF equipments. They are used as companion receivers with the model TED transmitter. They were designed mainly as single-channel, crystal-controlled receivers. Continuously variable manual tuning may also be used. These receivers are easy to tune. They feature single tuning controls for tuning to any frequency within their range, for either crystal-controlled or manual tuning. The

AN/URR-13( ) is a superheterodyne receiver whereas the AN/URR-35( ) is a double superheterodyne. Both receivers are similar in size, appearance, and operating controls. Only the AN/URR-35( ) is illustrated here. (See fig. 3-31.)

SHIPBOARD ANTENNAS

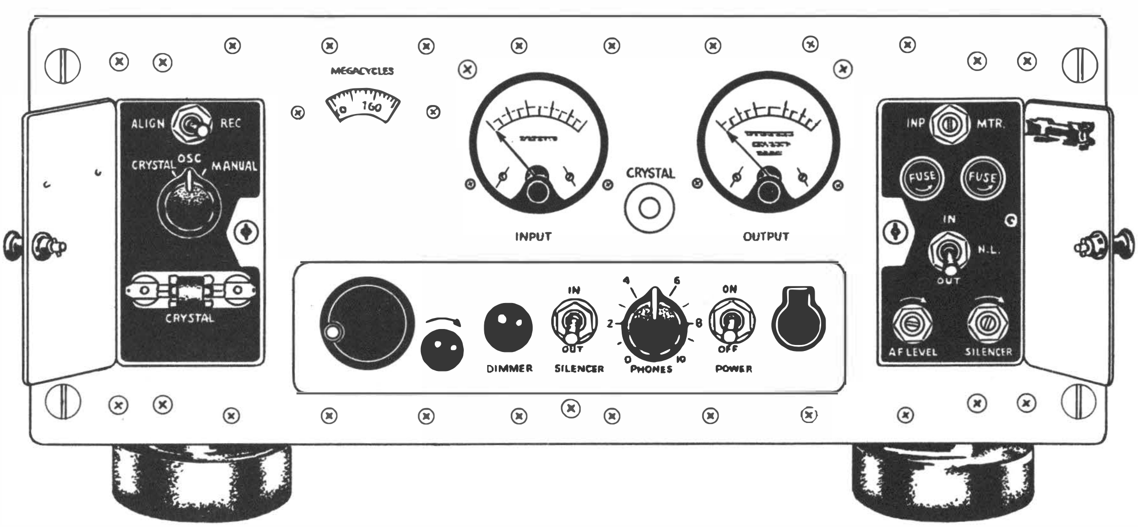
Antennas used for radio communications are so varied in design that it is impracticable to describe every antenna you may encounter aboard ship. This section, consequently, deals mainly with the use and physical appearance of some of the more common shipboard communication antennas. Any technical discussion of antenna theory is avoided, when possible. To understand why a particular antenna is suited for use at one frequency (or range of frequencies), yet is unsuited for others, you must have a knowledge of the relationship between an antenna's length and the frequency at which it is radiating.

The strength of the radio wave radiated by an antenna depends on the length of the antenna and the amount of current flowing in it. Because the antenna is a circuit element having inductance, capacitance, and resistance, the largest current is obtained when the inductive and capacitive reactances (opposition to the flow of alternating current) are tuned out; that is, when the antenna circuit is made resonant at the frequency being transmitted.

The shortest length of wire that will be resonant at any particular frequency is one just long enough to permit an electric charge to travel from one end of the wire to the other end and back again in the time of 1 cycle. The distance traveled by the charge is 1 wavelength. Because the charge must travel the length of the wire twice, the length of wire needed to have the charge travel 1 wavelength in 1 cycle is half a wavelength. Thus, the half-wave antenna, sometimes called a dipole, doublet, or Hertz is the shortest resonant length and is used as the basis for most antenna theory.

An antenna can be made resonant by two methods: (1) adjusting the frequency to suit a given antenna length; or, as usually is more practicable, (2) adjusting the length of the antenna wire to accommodate a given frequency. Every time the transmitter is changed to a new frequency, it is, of course, impracticable to lengthen or shorten an antenna physically. The antenna length may be changed electrically, however, by a process known as tuning, or loading, the antenna.

The dipole—a center-fed, half-wave antenna—is the basis for many complex antennas. When used for transmitting high frequencies, it usually is constructed of wire. At very high and ultrahigh frequencies, the shorter wavelength permits construction with metal rods or tubing. Because the dipole is an ungrounded antenna, it



32.45

Figure 3-31.—Radio receiver AN/URR-35( ).

may be installed far above the ground or other absorbing structures.

At low and medium frequencies (below 4 mc), half-wave antennas are rather long for use aboard ship. Another basic type of antenna, however, affords a solution to the problem of undue length. It is the quarter-wave (Marconi) antenna.

The earth is a fairly good conductor for medium and low frequencies, and acts as a large mirror for the radiated energy. The result is that the ground reflects a large amount of energy that is radiated downward from an antenna mounted over it. It is as though a mirror image of the antenna is produced, the image being located the same distance below the surface of the ground as the actual antenna is located above it. Even in high-frequency range (and higher), many ground reflections occur, especially if the antenna is erected over highly conducting earth or salt water.

Utilizing this characteristic of the ground, an antenna only a quarter-wavelength long can be made into the equivalent of a half-wave antenna. If such an antenna is erected vertically and its lower end is connected electrically to the ground, the quarter-wave antenna behaves like a half-wave antenna. Here, the ground takes the place of the missing quarter-wavelength, and the reflections supply that part of the radiated energy that normally would be supplied by the lower half of an ungrounded half-wave antenna.

Another method of operating a vertical quarter-wave antenna is to use a ground plane with the antenna. The ground plane usually is made of wires or rods extending radially from the base of the antenna. Actually, the ground plane substitutes for the ground connection, thereby establishing the ground level at the base of the antenna. Thus, the antenna can be installed on masts or towers high above ground. Ground plane antennas of this sort are used mostly for VHF and UFH communications.

Although discussions of antennas ordinarily concern those used for transmitting, an efficient transmitting antenna for any particular frequency is also an efficient receiving antenna for that same frequency. It must be remembered, however, that there may be other limitations affecting the use of an antenna for both transmitting and receiving.

Problems not usually present in land installations arise when antennas are installed on board ship. Most of the masts, stacks, and other structures above decks are connected electrically (grounded) to the ship's hull and, through the hull, to the water. To obtain adequate coverage from the antenna, it must be installed so that minimum distortion of the radiation pattern results from grounded structures.

The antennas described in the next six topics are only a sampling of the antennas used in the Navy. They are typical of the antennas you can expect to find installed aboard most Navy ships.

WIRE ANTENNAS

READ

Wire antennas (fig. 3-32) are installed on board ship for medium- and high-frequency coverage. Normally, they are not cut for a given frequency. Instead, a wire rope is strung either vertically or horizontally from a yardarm (or the mast itself) to outriggers, another mast, or to the superstructure. If used for transmitting, the wire antenna is tuned electrically to the desired frequency.

Receiving wire antennas usually are installed forward on the ship, rising nearly vertically from the pilothouse top to brackets on the mast or yardarm. They are located as far as possible from the transmitting antennas so that a minimum of energy is picked up from the local

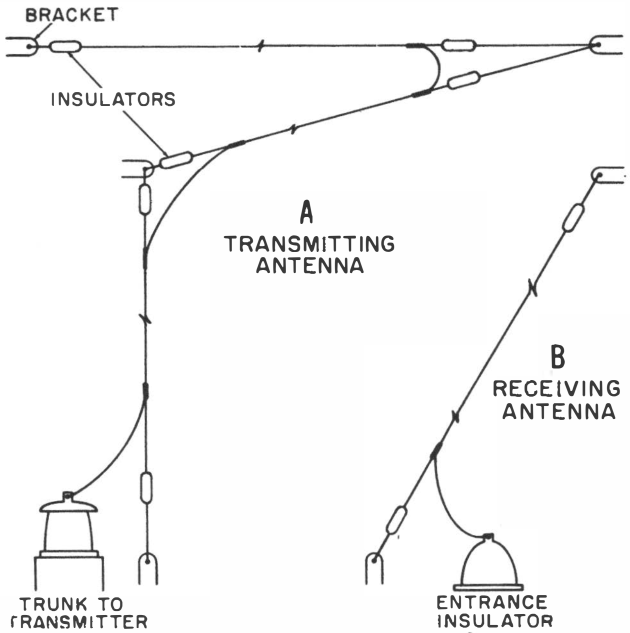


Figure 3-32.—Shipboard wire antennas.

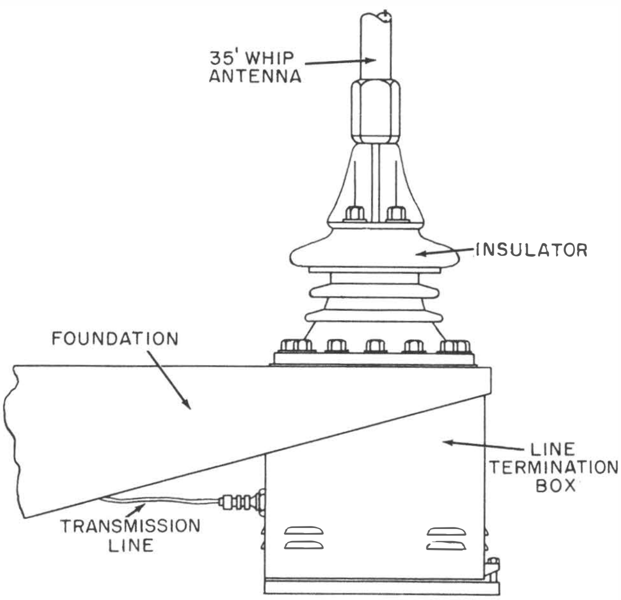
transmitters. The transmission line (lead-in) for each receiving antenna terminates in antenna transfer panels in the radio spaces.

Transmission lines of the transmitting antenna may be of coaxial cable or copper tubing. They are supported on standoff insulators and in some instances, are enclosed in rectangular metal ducts called antenna trunks. Each transmission line connects with an individual transmitter or with an antenna multicoupler (discussed later).

Metal rings, antenna knife switches, antenna hardware, and accessories associated with transmitting antennas usually are painted red. Hardware and accessories used with receiving antennas are painted blue. This color scheme is a safety precaution, and indicates, at a glance, whether an antenna is used for radiating or receiving.

WHIP ANTENNAS

Whip-type antennas have replaced many wire antennas in the frequency range 1.8 to 30 mc. Because they are essentially self-supporting, whip antennas may be installed in many locations aboard ship. They may be deck-mounted, or they may be mounted on brackets on the stacks or superstructure (fig. 3-33). Whip antennas commonly used aboard ship are 25, 28, or 35 feet in length, and are made up of several sections.



1.47

Figure 3-33.—Whip antenna.

On aircraft carriers, whip antennas located along the edges of the flight deck can be tilted. The tilting whip is pivoted on a trunnion, and is equipped with a handle for tilting and erecting the antenna. A counterweight at the base of the antenna is heavy enough to nearly balance the antenna in any position. The antenna may be locked in either a vertical or horizontal position.

FAN ANTENNA

The fan antenna (fig. 3-34) is designed principally for use in the low-frequency range. It also performs satisfactorily at high frequencies. This antenna is capable of radiating over a wide range of frequencies, for which reason it is known as a broadband antenna.

The antenna usually consists of four radiating elements (wires) that are cut for one-quarter wavelength at the lowest frequency to be transmitted. Whether one or all of these elements are fed energy by the transmitter, the overall effect of the paralleled elements is to increase the radiating surface. Effectively, the fan antenna is a single radiator whose diameter is substantially large in comparison to its length.

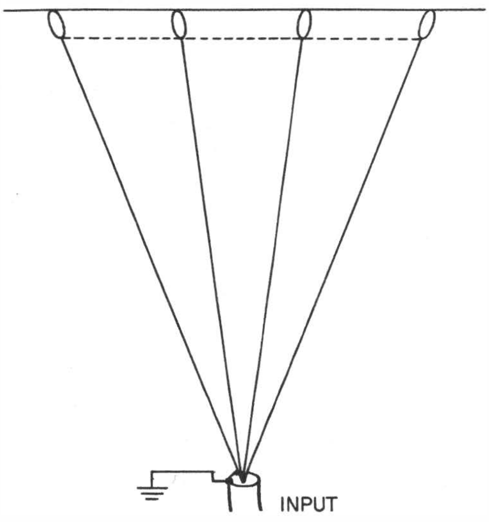
SLEEVE ANTENNA

The sleeve antenna (fig. 3-35), originally developed to fill the need for a versatile, long-distance antenna ashore, now is installed aboard many ships. Essentially, the sleeve antenna is a grounded, quarter-wave antenna that operates over a wide range of frequencies in the high-frequency band. Although similar in appearance to the whip antenna, it is identified easily by the large diameter sleeve at its base. The sleeve usually is welded to the deck or superstructure of the ship.

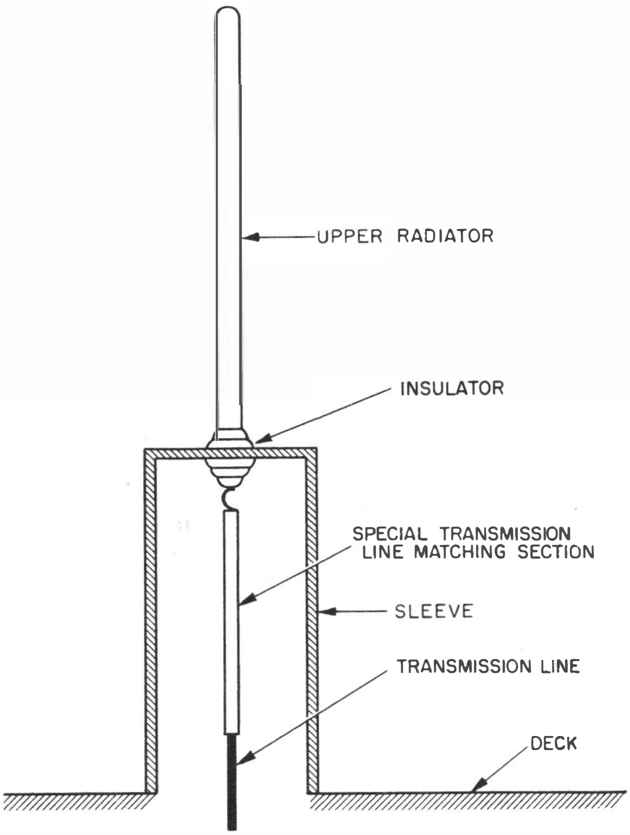
CONICAL MONOPOLE ANTENNA

Another broadband antenna used extensively is the conical monopole shown in figure 3-36. Like the sleeve antenna, it is used both ashore and aboard ship.

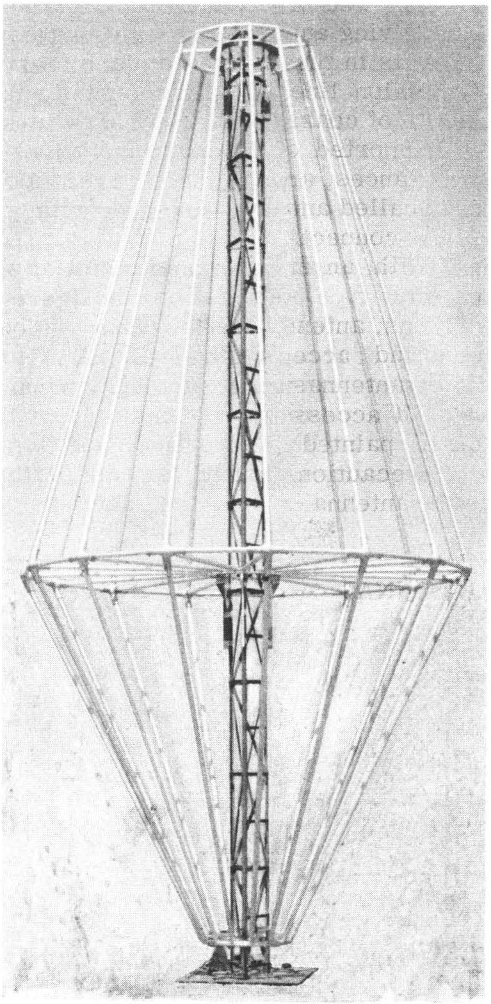
When operating at frequencies near the lower limit of the high-frequency band, the conical radiates in much the same manner as a regular vertical antenna (omnidirectional on the horizontal plane). At the higher frequencies



25.216
Figure 3-34.—Fan antenna.



25.217
Figure 3-35.—Sleeve antenna (shipboard).



25.214
Figure 3-36.—Conical monopole antenna.

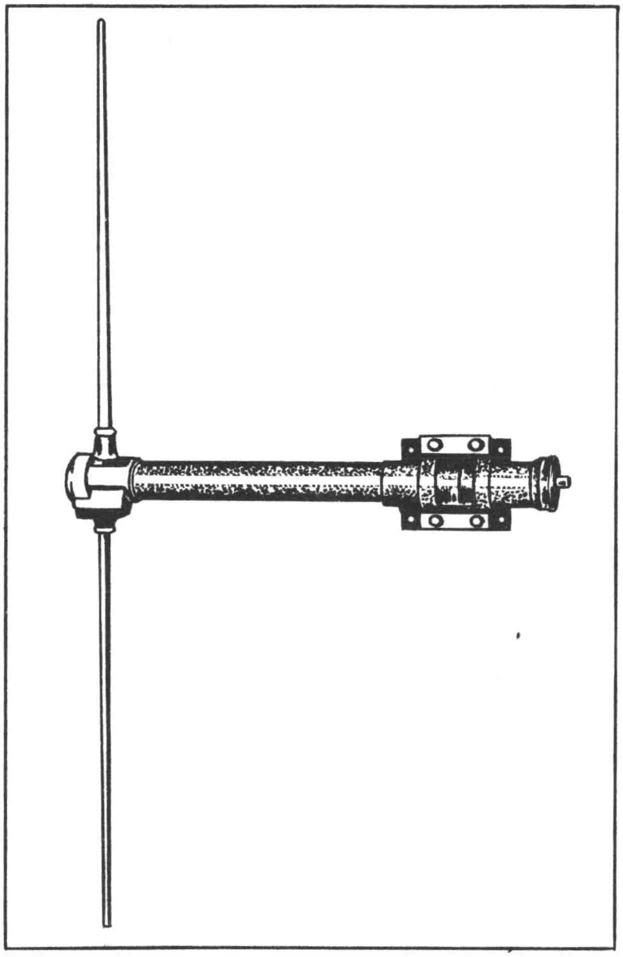
the lower cone section radiates, and the effect of the top section is to push the signal out at a low angle. The low angle of radiation causes the skywave to return to the earth at great distances from the antenna. Hence, the conical monopole antenna is well suited for long-distance communication in the high-frequency range.

VHF-UHF ANTENNAS

At VHF and UHF frequencies, the shorter wavelength makes the physical size of the antenna relatively small. Aboard ship these antennas are installed as high and as much in the clear as possible.

For best results in the VHF and UHF ranges, both transmitting and receiving antennas must be mounted on the same plane (vertically or horizontally). Vertically mounted antennas are used for all ship-to-ship, ship-to-shore, and air-ground VHF-UHF communications. Usually, either a vertical half-wave dipole or a vertical quarter-wave antenna with ground plane is used.

The VHF antenna commonly installed aboard ships is Navy type 66095, shown in figure 3-37. The horizontal portion of the antenna does not radiate, but acts as a mounting arm for the antenna and as an enclosure for the antenna feedline. The antenna is installed with the radiating portion in the vertical position. Although designed originally for use with VHF transceiver AN/ARC-1, the antenna works equally well with any transmitter and receiver operating in the frequency range 100 to 156 mc.



120.10
Figure 3-37.—VHF antenna NT-66095.

An antenna frequently used with UHF installations is the AT-150/SRC (fig. 3-38). This antenna is of the half-wave (dipole) type, and it covers the frequency range 225 to 400 mc. Like the VHF antenna just described, the horizontal (longer) section does not radiate, but serves as a mounting arm for the antenna. The antenna is mounted so that the radiator is vertical.

The AS-390/SRC (fig. 3-39) is another UHF antenna that operates at frequencies between 225 and 400 mc. It is a quarter-wave antenna with a ground plane. The ground plane consists of a round plate (called a counterpoise) and eight equally spaced drooping radials (rods). The antenna is mounted vertically.

The AS-1018/URC (not shown) is an additional 225- to 400-mc antenna often installed aboard ships. This antenna is the UHF version of the broadband sleeve antenna described previously.

AUXILIARY EQUIPMENT

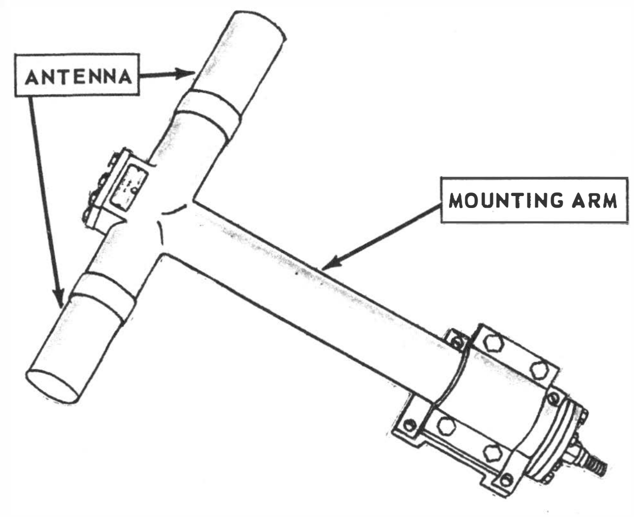
The term "auxiliary" often is misleading, particularly in the field of electronics. In most instances, material categorized as auxiliary equipment is essential to the efficient operation of an overall system. But, because it is subordinate to the primary equipments, such as transmitters, receivers, and antennas, it is classified as an auxiliary.

Some of the more prominent auxiliary equipments used in communication systems are discussed in the ensuing topics of this chapter.

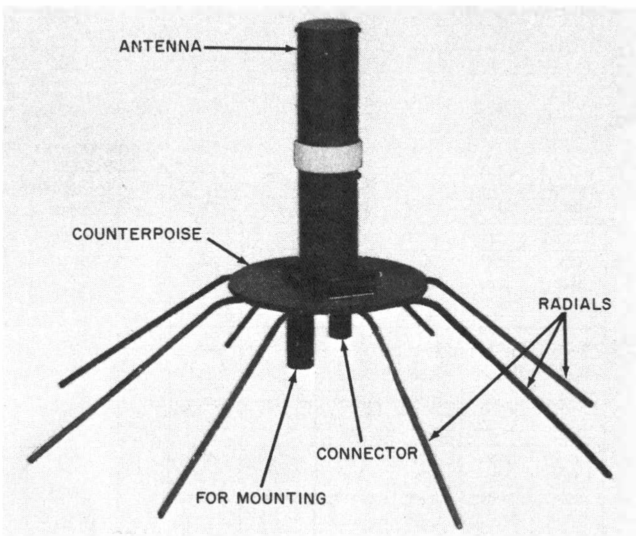
ANTENNA MULTICOUPLERS

Because of the large number of transmitters and receivers on board ships, it is infeasible to use a separate antenna for each equipment. One satisfactory approach to the problem of antennas is provided by multicouplers.

Antenna multicouplers are devices that permit the simultaneous operation of several transmitters and/or receivers into (or from) the same antenna. The term "multicoupler" is descriptive of two or more couplers stacked or grouped together to form a single equipment, which then is connected to a broadband antenna. A separate coupler is required for each transmitter or receiver. Normally, the same antenna cannot be used for both transmitting and receiving simultaneously.



25.219
Figure 3-38.—UHF antenna AT-150/SRC.



25.220
Figure 3-39.—UHF antenna AS-390/SRC.

Multicouplers AN/SRA-13, -14, -15, -16

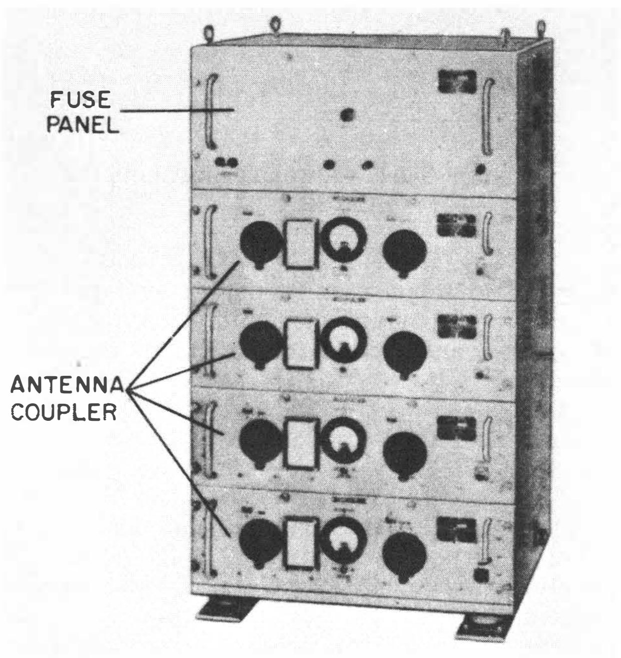
Four antenna coupler groups that operate in the MF-HF range are the AN/SRA-13, -14, -15, and -16. They provide complete coverage of frequencies between 2 and 26 mc. The frequency coverage afforded by each multicoupler is as follows: AN/SRA-13, 2 to 6 mc; AN/SRA-14, 4 to 12 mc; AN/SRA-15, 6 to 18 mc; and AN/SRA-16, 9 to 26 mc.

Typical of this group is the AN/SRA-15, which is illustrated in figure 3-40. The four couplers comprising the multicoupler provide for the simultaneous operation of four transmitters (each with 500-watt power output) into a single broadband antenna. As long as there is adequate separation between the operating frequencies, the four transmitters connected to the multicoupler may be operated anywhere in the frequency range from 6 to 18 mc. Separation of 10 percent of the highest operating frequency is considered sufficient.

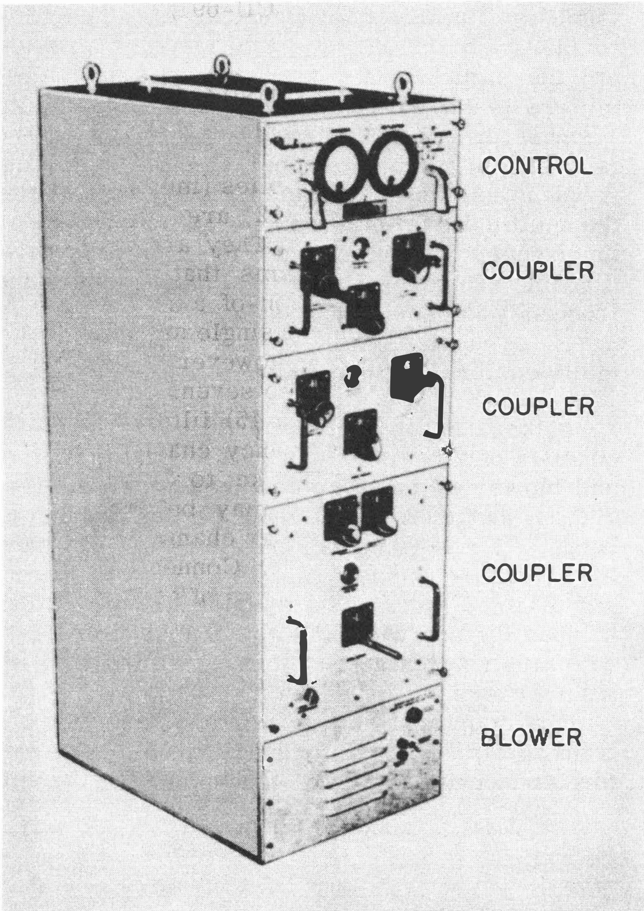
Multicoupler AN/SRA-23

Antenna multicoupler AN/SRA-23 (fig. 3-41) consists of three couplers and associated control and blower units. The couplers cover the frequency range 2 to 27 mc in three frequency bands. Each coupler operates in a different band. These bands are 2 to 6 mc, 5 to 15 mc, and 9 to 27 mc. The coupler group was developed for use with 500-watt transmitters, but, with minor adjustments, it is capable of handling transmitters with 1000-watt outputs.

One coupler group accommodates only one transmitter. Provisions are made, however, for connecting up to eight of these groups



120.11
Figure 3-40.—Antenna multicoupler AN/SRA-15.



120.12
Figure 3-41.—Antenna multicoupler AN/SRA-23.

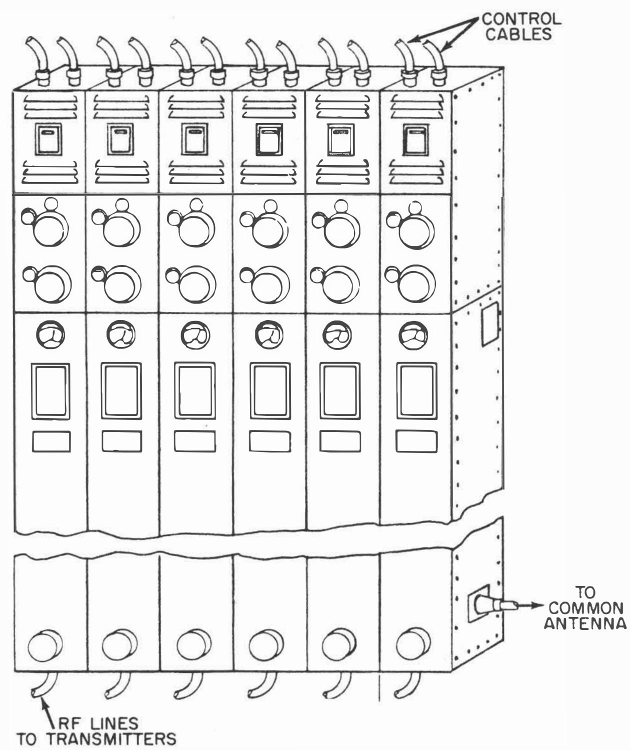
together to form a multicoupler system. This arrangement permits the simultaneous operation of eight transmitters into a single broadband antenna.

Antenna Couplers CU-255/UR and CU-332A/UR

One type of VHF-UHF antenna coupler is the CU-255/UR, seen in figure 3-42. When six couplers are used (as shown), a multicoupler system is provided for operating six transmitters (or transmitter-receiver combinations) into a single antenna. One coupler is required for each transmitter or transmitter-receiver combination. The frequency range of this particular multicoupler is 230 to 390 mc. The CU-255/UR couplers can be tuned manually to any frequency in this range. When used with automatic tuning transmitters, such as AN/GRC-27, they may be tuned automatically to any one of 10 preset channels in this band. Automatic tuning is accomplished by dialing the desired channel locally on the transmitter or on a remote channel-selector unit.

Type CU-332A/UR antenna coupler is identical to the CU-255/UR, except for the drive mechanism. The CU-332A/UR provides for manual tuning only, whereas the other has both automatic and manual tuning. The CU-332A/UR is used with manually tuned UHF equipment, such as the model TED transmitter, or any other manually tuned equipment operating in the 230- to 390-mc frequency range.

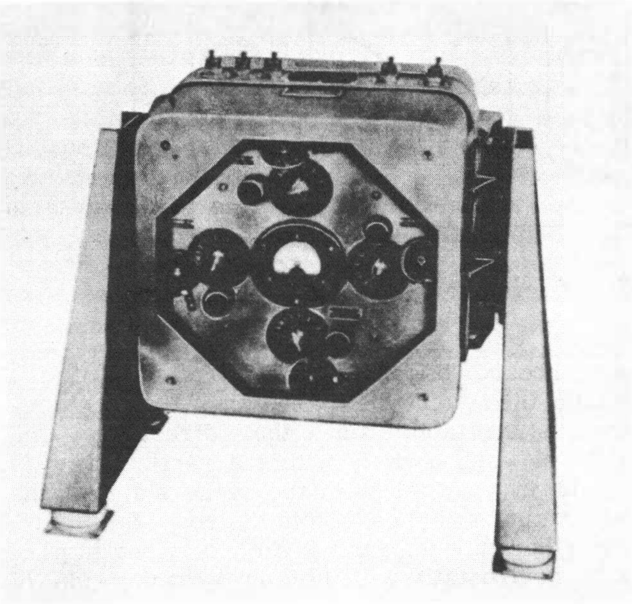
Like most VHF-UHF couplers, the performance characteristics of these two types of couplers require that operating frequencies on the common antenna be separated by approximately 15 mc.



1.266
Figure 3-42.—VHF-UHF multicoupler CU-255/UR.

Multicoupler CU-274/UR

Although not as efficient as the multicouplers just described, the CU-274/UR (fig. 3-43) is installed aboard small ships where space is a prime consideration. It provides for simultaneous operation of four UHF radio channels (transmitting or receiving) into a single antenna.



120.13

Figure 3-43.—VHF-UHF antenna multicoupler CU-274/UR.

This multicoupler can be tuned either automatically or manually to any frequency in the range 225 to 400 mc. For automatic tuning each channel first must be pretuned to 10 corresponding frequency channels in the frequency range of the attached transmitter or receiver. Thereafter, selected channels are returned atuomatically by means of an autotune mechanism.

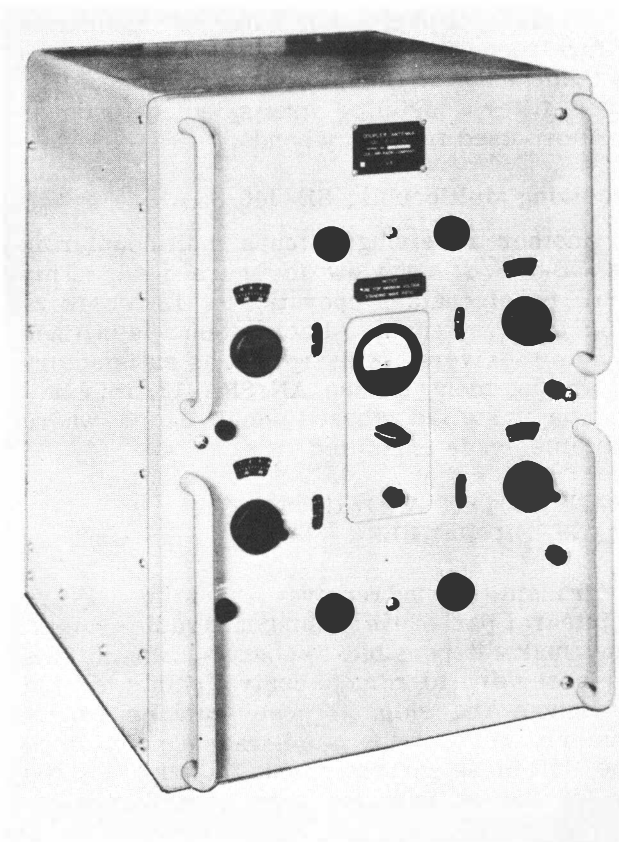
Multicouplers CU-691/U and CU-692/U

Both the CU-691/U and the CU-692/U are VHF-UHF multicouplers operating at frequencies between 225 and 400 mc. Except for their physical dimensions and the number of channels, the two sets are identical. The CU-691/U provides for the operation of four transmitters or receivers, whereas the CU-692/U accommodates only two. Both multicouplers are tuned manually. The CU-691/U is shown in figure 3-44.

Receiving Multicouplers AN/SRA-9 and AN/SRA-12

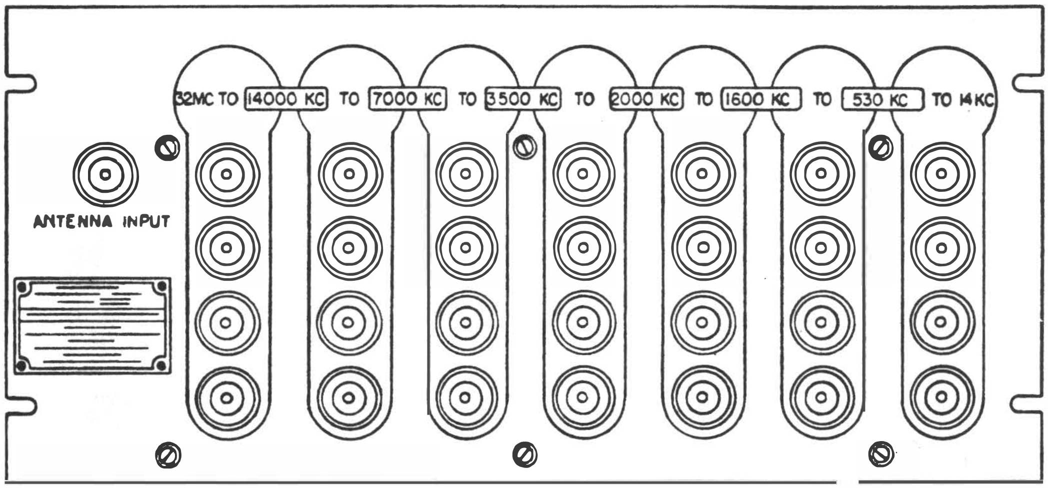
Electrical filter assemblies (multicouplers) AN/SRA-9 and AN/SRA-12 are identical in appearance and function. They are receiving antenna distribution systems that make possible the multiple operation of a maximum of 28 radio receivers from a single antenna. Ordinarily it is preferable, however, to limit the total number of receivers to seven.

The AN/SRA-12 (fig. 3-45) filter assembly provides seven radiofrequency channels in the frequency range from 14 kc to 32 mc. Any or all of these channels may be used independently of any of the other channels, or they may operate simultaneously. Connections to the receivers are made by means of coaxial patch



120.14

Figure 3-44.—VHF-UHF antenna multicoupler CU-691/U.



1.115

Figure 3-45.—Electrical filter assembly AN/SRA-12.

cords, which are short lengths of cable with plugs attached to each end.

A set of nine plug-in type filter subassemblies is furnished with the equipment, but only seven of them may be installed at one time. The seven filters installed are selected to cover the most-used frequency bands.

Receiving Multicoupler SB-346/S

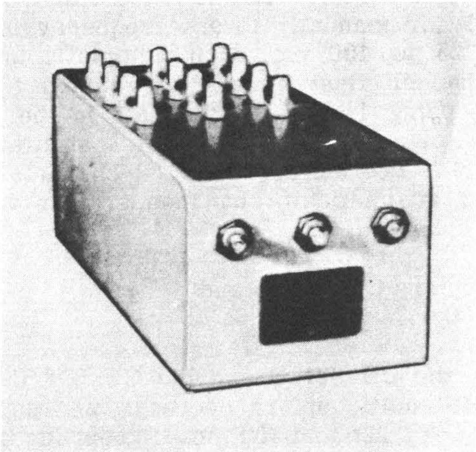
Another receiving antenna multicoupler is the SB-346/S, on view in figure 3-46. This small panel enables operation of 12 receivers from three antennas. Each antenna is utilized by four receivers. Although not as satisfactory an arrangement as the AN/SRA-12, this unit can be installed aboard small ships where available space is limited.

TRANSMITTER AND RECEIVER TRANSFER PANELS

Transmitter and receiver transfer panels are an integral part of every shipboard radio system. They make it possible to connect transmitters and receivers to remote control points located throughout the ship. These transfer panels formerly were of the cumbersome patch cord type, but those currently installed aboard ships are of the switchboard type described here.

Receiver Transfer Switchboard SB-82/SRR

Receiver transfer switchboard, type SB-82/SRR, is shown in figure 3-47. The receiver switchboard has five vertical rows of ten single-throw (ON-OFF) switches that are continuously rotatable in either direction. One side of each switch within a vertical row is wired in parallel with the same sides of the other nine switches within the row. Similarly, the other side of each switch is wired in parallel horizontally with the corresponding sides of each of the other four switches in a horizontal row. This method of connecting the switches permits a high degree of flexibility.



120.15

Figure 4-46.—Receiving antenna multicoupler SB-346/S.

In general, there are more remote stations than radio receivers, hence the audio outputs of five receivers are fed to the five vertical rows, and ten remote stations are connected to the ten horizontal rows. With this arrangement, a selected receiver output is connected to any or all of the remote stations by closing the proper switch(es). When one switchboard is inadequate for accommodating all of the receivers and remote stations installed in a ship, several of these switchboards are mounted together and interconnected so that they form a bank of switchboards.

The knob of each switch is marked with a heavy white line to provide visual indication of whether the switch is in the ON or OFF position. Switchboards always are installed with the line positioned vertically when the switch is open (off). To further standardize all installations, receivers usually are connected to the vertical rows of switches, and remote stations are connected to the horizontal rows.

Identification of the receivers and remote stations is engraved on the laminated bakelite label strips fastened along the top and left edges of the panel front.

Receiver Transfer Switchboard
SB-973/SRR

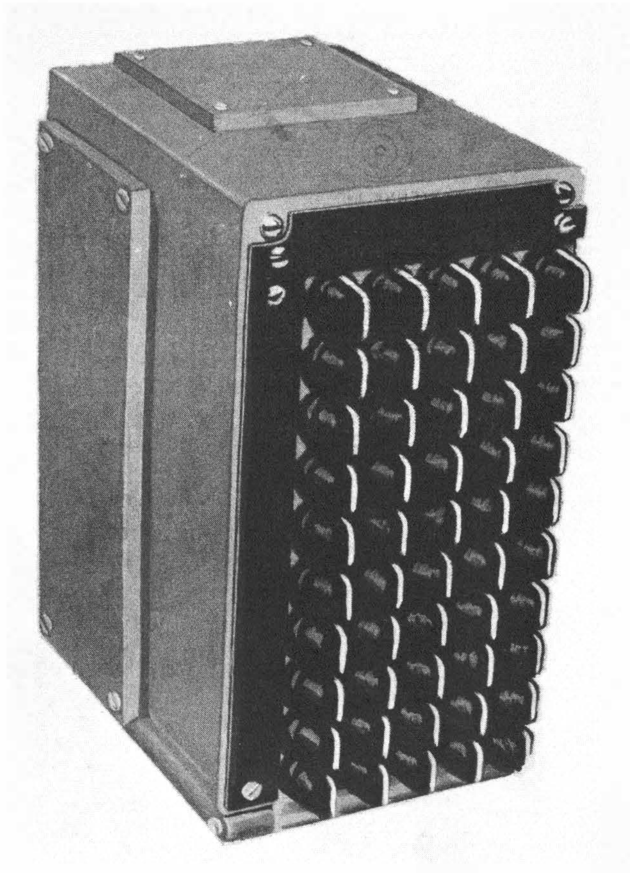
A recent model receiver transfer switchboard is the SB-973/SRR, illustrated in figure 3-48. This switchboard contains 10 seven-position rotary selector switches. Each switch or operating knob relates to a remote control station. Switch positions one through five relate to receivers.

Position X on each switch serves to transfer the remote control stations connected to the original switchboard to the corresponding switches in additional switchboards. In this manner, any number of receivers can be connected to the ten remote control stations. An additional switchboard is needed for each five additional receivers.

Switchboards providing facilities for additional remote control stations are mounted in vertical sequence, whereas those containing additional receivers are mounted in horizontal sequence.

Transmitter Transfer Switchboard SB-83/SRT

Transmitter transfer switchboard, type SB-83/SRT, is shown in figure 3-49. The

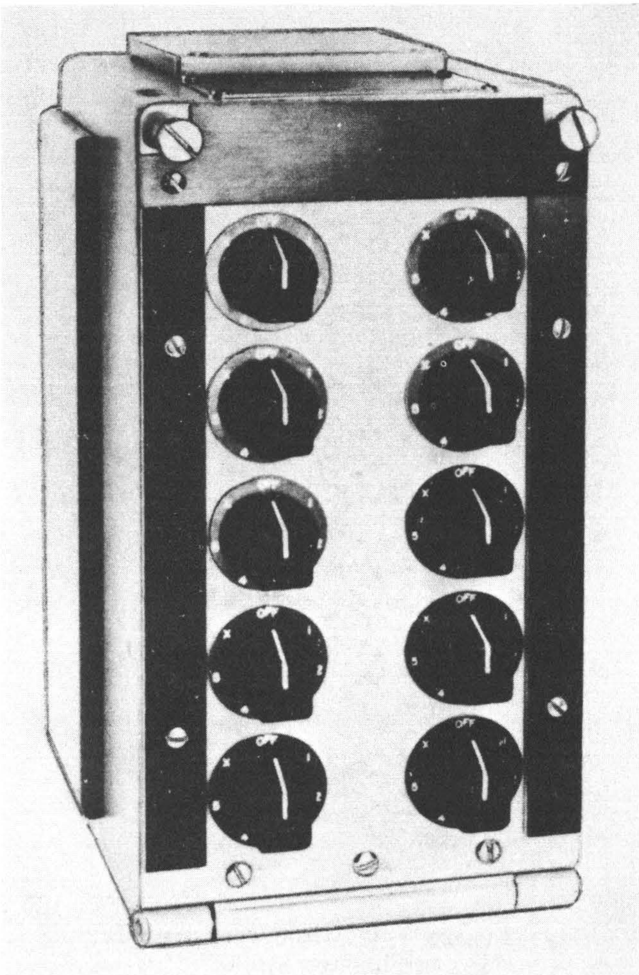


36.69

Figure 3-47.—Receiver transfer switchboard SB-82/SRR.

switchboard has five vertical rows of ten switches. Radio transmitters are wired to the five vertical rows; remote stations are connected to the ten horizontal rows. Switches are off when the white lines on the knobs are vertical.

Although the switches are of the continuously rotatable type, most switchboards are equipped with a spring-loaded, mechanical interlock that allows the switches to be closed by turning the knobs in a clockwise direction. The switches then are opened by turning the knobs counterclockwise. The interlock also prevents additional switches in each horizontal row from being closed when any one of the five switches in that row is closed already. This arrangement prevents serious damage that is certain to result from two or more transmitters feeding a single remote-control station at the same time.



120.16
Figure 3-48.—Receiver transfer switchboard SB-973/SRR.

By wiring several of these boards together, facilities are available for transferring any transmitter to any or all remote control stations.

Transmitter Transfer Switchboard SB-863/SRT and SB-988/SRT

The models SB-863/SRT and SB-988/SRT transmitter transfer switchboards are replacing the SB-83/SRT in shipboard installations. Except for their transmitter-handling capacity, these two newer switchboards are identical. The SB-863/SRT (fig. 3-50) handles up to 19 transmitters, whereas the SB-988/SRT (not illustrated) handles only 6.

Both of these switchboards have 10 rotary selector switches in two vertical columns. Each rotary switch corresponds to a remote-control station, and each switch position either corresponds to a controlled transmitter or serves to transfer the remote station to an adjacent switchboard. The remote station assigned each rotary switch and the transmitter assigned each switch position are identified on the bakelite plates attached to the front of each switchboard.

REMOTE-CONTROL UNITS

To operate radio transmitters from remote locations requires the use of remote-control units. Most of these units are used as radiophone units. (RPUs). They provide for energizing and deenergizing transmitters, for

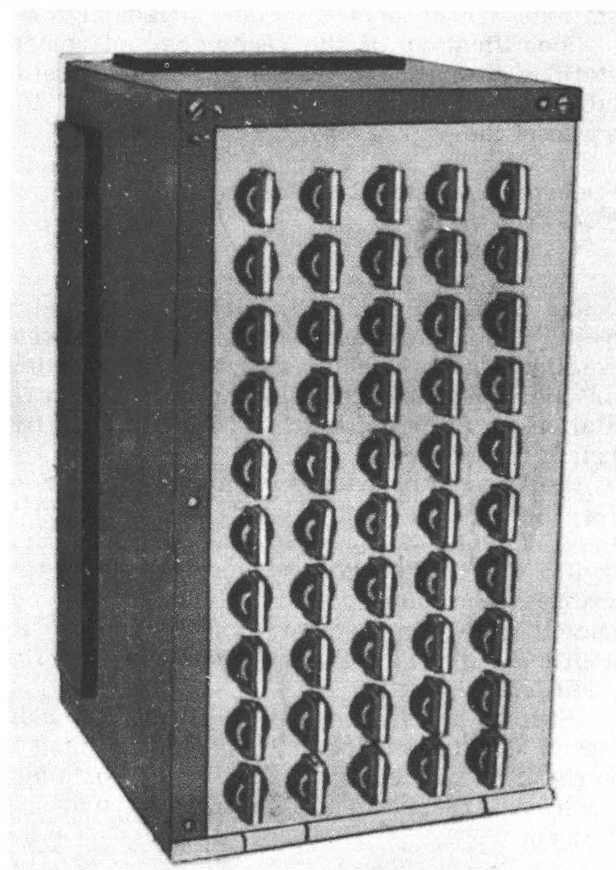


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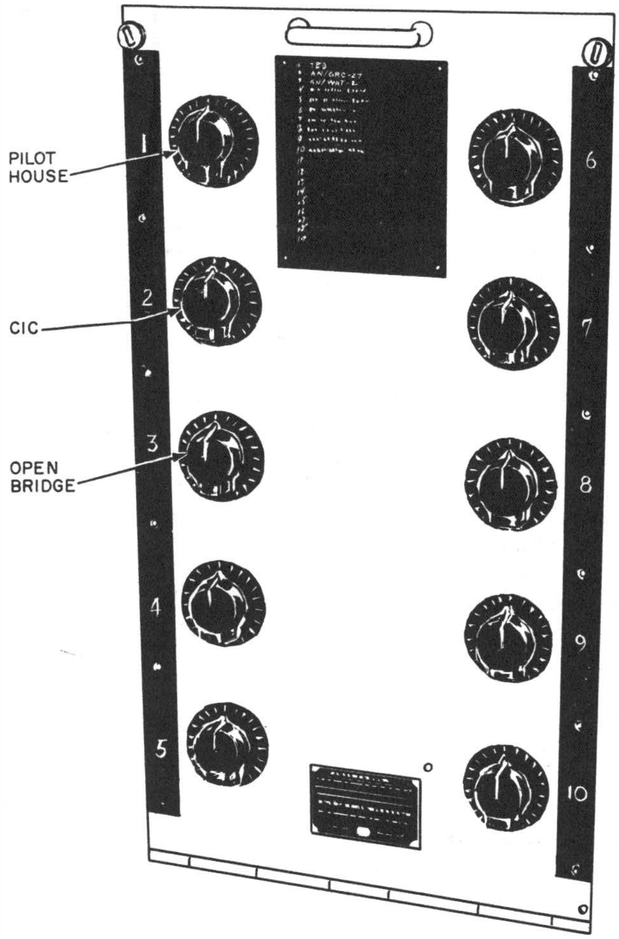
Figure 3-49.—Transmitter transfer switchboard SB-83/SRT.



70.64
Figure 3-50.—Transmitter transfer switchboard SB-863/SRT.

connecting microphones, handsets, chestsets, telegraph keys, and headphones, and for controlling the audio output level (volume) of radio receivers. Some units also enable remote selection of radio channels when they are utilized to control multichannel transmitters and receivers (such as the model AN/GRC-27).

Radio Set Control C-1138( )/UR

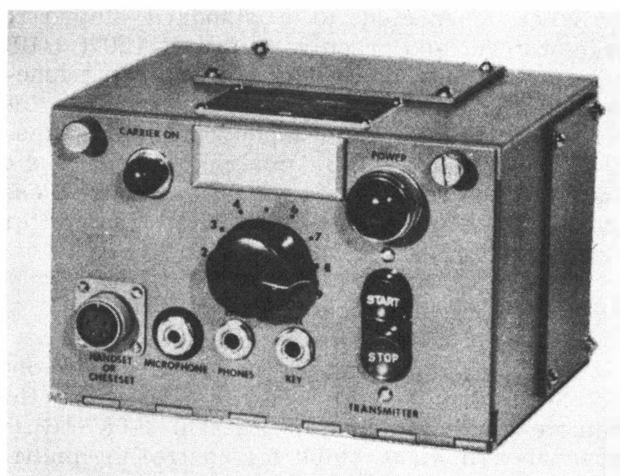
Radio set control C-1138( )/UR (fig. 3-51) is a remote-control unit designed for installation in protected locations, as in the CIC or pilothouse. This unit contains a start-stop switch for turning a transmitter on or off, jacks for connecting a handset or chestset, microphone, headphones, or telegraph key, a volume control for the headphone or loudspeaker, and indicator lamps for transmitter-on (power) and carrier-on indications. Although provisions are made for CW operation, the unit seldom is used for this purpose. In most instances it is utilized for radiotelephone communications.

By means of transmitter and receiver transfer switchboards, as many as four of these remote-control units may be connected to the same transmitter or receiver. This arrangement is utilized when it is necessary that a radio channel be controlled from more than one remote location.

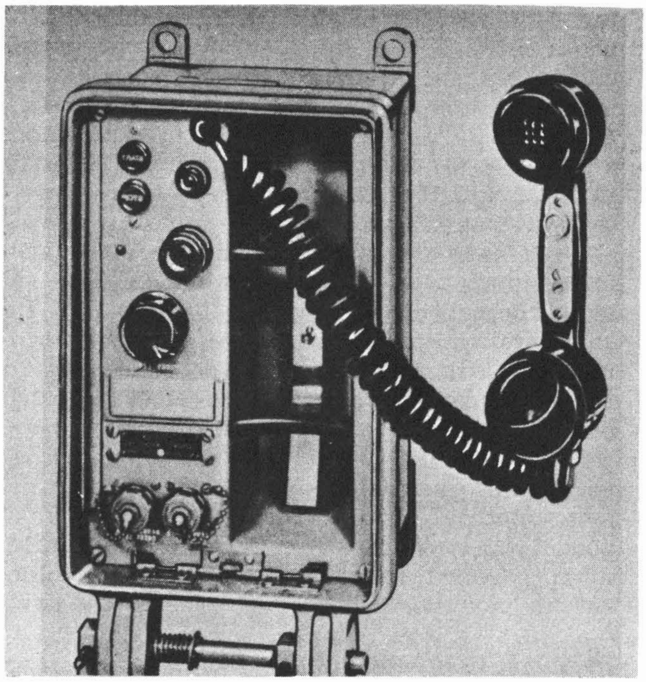
The model C-1138( )/UR is an improved version of the older and slightly larger remote-control unit NT-23500, still in service aboard many ships. The two units are similar in appearance and function, hence the older set is not described nor illustrated here.

Radio Set Control C-1207( )/UR

Radio set control C-1207( )/UR, shown in figure 3-52, is designed for installation in areas that are exposed to the weather. Access to its controls is obtained by opening the front cover, which is hinged to the unit. The controls, consisting of a handset, a transmitter start-stop switch, and a receiver volume control, are mounted on the front panel of the unit. Also



7.40.2A
Figure 3-51.—Radio set control C-1138( )/UR.



7.40

Figure 3-52.—Radio set control C-1207( )/UR.

mounted on the panel are two indicator lamps that provide visual indication of whether the transmitter power and carrier-on circuits are energized or deenergized, and two jacks for connecting a chestset and a set of headphones.

When connected to a standard shipboard transmitter and receiver, the C-1207( )/UR permits remote control of the following functions: (1) energizing and deenergizing the transmitter, (2) voice modulating the transmitter input, and (3) controlling the audio output of the receiver. As many as four of these units may be connected to the same transmitter and receiver.

Remote-Control/Indicator Unit NT-23496

Although designed for use with a now obsolete transmitter-receiver combination, the remote-control/indicator unit NT23496 still is used aboard many ships for controlling multichannel transmitters and receivers. The unit, illustrated in figure 3-53, is capable of handling a transmitter and two receivers simultaneously. This arrangement permits guarding two radio channels, with the transmitter available for use on either channel. By operating an equipment selector switch and a dial-type channel selector, the operator can select any of ten preset radio channels on any multichannel transmitter or receiver controlled by the unit. A set of the usual remote controls is provided for each equipment operated by the remote-control unit.

Control Panel Telegraph Key SB-315B/U

Control panel telegraph key SB-315B/U (fig. 3-54) contains the components and circuitry necessary to control the operation of a radio transmitter from a remote position. Located on the plastic control panel are (1) a toggle switch for turning the transmitter on or off, (2) an indicator light that glows red when the transmitter is on, (3) a telegraph key that provides a means for keying the transmitter, and (4) a key jack that provides for an auxiliary telegraph key.

This combination control panel and telegraph key is used in conjunction with a CW transmitter for the purpose of transmitting messages in international Morse code.

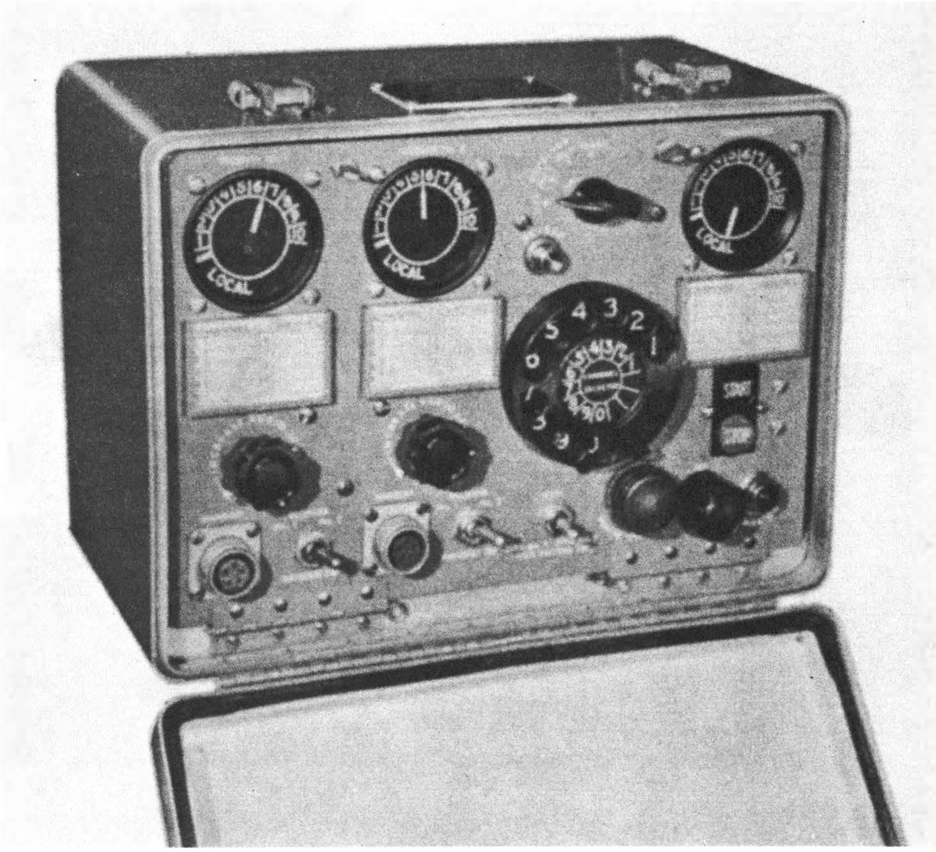
LOUDSPEAKERS AND AMPLIFIER UNITS

In certain instances, utilizing loudspeakers and their associated audioamplifier units to monitor radio communication channels is more advantageous than using headphones. When a ship is involved in a rapidly changing tactical situation, for example, information received over the tactical voice circuits is of vital concern to most bridge and CIC personnel. By placing these circuits on loudspeakers, all incoming information is available instantly to everyone within hearing distance of the loudspeakers.

Four equipments currently installed aboard ships for use in monitoring voice (or CW) communication channels are the audioamplifier unit AM-215( )/U, loudspeakers NT-49546 and LS-195/U, and amplifier-speaker unit NT-49545.

Audioamplifier Unit AM-215( )/U

The AM-215( )/U (fig. 3-55) is an audioamplifier unit that amplifies low-level audio signals for reproduction through loudspeakers. As many as five radio receivers and five loudspeakers can be connected to this unit, but only



20.17

Figure 3-53.—Remote-control/indicator unit NT-23496.

one signal is amplified and reproduced at any one time. The signal to be amplified and reproduced is selected by means of a channel selector switch located on the front of the amplifier unit. Other controls on the unit's front panel are a volume control, a power on-off switch, and a power-on indicating lamp. Usually these units are used in conjunction with the NT-49546 loudspeaker, described next.

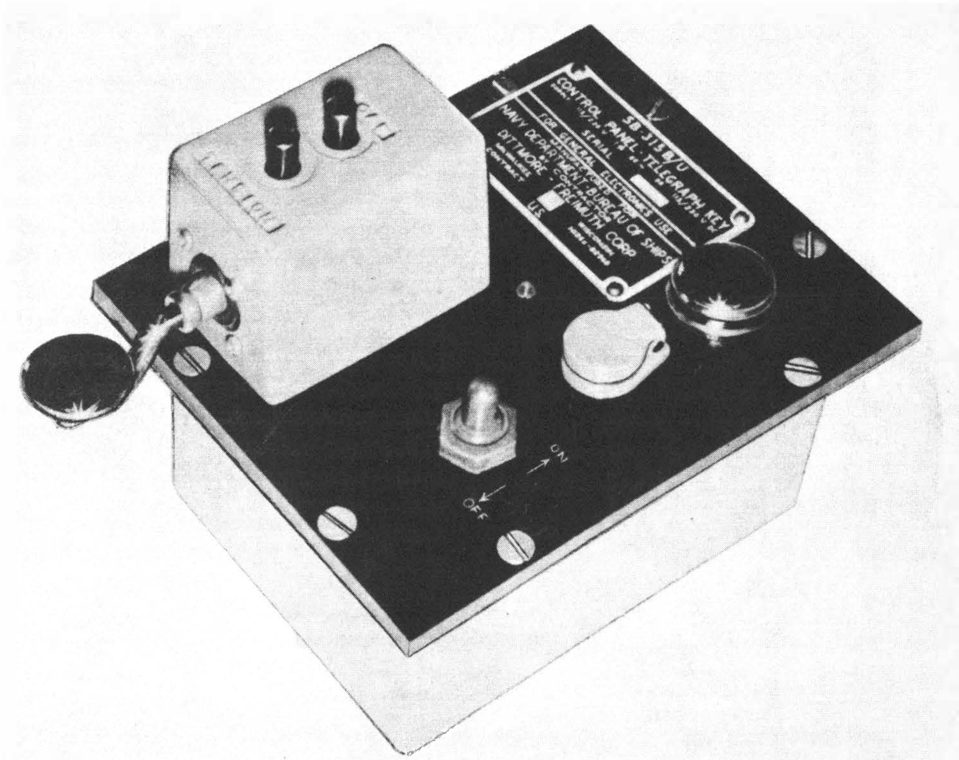
Loudspeaker NT-49546

Although it is a general-purpose communication loudspeaker, the NT-49546 (fig. 3-56) is used principally for reproducing voice transmissions. The unit can be connected directly to a radio receiver, or it can be operated through an audioamplifier unit, such as the AM/215( )/U. Best results are obtained with the audioamplifier unit.

The loudspeaker, designed as a watertight and shockproof unit for installation in exposed areas, also is used extensively in such spaces as the pilothouse and CIC. It usually is mounted on the bulkhead above or near its controlling amplifier unit.

Loudspeaker LS-195/U

Another general-purpose communication loudspeaker is the LS-195/U, shown in figure 3-57. Like the NT-49546, this unit is used mainly for monitoring voice channels. Unlike the NT-49546, however, the unit cannot withstand prolonged exposure to the weather; it is designed for installation in protected areas only. In addition, it has a front panel volume control and is transportable, whereas the NT-49546 has a preset, covered volume control and is mounted permanently.



20.18

Figure 3-54.—Control panel telegraph key SB-315B/U.

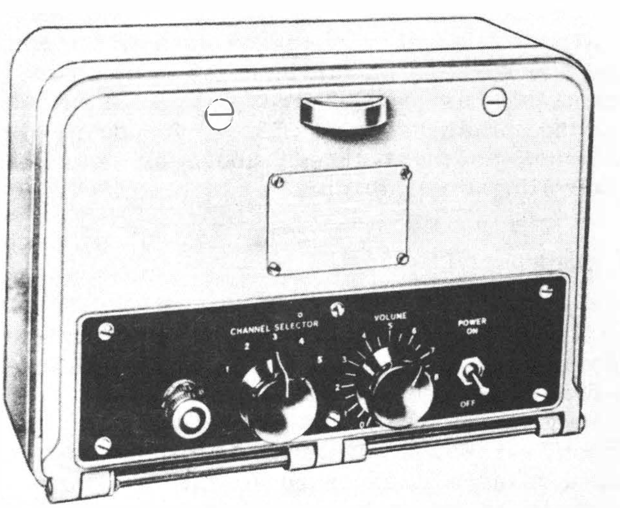


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Figure 3-55.—Audioamplifier unit AM-215( )/U.

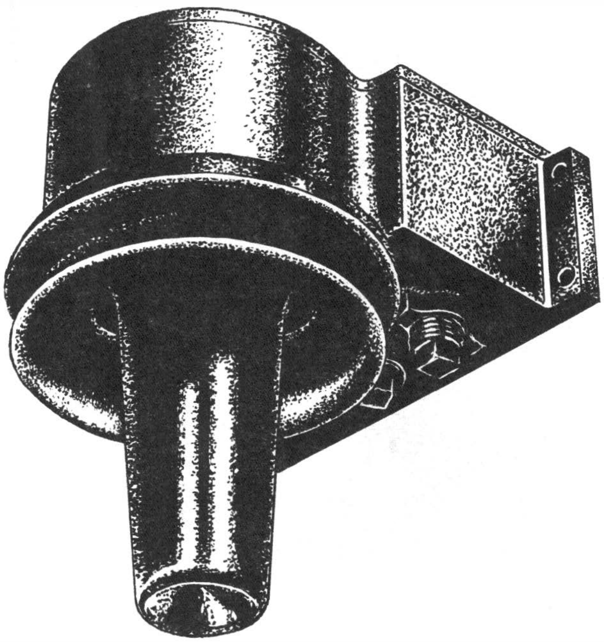
Amplifier-Speaker Unit NT-49545

The Navy type 49545 amplifier-speaker unit, seen in figure 3-58, is a combination audioamplifier and loudspeaker assembly. Its reproduction qualities are considered good. Aboard most ships, it is installed in berthing and messing compartments as an entertainment loudspeaker.

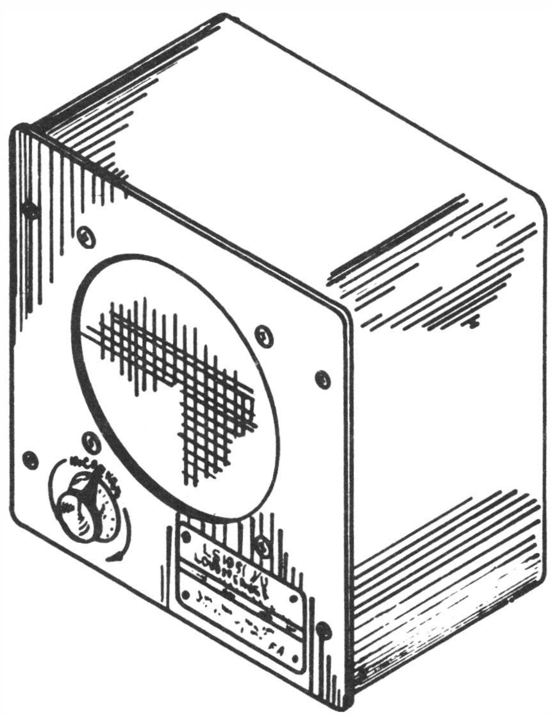
All operating controls of the unit are located on the front panel. They consist of a power on-off switch, a power-on indicating lamp, a tone control, a volume control, and a channel selector switch that permits selection of up to five different entertainment (or communication) channels.

FREQUENCY METERS

Frequency meters (standards) are instruments for tuning transmitters/receivers and determining the frequency of received signals.



74.71.2
Figure 3-56.—Loudspeaker NT-49546.

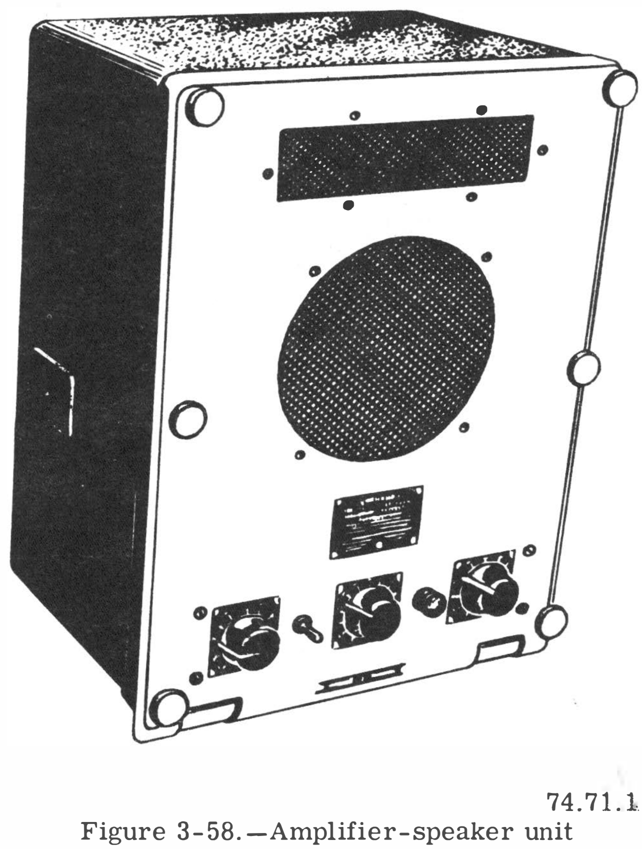


120.20
Figure 3-57.—Loudspeaker LS-195/U.

In the past, few transmitters could be tuned without a frequency meter. With the current trend toward equipment that utilizes automatic frequency selection and control, the frequency meter is used more as a test equipment than as a required equipment for the operational tuning of transmitters. Although test equipment, as such, is not described in this text, frequency meters are included because they are necessary for the proper tuning of some of the old-type transmitters still in service aboard numerous ships.

Frequency Meter IM-( )

Several models of the IM-( ) frequency meter have been built. Except for the power supply and some minor mechanical differences, these models are similar. The model IM-18 frequency meter, shown in figure 3-59, is representative of the IM series. It offers a simple, accurate



74.71.1
Figure 3-58.—Amplifier-speaker unit NT-49545.

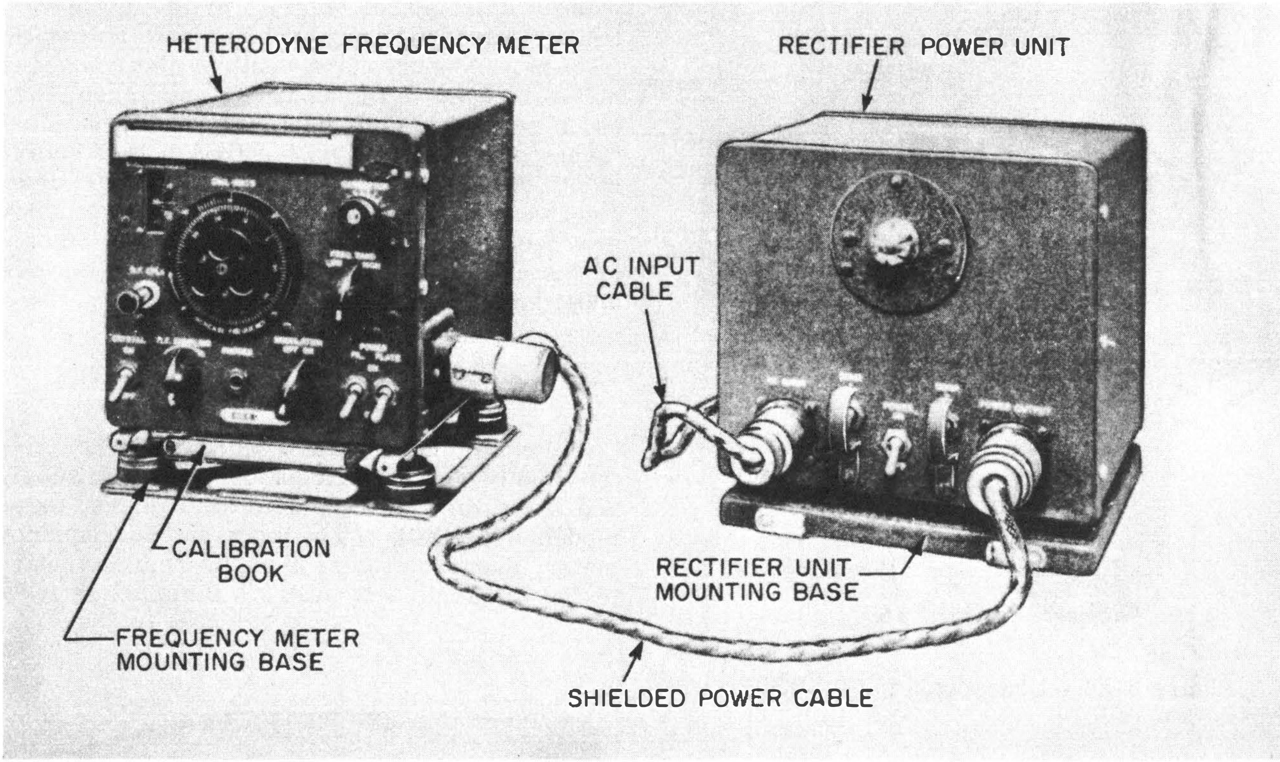


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Figure 3-59. —Frequency meter model IM-18.

means of adjusting transmitters and receivers to and desired frequency in the range from 125 kc to 20 mc. It serves both as a heterodyne frequency meter for transmitter adjustment and as a signal source for receiver calibration. It also is used for measuring the frequency of received radio signals.

The IM-18 is accurate within .02 percent in the 125- to 2000-kc band, and within .01 percent in the 2000-kc to 20-mc band.

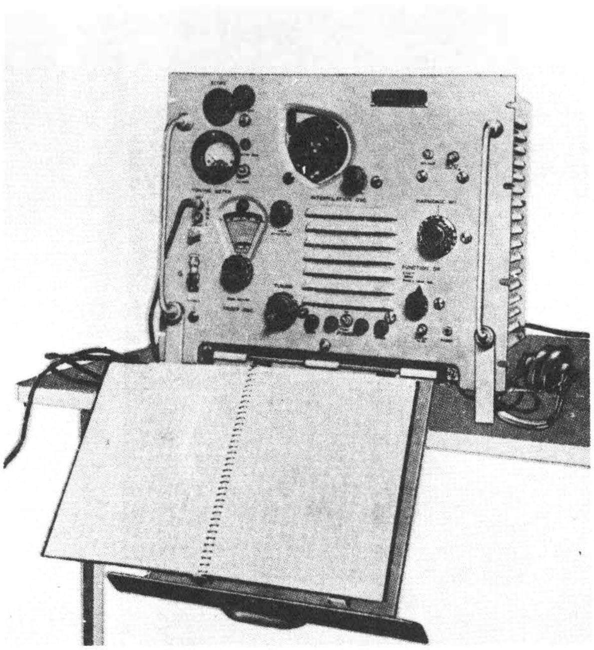
Frequency Meter AN/URM-82

One of the frequency meters now replacing older models is AN/URM-82, illustrated in figure 3-60. The AN/URM-82 is a precision instrument for measuring frequencies in the range of 100 kc to 20 mc. It is used also to tune radio transmitters to an accuracy of .001 percent. Features of the AN/URM-82 include a blinker light, in addition to earphones, to provide visual as well as aural indications of correct frequency settings. A built-in cathode ray tube aids in adjusting the frequency meter to the desired frequency.

Frequency Meter AN/USM-29

Frequency meter AN/USM-29 (fig. 3-61) is designed for precise generation or measurement of frequencies in the range of 15 kc through 30 mc. Output frequencies generated by the frequency meter are controlled by eight dials arranged on a decade basis. The value set up on the dials is the frequency generated by the equipment. The generated signal is accurate to within .0001 percent of the value selected on the dials.

When measuring a signal of unknown frequency, the AN/USM-29 compares the unknown frequency against the accurate, known frequency it is generating. It presents the results of the comparison both aurally and visually by means of headphones, an indicating meter, and a cathode ray tube.



76.30

Figure 3-60.—Frequency meter AN/URM-82.

Frequency Standard AN/URQ-9

One of the latest frequency standards is the AN/URQ-9, pictured in figure 3-62. This highly stable frequency standard is designed for continuous-duty use aboard ships and at shore facilities. It has three fixed output frequencies: 5 mc, 1 mc, and 100 kc.

Because it is intended as a frequency standard against which other frequency-generating equipment can be compared, the AN/URQ-9 is energized and calibrated at special calibration laboratories. Once it is placed in operation and is calibrated properly, the frequency standard must not be turned off. Any interruption in its operation will cause a change in its output frequencies. Hence, the equipment is transferred to the using activity while still operating.

A battery, which is built into the equipment, maintains operation during the time the frequency standard is in transit. It also supplies power to the unit in the event of power failure aboard ship. When fully charged, the battery is capable of operating the equipment for approximately 2 hours.

TRAINING DEVICES

For shipboard training purposes, the availability of the actual radio equipment makes it unnecessary to maintain a large number of special training devices. Most radio equipment can be arranged to simulate actual operating conditions. Such an arrangement, moreover, provides a more realistic training situation than can be attained by using special equipment.

One training device available for use in training radiotelegraph operators is the model OAH-4 code practice equipment. (See fig. 3-63.) The equipment provides facilities for as many as seven operators at one time, and it can be used for both sending and receiving international Morse code. The operators may be grouped into one, two, or three communication nets. Such grouping permits the exchange of messages between operators under realistic operating conditions.

ADDITIONAL RADIO EQUIPMENT

The radio equipment described in the preceding text is mostly of the general-purpose communication type. Additional and more specialized types of radio equipment are discussed in the following chapter, as well as in chapter 9.

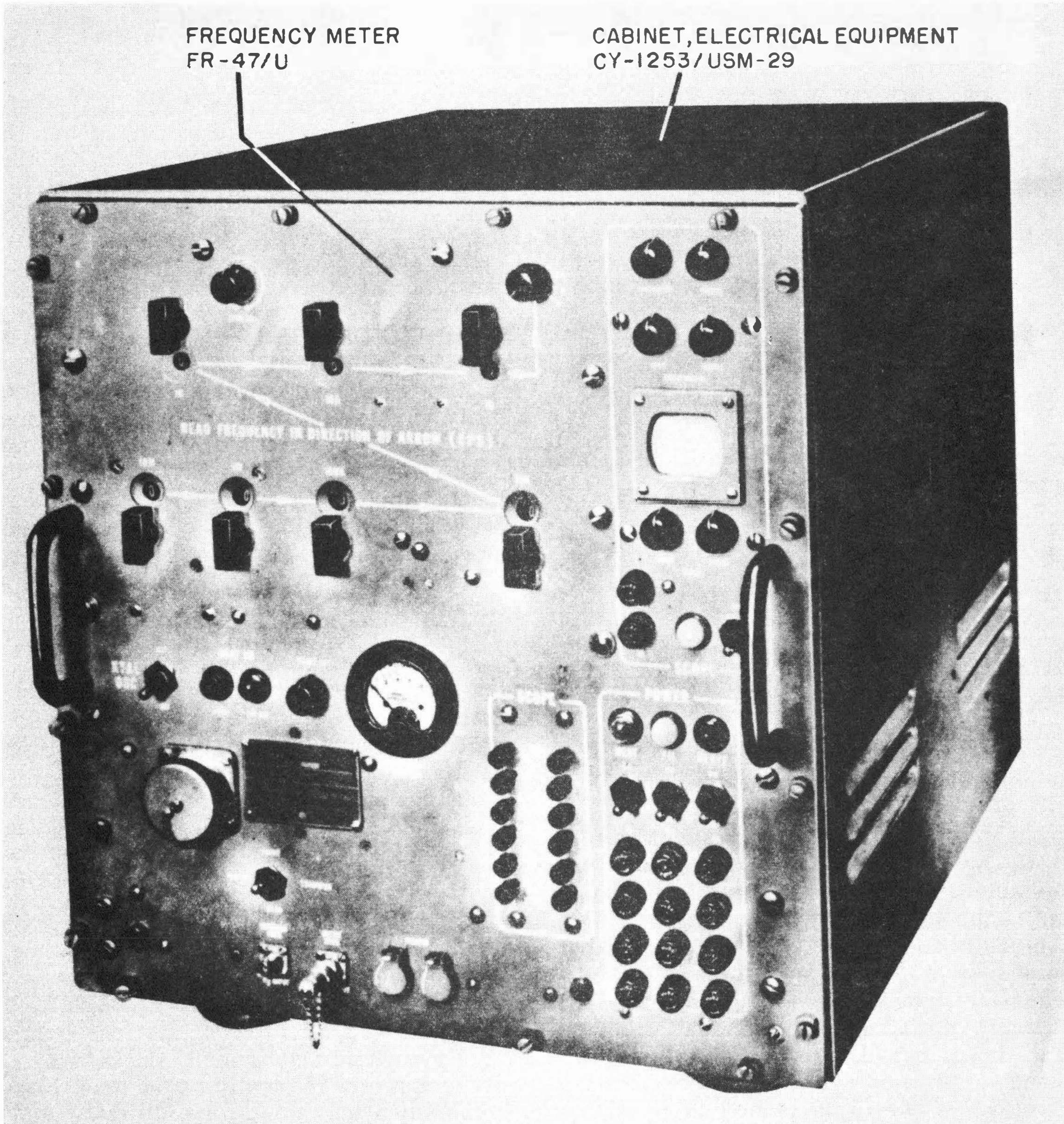


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Figure 3-61.—Frequency meter AN/USM-29.

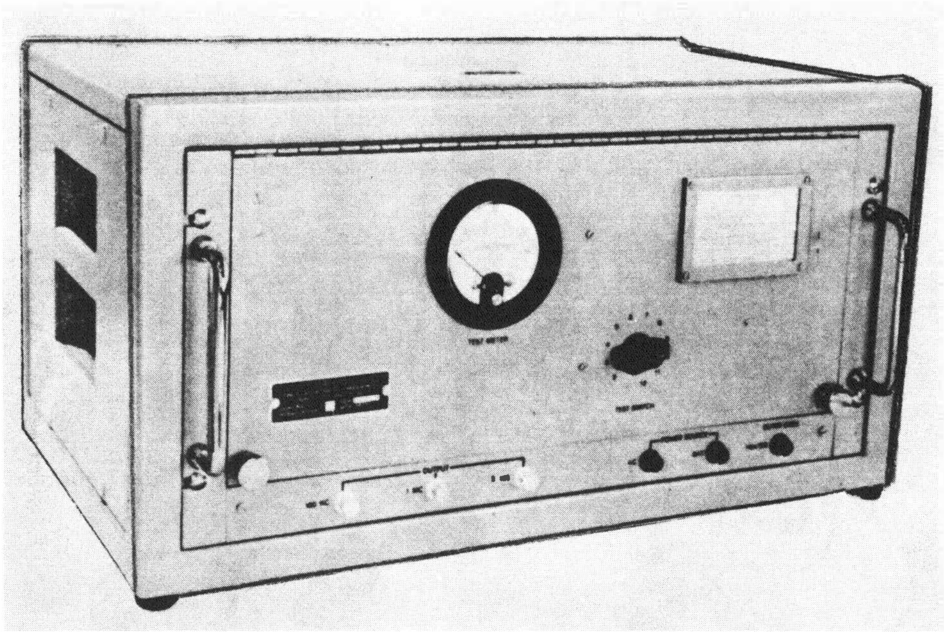

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Figure 3-62.—Frequency standard AN/URQ-9.

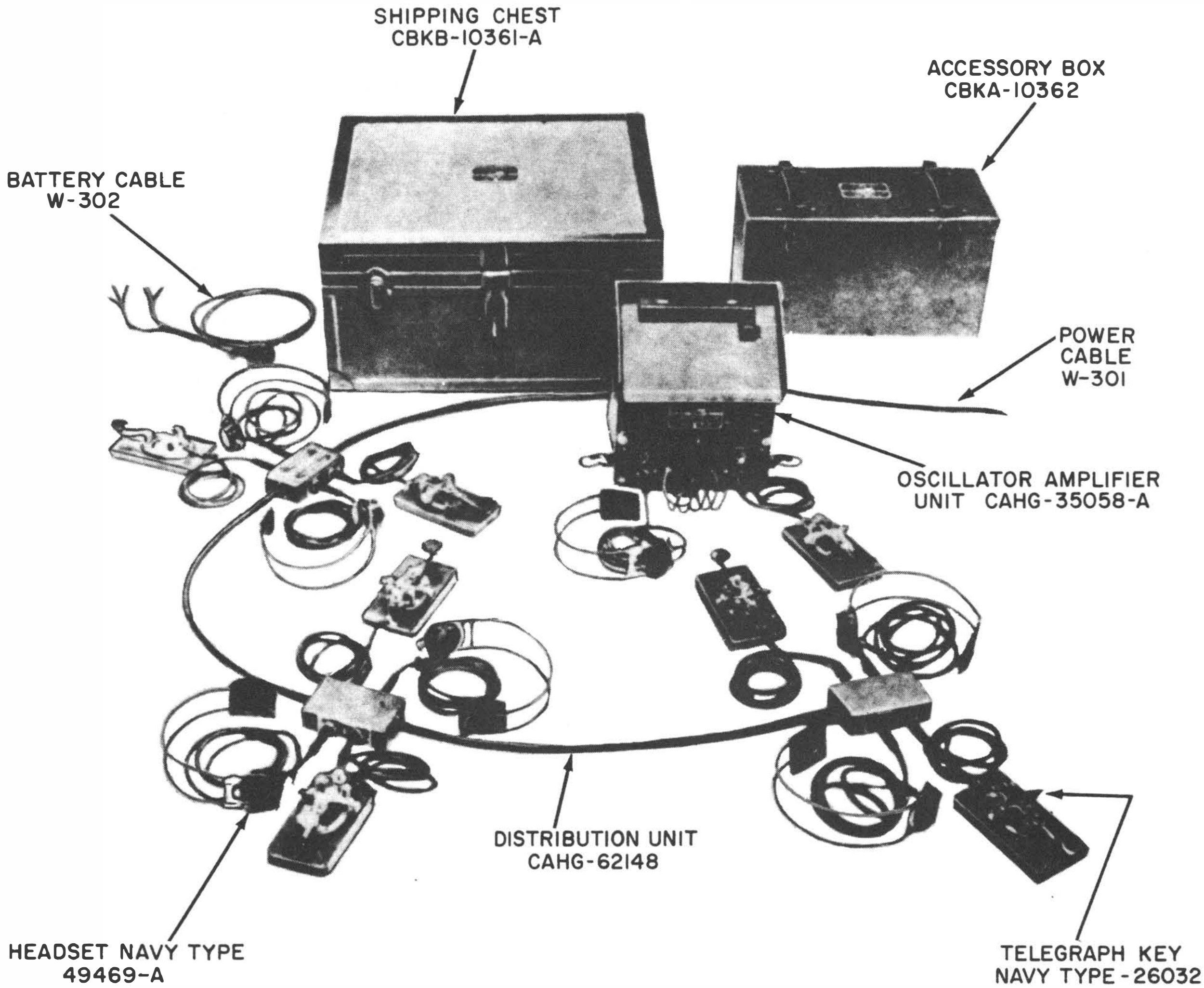

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Figure 3-63.—Code practice equipment model OAH-4.

CHAPTER 4

TELETYPE AND FACSIMILE

The teletypewriter is little more than an electrically operated typewriter. The prefix "tele" means "at a distance." Coupled with the word "typewriter" it forms a word meaning "typewriting at a distance." By operating a keyboard similar to that of a typewriter, signals are produced that cause the teletypewriter to print the selected characters (letters, figures, and symbols). The characters appear at both sending and receiving teletypewriters, and one teletypewriter actuates as many machines as may be connected together.

To see how intelligence is sent by teletypewriter, let us consider one of the simpler devices for electrical communication: the manual telegraph circuit. In this series or loop-connected circuit, shown in figure 4-1, we have a telegraph key, a source of power (called battery), a telegraphic sounder, and a movable sounder armature. If the key is closed, current flows through the circuit and the armature is attracted to the sounder by magnetism. This action causes a clicking sound. When the key is opened, current stops flowing and the armature returns to its original position. With these two electrical conditions of the circuit—closed and open—it is possible, by means of a code, to transmit intelligence.

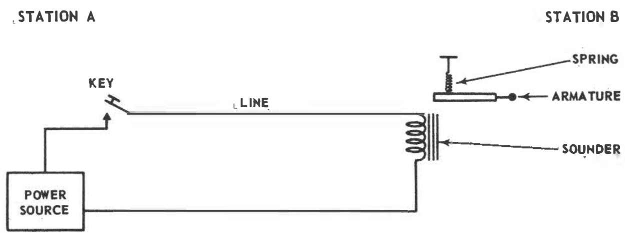
The telegraph circuit in figure 4-1 can be converted to a simple teletypewriter circuit by substituting a transmitting teletypewriter for the key at station A, and a receiving teletypewriter for the sounder at station B. This arrangement is shown in figure 4-2. Both circuits operate on the same principle. In the teletypewriter circuit each current and no-current interval consumes a set period of time, whereas in the telegraph circuit these time intervals vary with the code being transmitted.

If a teletype signal could be drawn on paper, it would resemble the marks and spaces in figure 4-3. Shaded areas show intervals during which the circuit is closed (called marking), and the blank areas show the intervals during which the circuit is open (called spacing). The signal contains a total of seven units. Five of these are numbered, and are called intelligence units. Various combinations of marking and spacing in the intelligence units represent different characters. The first and last units of the signal, labeled start and stop, are named after their functions: the first starts the signal and the last stops it. These are a part of every teletype code character, and are the means by which the teletypewriter machines and signals are kept in synchronization with each other.

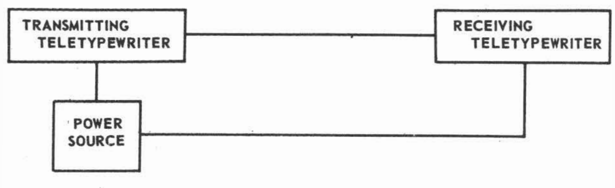
When the sending and receiving teletypewriters are wire-connected, the exchange of intelligence between them is direct. But when the teletypewriters are not joined by wire, operation is more complex. Direct-current mark and space intervals cannot be sent through the air. The gap between the machines must be bridged by radio.

RADIOTELETYPE (RATT) SYSTEMS

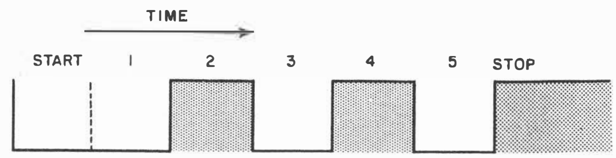
The Navy uses two basic radioteletype systems aboard ship. One, the tone-modulated system for short-range operation, is similar to the familiar a-m radio. The other, the carrier frequency shift (CFS) system for long-range



1.196
Figure 4-1.—Manual telegraph circuit.



1.200
Figure 4-2.—Simple teletypewriter circuit.



1.197
Figure 4-3.—Mark and space signals in the teletypewriter character R.

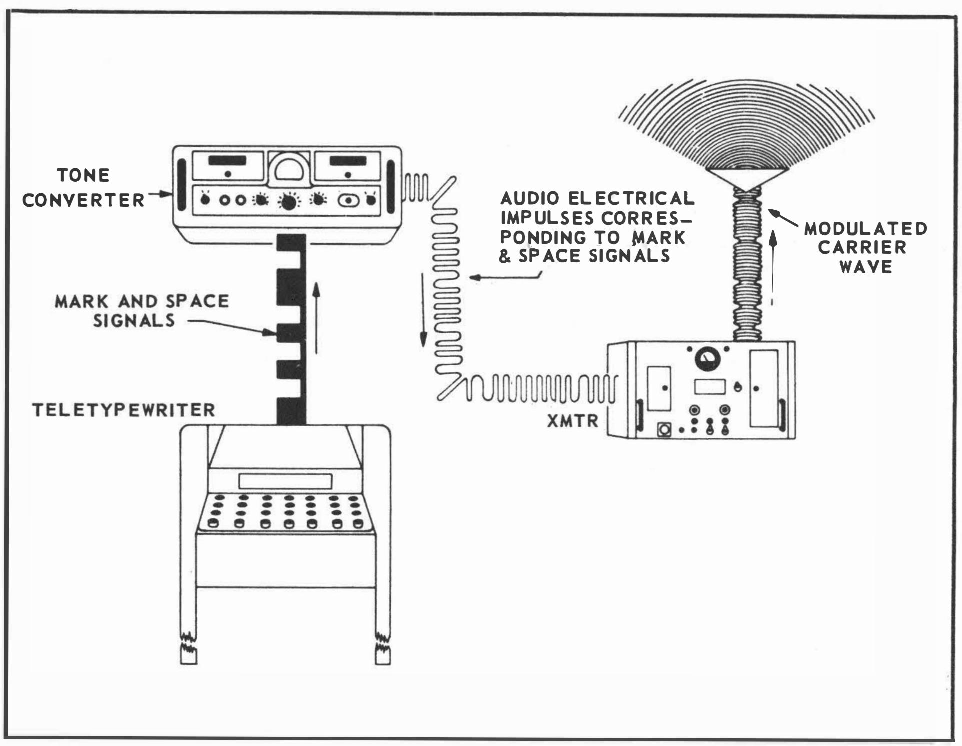
operations, is similar to the standard f-m radio.

TONE-MODULATED SYSTEM

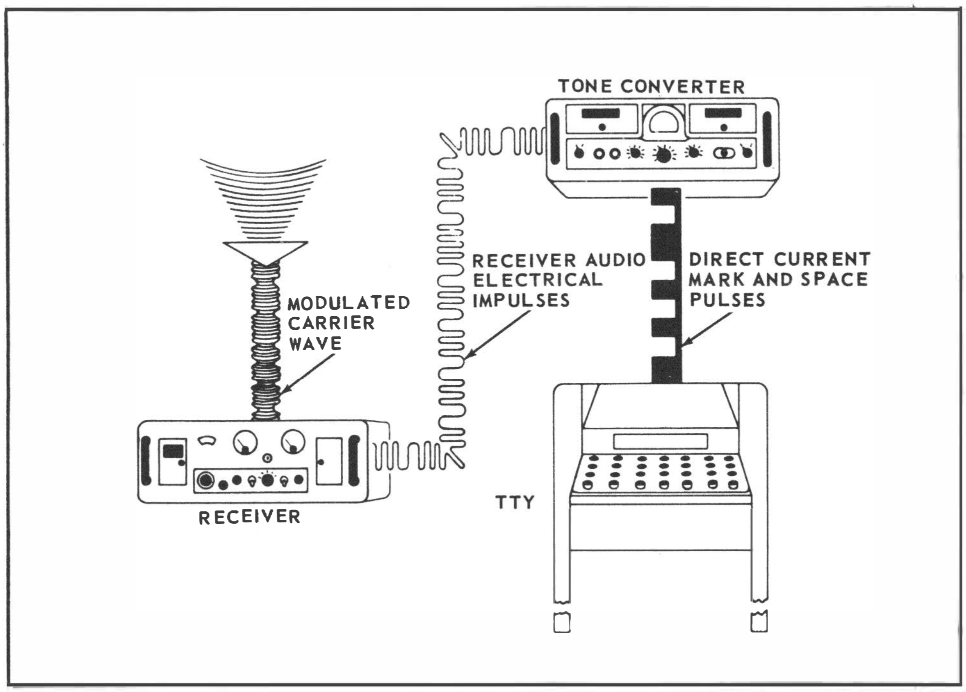
To transmit messages by the tone-modulated system, a teletypewriter, a tone converter, and a transmitter are used. The teletypewriter sends out a d-c signal. The signal is changed to audio tones in the tone converter. The transmitter impresses the audio tones on the carrier and sends out a tone-modulated carrier wave (fig. 4-4).

To receive messages with the tone-modulated system, a radio receiver, a tone converter, and a teletypewriter are required. The tone-modulated carrier wave enters the receiver, which extracts the signal intelligence and sends the audio tones to the tone converter. The converter changes the audio tones into d-c mark and space pulses for the teletypewriter (fig. 4-5).

In practice, the same tone terminal is used for the receiving and the sending circuits



1.228
Figure 4-4.—Tone-modulated system transmit.



1.229

Figure 4-5.—Tone-modulated system receive.

inasmuch as it contains both a transmit keyer unit and a receive converter unit.

CARRIER FREQUENCY SHIFT (CFS) SYSTEM

At the transmitting end of the long-range CFS system are a teletypewriter, a transmitter, and a frequency shift keyer unit. The keyer unit is built into the newer transmitters, but in some older systems it is a separate equipment. When the teletypewriter is operated, the d-c mark and space signals are changed by the keyer unit into frequency shift intervals. The frequency shift intervals are transmitted as carrier frequency shift signals (fig. 4-6).

On the receiving side of the long-range system are a receiver, a frequency shift converter, and a teletypewriter. When the carrier frequency shift signal enters the receiver, it is detected and changed into a corresponding frequency-shifted audio signal. The audio output of the receiver is fed to the converter, which changes the frequency-shifted audio signal into d-c mark and space signals (fig. 4-7).

In both the tone-modulated system and the carrier frequency shift system, all teletypewriter signals pass through the teletypewriter panel that controls the looping current in all the circuits. As illustrated in figure 4-8, the teletypewriter panel integrates the tone-modulated and the carrier frequency shift systems. It provides every possible RATT interconnection available on board ship. This operational flexibility gives maximum efficiency with the fewest circuits and the least amount of equipment in the Navy's compact RATT systems afloat.

TELETYPE EQUIPMENT

Because of the increasing variety of teletype equipment installed aboard ship, it is impractical to describe every piece of equipment you are likely to encounter. The equipment discussed in the ensuing paragraphs, however, is representative of the types commonly employed in shipboard installations. In some instances, this same equipment may be designated by nomenclature different from that given in this text. But, in most of these instances, this variance in nomenclature merely indicates a modification of the basic equipment described herein.

TELETYPEWRITER SETS

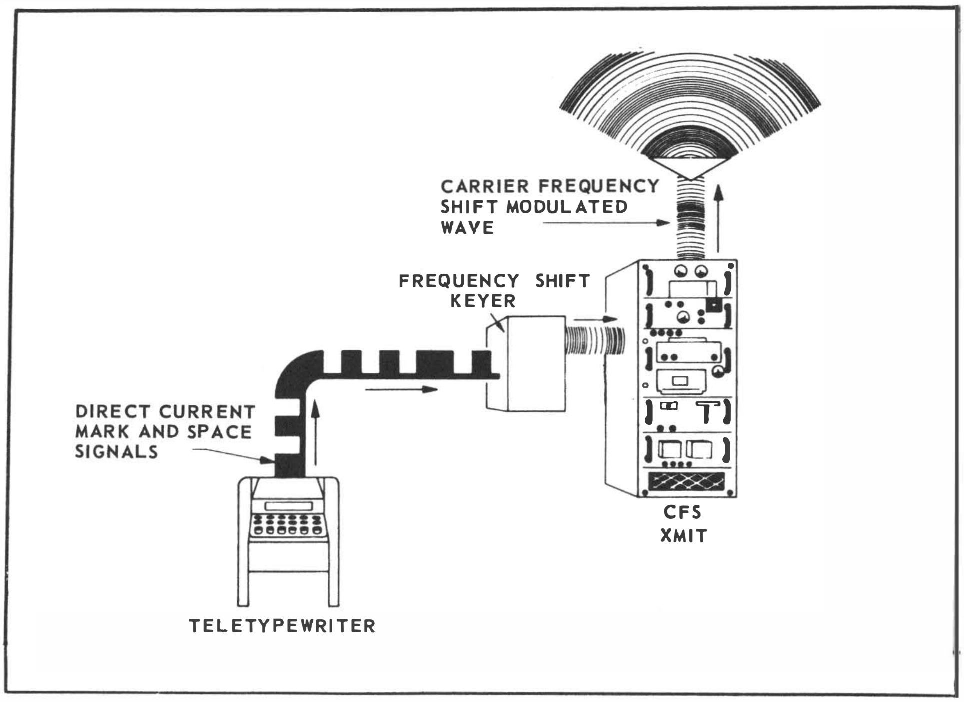
Most of the teletypewriter sets used by the Navy belong to the model 28 family of teletypewriter equipments. The model 28 equipments feature light weight, small size, quiet operation, and high operating speeds. They present relatively few maintenance problems, and are suited particularly for shipboard use under severe conditions of roll, vibration, and shock.

Another feature of the model 28 teletypewriters is their ability to operate at speeds of 60, 75, or 100 words per minute. Conversion from one speed to another is accomplished by changing the driving gears that are located within the equipment. The majority of the Navy's teletypewriters presently are operated at 100 words per minute.

Teletypewriters TT-47( )/UG, TT-171( )/UG, and TT-69( )/UG

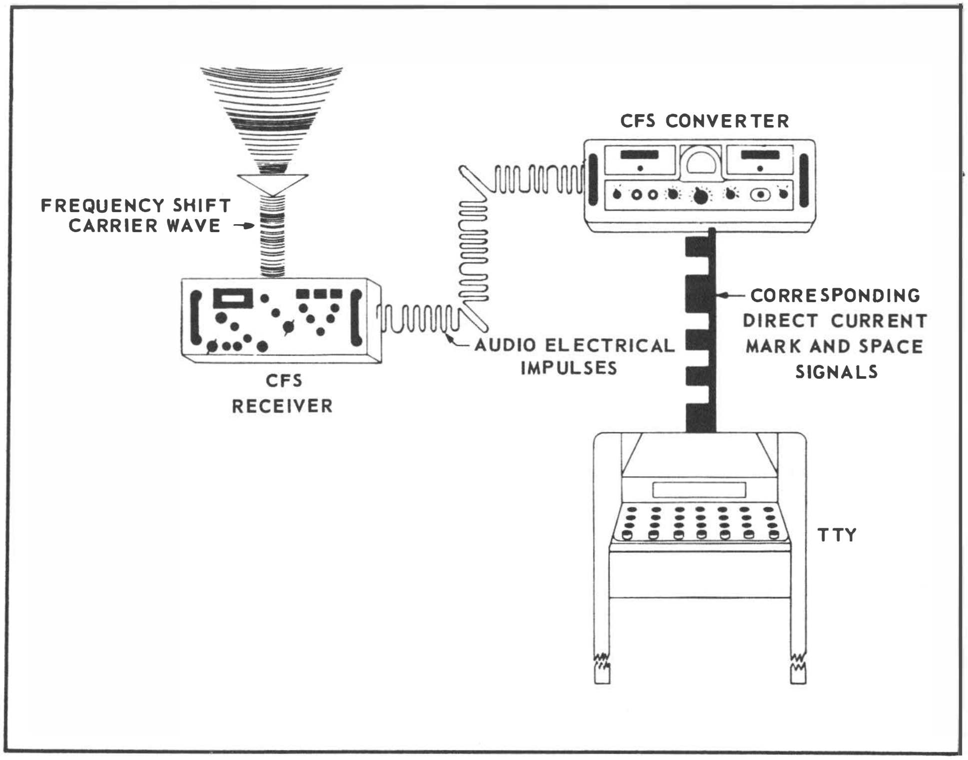
One component of the model 28 line (designated TT-47( )/UG) is the keyboard-sending and page-receiving teletypewriter shown in figure 4-9. The TT-47( )/UG provides means for exchanging typewritten page messages between two or more ships or stations that are similarly equipped and connected by a radio (or wire) circuit. While transmitting from the keyboard, monitor copy is presented by the typing unit. Hence, messages cannot be transmitted and received simultaneously.

By removing the keyboard from the TT-47( )/UG, and thus removing its transmitting capability, it becomes the TT-171( )/UG receive-only teletypewriter. This set is illustrated in figure 4-10. Because it lacks the transmitting capability, the TT-171( )/UG seldom is found aboard small ships. On larger ships, it is used chiefly for copying messages from the fleet broadcast.



1.230

Figure 4-6.—Carrier frequency shift system transmit.



1.231

Figure 4-7.—Carrier frequency shift system receive.

Another example of how a slight modification in a basic equipment changes the nomenclature of a teletypewriter set is the TT-69( )/UG shown in figure 4-11. Except for being installed in a cut-down cabinet, the TT-69( )/UG is identical to the TT-47( )/UG. It serves the same purpose, and it functions in the same manner. Usually, the TT-69( )/UG is installed on small ships where space is a prime consideration.

Teletypewriter Perforator-Reperforator TT-253/UG

An extremely useful teletypewriter equipment is the TT-253/UG shown in figure 4-12. Its chief use is for preparing messages in tape form for transmission by automatic means. When connected to an external circuit, however, the machine also can be utilized to transmit and receive messages.

When a character is typed on the keyboard, its corresponding teletype code is perforated in the paper tape. Simultaneous with this action, the character is printed on the tape. In addition, the mark and space combinations for that character are sent from the keyboard directly to the external circuit (if connected).

Signals from the external circuit cause the machine to perform as just described. Thus, the TT-253/UG can be employed for communicating directly with distant stations or for the off-circuit preparation of message tapes. If both tape and printed page copy of a message are desired, the perforator-reperforator is used in conjunction with a page-receiving teletypewriter.

Type Reperforator TT-192( )/UG

The typing reperforator shown in figure 4-13 is designated TT-192( )/UG. Except for not having a keyboard, it is basically the same as the TT-253/UG just described. Most shipboard installations of the TT-192( )/UG, however, do not include the table shown in the illustration.

Normally, the reperforator's wiring is terminated in a patch panel (described later in this chapter) so that it can be patched or connected into any teletype circuit wired through the panel. By patching the reperforator into a circuit, a tape copy of each message is obtained, and messages requiring further processing in tape form need not be retyped by the operator.

Transmitter Distributor TT-187( )/UG

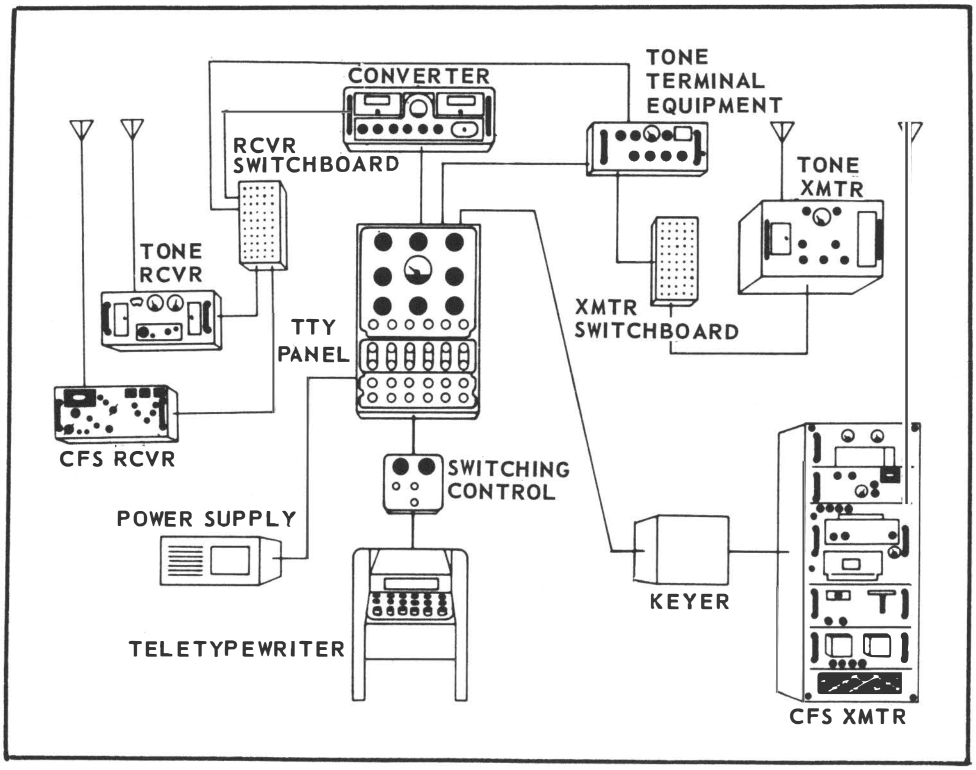
The transmitter distributer (fig. 4-14) is a mechanical tape reader used to convert messages on perforated tapes to the electrical impulses of the teletypewriter code. Conversion of the perforations in the tape to electrical impulses is accomplished by passing the tape over sensing pins. These sensing pins activate a mechanical mechanism that operates a set of contacts to send out either a mark or space impulse, depending upon whether the sensing pins rise into a perforation or are held stationary by the tape.

Like the reperforator, the transmitter distributor's wiring usually is terminated in a panel so that it can be connected into any circuit. With this arrangement, messages previously prepared on tape can be transmitted to distant stations at a constant speed.

The illustrated unit is self-contained, and can be mounted in any convenient space that is large enough to accommodate its base.

Teletypewriter Set AN/UGC-6

The AN/UGC-6 teletypewriter (fig. 4-15) is a versatile communication equipment. It receives messages from the signal line and prints them on page size copy paper. In addition, it can receive messages and record them on tape in both perforated and printed form. With page-printed monitoring, the teletypewriter transmits messages that are



1.225

Figure 4-8.—Integrated RATT system.

1.217

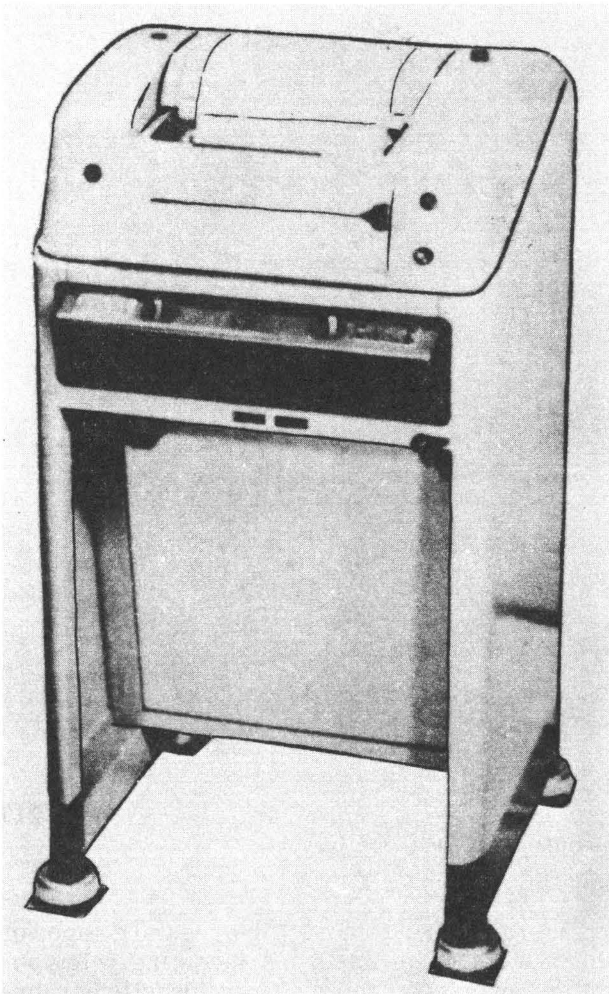
Figure 4-9.—Model 28 teletypewriter TT-47( )/UG.

originated either by perforated tape or by keyboard operation. It mechanically prepares perforated and printed tape for separate transmission with or without simultaneous transmission and page-printed monitoring.

The teletypewriter set is composed of the following components: a cabinet, a keyboard, an automatic typer, a typing perforator, a transmitter distributor (TD), a typing reperforator, and power distribution panels.

In operation, the components are linked 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. Transmission signals are initiated through the keyboard or through 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 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 excluding various components from the line. The external signal line is connected to the equipment through a line-test switch located below the selector switch on the front of the cabinet. This arrangement provides a means of disconnecting the equipment from the line for local testing of the components. The typing reperforator is operated by a separate motor and power



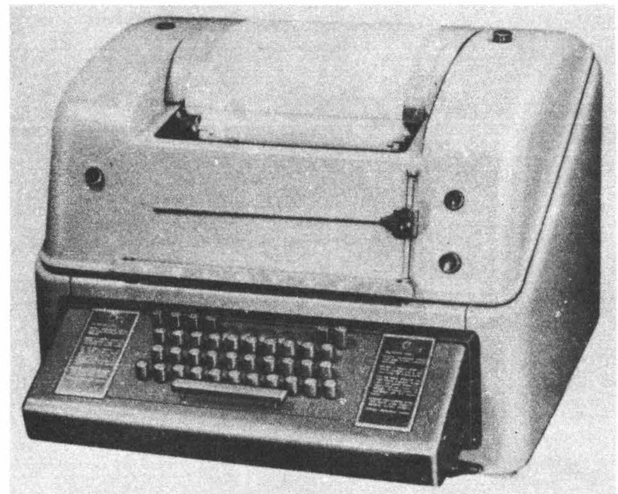
120.25
Figure 4-10.—Teletypewriter TT-171( )/UG.

distribution system. It also is connected to a separate external signal line.

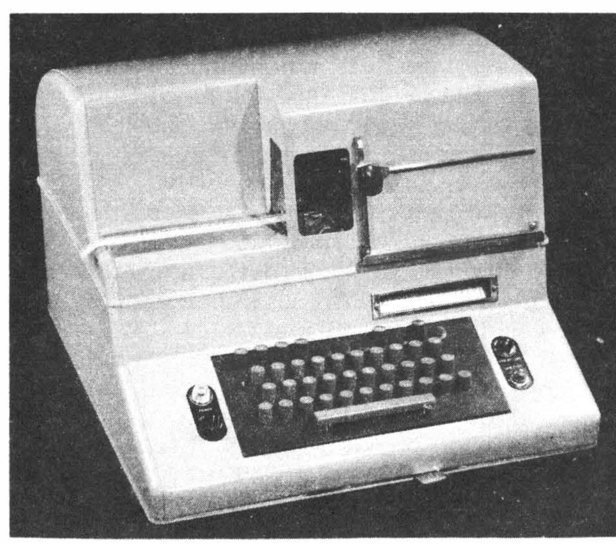
Teletypewriter Projector Unit TT-71/UG

Teletypewriter projector unit model TT-71/UG, shown in figure 4-16, enables a teletypewriter message to be read simultaneously by groups of persons. It is installed in the pilot readyrooms in aircraft carriers and in teletypewriter conference rooms ashore.

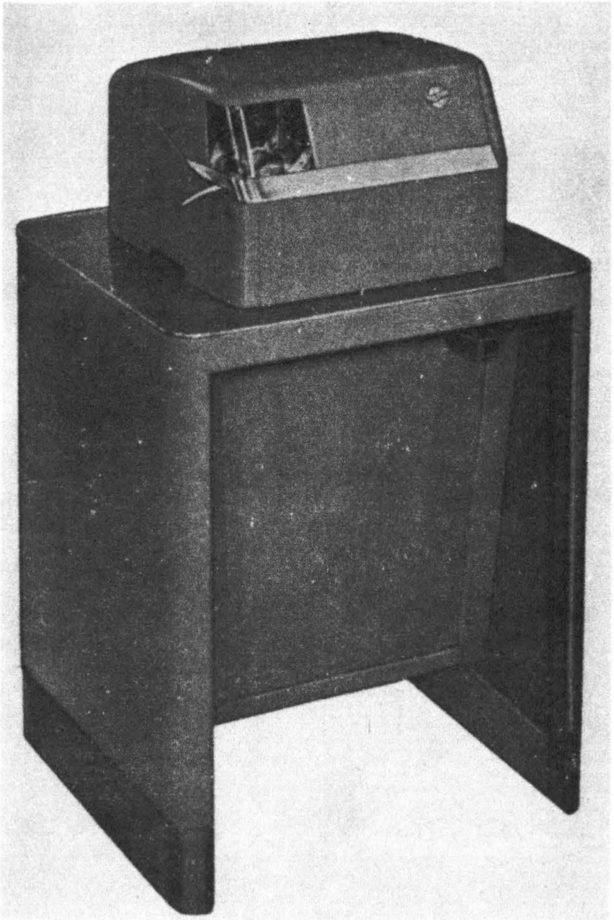
The bottom of the cabinet houses a page-printing teletypewriter. The message is printed on a roll of transparent cellophane. An optical lens system with a powerful lamp enlarges the image of the teletypewriter message and projects it onto a tilted mirror at the top rear of the cabinet from where it is reflected onto the translucent screen. The message is visible along the lower edge of the screen as it is being



76.35
Figure 4-11.—Teletypewriter TT-69( )/UG.



50.116
Figure 4-12.—Send/receive typing perforator-reperforator TT-253/UG.



50.114
Figure 4-13.—Receive-only typing reperforator TT-192( )/UG.

printed. With each successive line the message advances upward on the screen one line at a time and finally moves out of view at the top. A tape-typing unit provides a permanent typewritten record of transmissions in the projector unit, but at most installations this feature is not used because a page copy from an additional teletypewriter patched into the same circuit has been found to provide a more readable and more convenient file copy.

KEYERS AND CONVERTERS

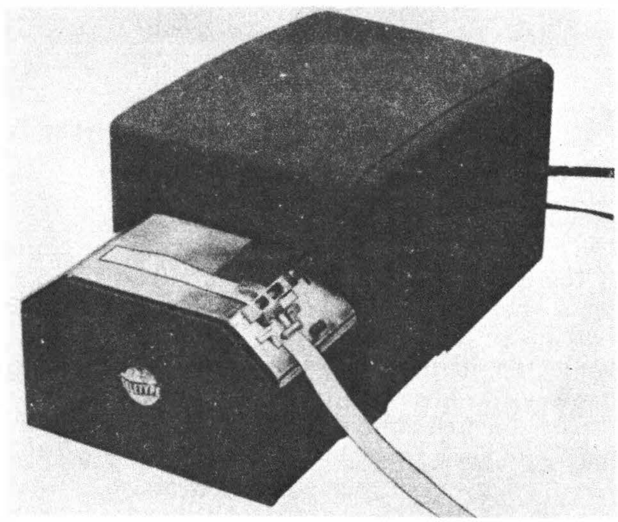
Keyers and converters are an integral part of every radioteletype system. In some instances, the keyer is built into the radio transmitter, but the converter is a separate piece of equipment.

Tone Shift Keyer/Converters AN/SGC-1( ) and AN/UGC-9( )

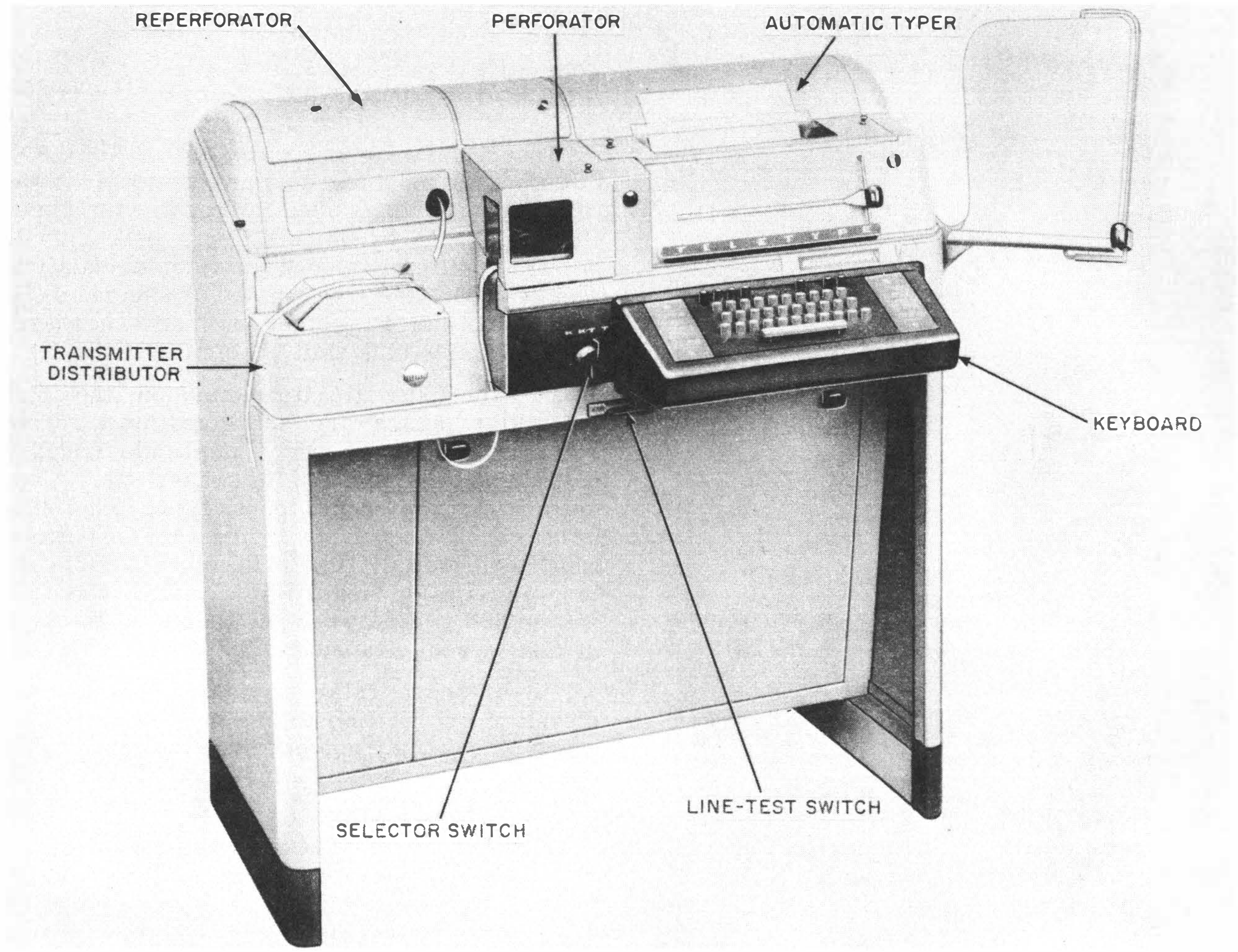
Tone shift keyer/converter model AN/SGC-1( ) is used for short-range RATT operation. Normally it is used for communication on UHF and VHF bands, but it can be used with any transmitter designed for voice modulation. The AN/SGC-1( ) is shown in figure 4-17, with blocks indicating other equipment necessary for a complete tone shift system.

In tone modulation transmission, the teletypewriter pulses are converted into corresponding audio tones, which amplitude modulate the carrier frequency of the transmitter. Conversion to the audio tones is accomplished by an audio oscillator in the tone converter, which operates at 700 cycles when the teletype loop is in a closed-circuit (mark) condition and at 500 cycles when the loop is in an open-circuit (space) condition.

An internal relay in the tone converter closes a control line to the radio transmitter, which places the transmitter on the air when the operator begins typing a message. The control line remains closed until after the message is transmitted.



1.210
Figure 4-14.—Transmitter distributor TT-187( )/UG.



31.29A

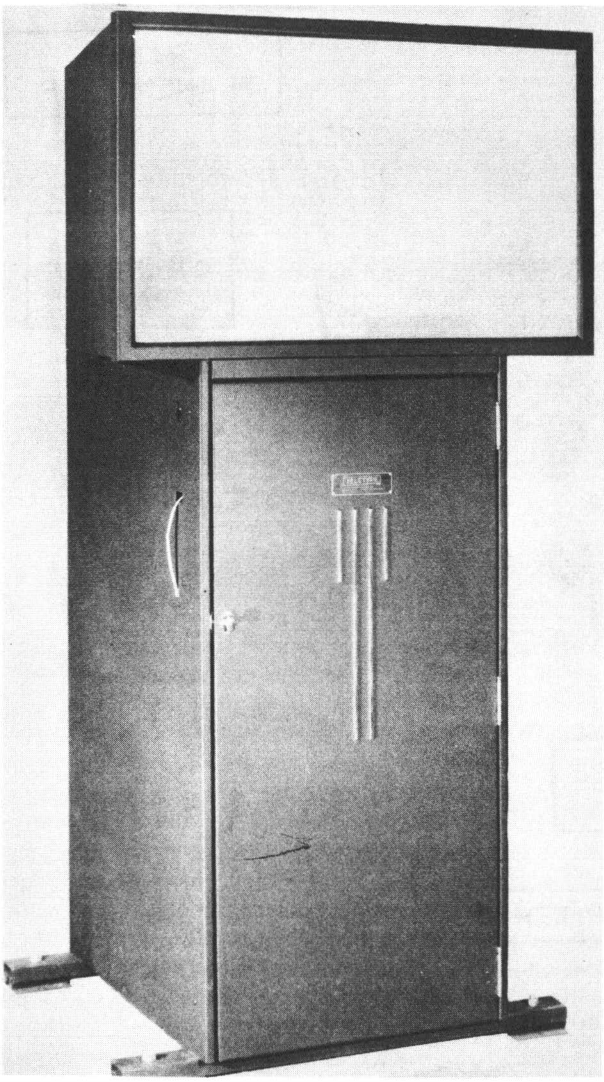
Figure 4-15.—The AN/UGC-6 teletypewriter.

When receiving messages, the tone converter accepts the mark and space tones coming in from an associated radio receiver and converts the intelligence of the tones into signals that close and open the contacts of a relay connected in the local teletypewriter d-c loop circuit. This action causes the local teletypewriter to print in unison with the mark and space signals from the distant teletypewriter.

The AN/UGC-9( ) tone shift keyer/converter (not illustrated) is the transistorized version of the AN/SGC-1( ). It serves the same purpose and performs in the same manner. Because transistors are much smaller than conventional electron tubes, the AN/UGC-9( ) is smaller in size than the AN/SGC-1( ). Thus, it is better suited for shipboard installation.

Frequency Shift Keyer KY-75/SRT

The purpose of frequency shift keyer KY-75/SRT (fig. 4-18) is to replace the conventional exciter (oscillator) of a CW transmitter with a source of excitation that can be shifted a small amount upward or downward to produce RATT signals corresponding to the d-c mark and space teletypewriter signals connected to the input of the keyer. The frequency-modulated output of the keyer then is raised to the



31.34
Figure 4-16.—Teletypewriter projector unit TT-71/UG.

desired transmission frequency and power output by the transmitter.

During frequency shift keying operation, the frequency of the transmitter's carrier appears at a certain frequency during a space signal and shifts a few hundred cycles higher for a mark signal. The amount of this frequency shift is controlled by the keyer. Usually, the keyer is adjusted for an 850-cycle shift, which means that the mark signal is 425 cycles above the average carrier frequency, and the space signal is 425 cycles below the carrier.

The KY-75/SRT keyer is used also for facsimile transmission (discussed later in this chapter). Newer models of Navy transmitters have built-in keying circuits for frequency shift mode of operation and do not require an external keyer for either RATT or facsimile transmission.

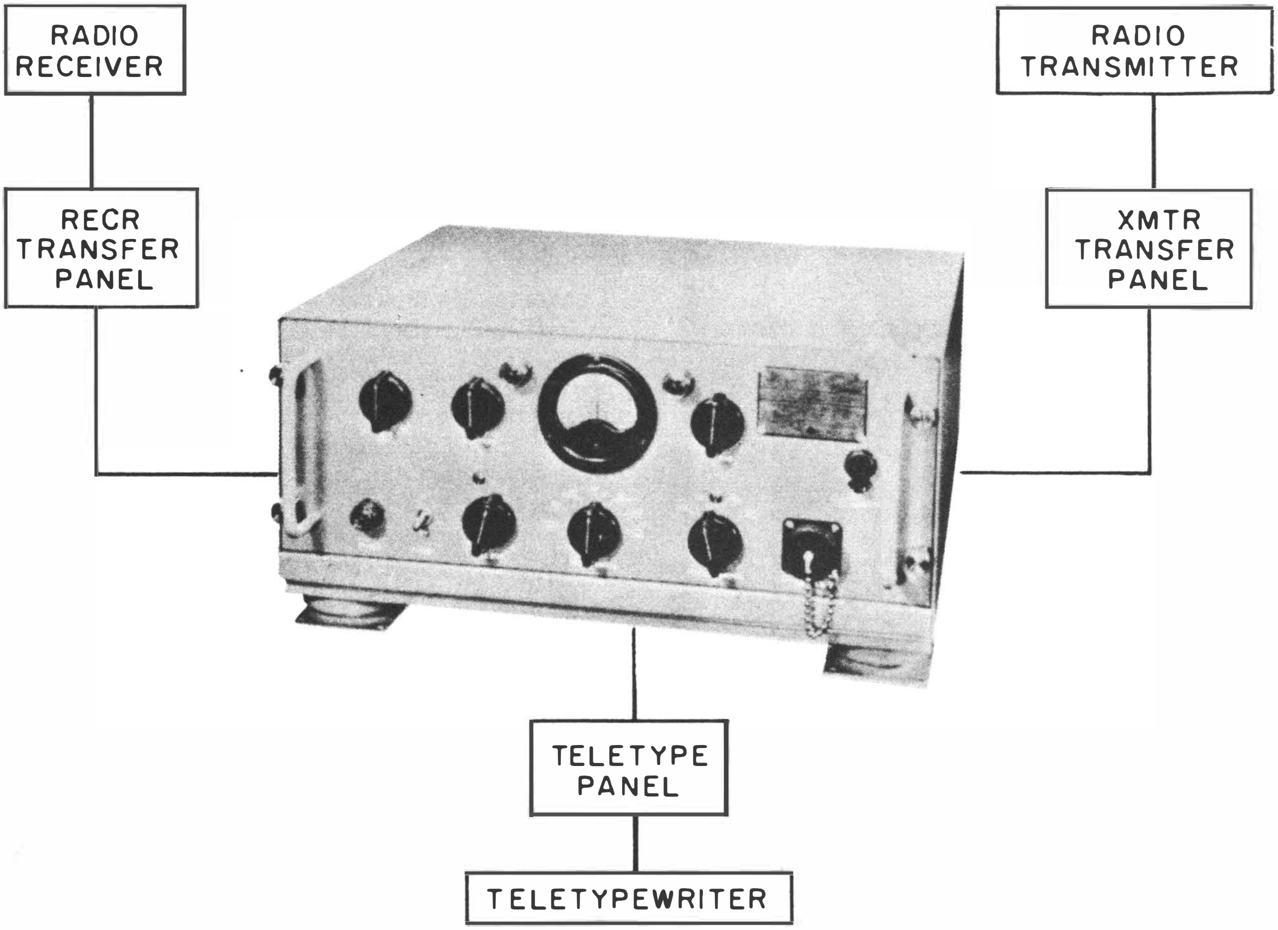
Converter-Comparator Groups AN/URA-8( ) and AN/URA-17( )

The AN/URA-8( ) frequency shift converter-comparator group, shown in figure 4-19, is used for diversity reception of RATT and FAX signals. The equipment consists of two frequency shift converters (top and bottom units) and a comparator (middle unit).

For either space diversity or frequency diversity reception, two standard Navy receivers are employed in conjunction with the converter-comparator group. In space diversity operation, the two receivers are tuned to the same carrier frequency, but their receiving antennas are spaced some distance apart. Because of the required spacing between antennas, space diversity usually is limited to shore station use. In frequency diversity operation, the two receivers are tuned to different carrier frequencies that are carrying identical intelligence. Frequency diversity reception commonly is used aboard ship for copying fleet braodcasts, which are keyed simultaneously on several frequencies.

In diversity reception, the audio output of each receiver is connected to its associated frequency shift converter, which converts the frequency shift characters into d-c pulses. The d-c (or mark-space) pulses from each converter are fed to the comparator. In the comparator, an automatic circuit compares the pulses and selects the better mark and the better space pulse for each character. The output of the comparator is patched to the teletypewriter. The converter units also can be used individually with separate teletypewriters to copy two different FSK signals.

The newest converter-comparator group is the AN/URA-17( ) shown in figure 4-20. This is a completely transistorized equipment designed to perform the same functions as the



1.240

Figure 4-17.—Tone shift keyer/converter AN/SGC-1( ).

AN/URA-8( ). Although present procurement of frequency shift converters is confined to the AN/URA-17( ), there are relatively few installations compared with the larger number of AN/URA-8( ) converters.

The AN/URA-17( ) consists of two identical converter units. Each converter has its own comparator circuitry. Hence, a separate comparator unit is not required. The physical size of the AN/URA-17( ) is further reduced by using transistors and printed circuit boards. The complete equipment is less than half the size of the older AN/URA-8( ).

Proper tuning of the receivers employed with these converter-comparator groups is of the utmost importance. Each converter has a small monitor oscilloscope that gives a visual indication of the receiver tuning. The scope patterns for correct and incorrect tuning are shown in figure 4-21.

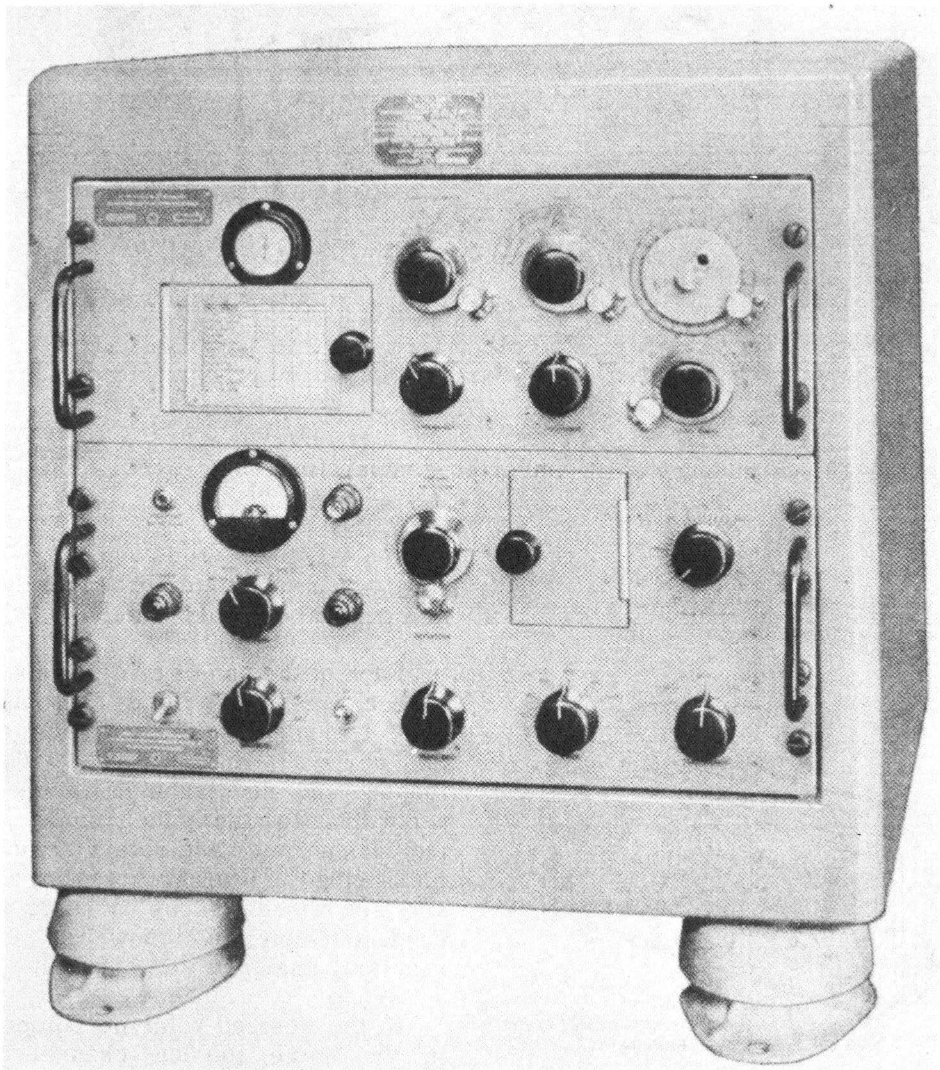
TELETYPE PATCH PANELS

To provide flexibility in teletype systems, the wiring of all teletypewriter and associated equipments is terminated on jacks in teletype patch panels. The equipment then is connected electrically in any desired combination by means of patching cords (lengths of wire with plugs on each end). The plugs on the cords are inserted into the jacks at the front of the panel. In some instances, commonly used combinations of equipment are permanently wired together within the panel (called "normal-through"). They are wired in such a manner, however, that the individual pieces of equipment can be "lifted" from the combination, and then used alone or in other combinations.

In addition to providing flexibility, teletype panels also furnish a central point for connecting the d-c voltage supply into the teletypewriter circuits. Thus, one source of supply can be used for all circuits passing through a particular panel.

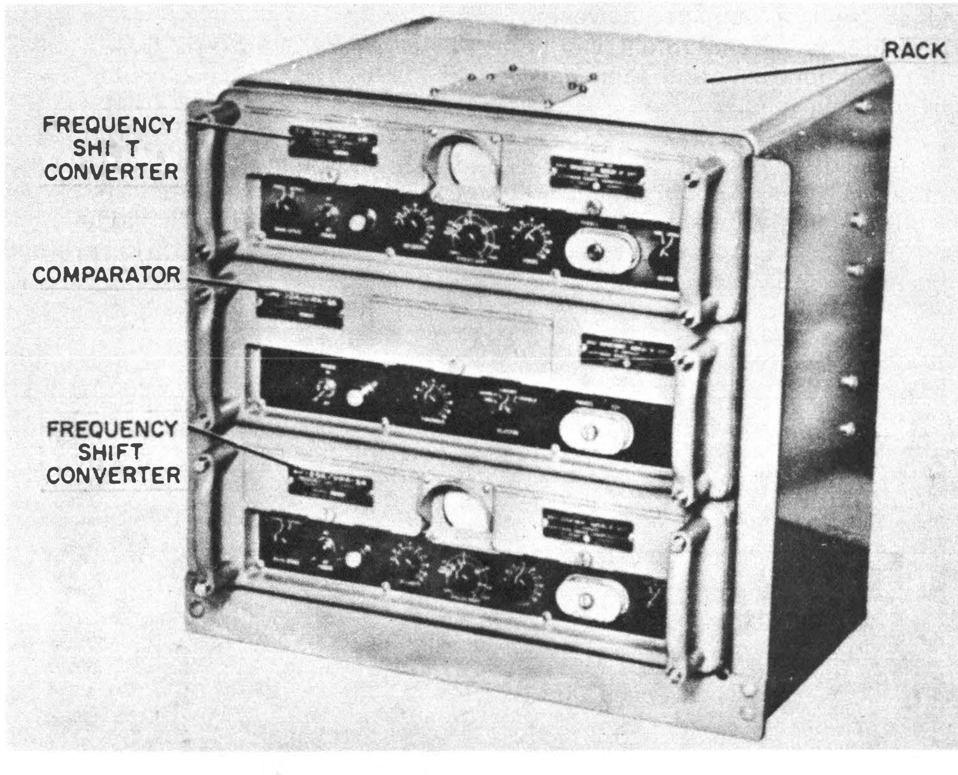
Teletype Panels SB-1203/UG and SB-1210/UGQ

Teletype panels SB-1203/UG and SB-1210/UGQ, shown in figure 4-22, are used for interconnection and transfer of teletypewriter equipment aboard ship with various radio adapters, such as frequency shift keyers and converters.



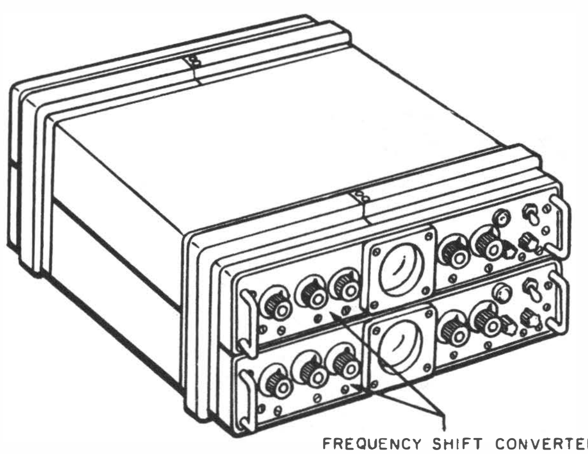
31.35

Figure 4-18.—Frequency shift keyer KY-75/SRT.



1.235

Figure 4-19.—Frequency shift converter-comparator group AN/URA-8( ).



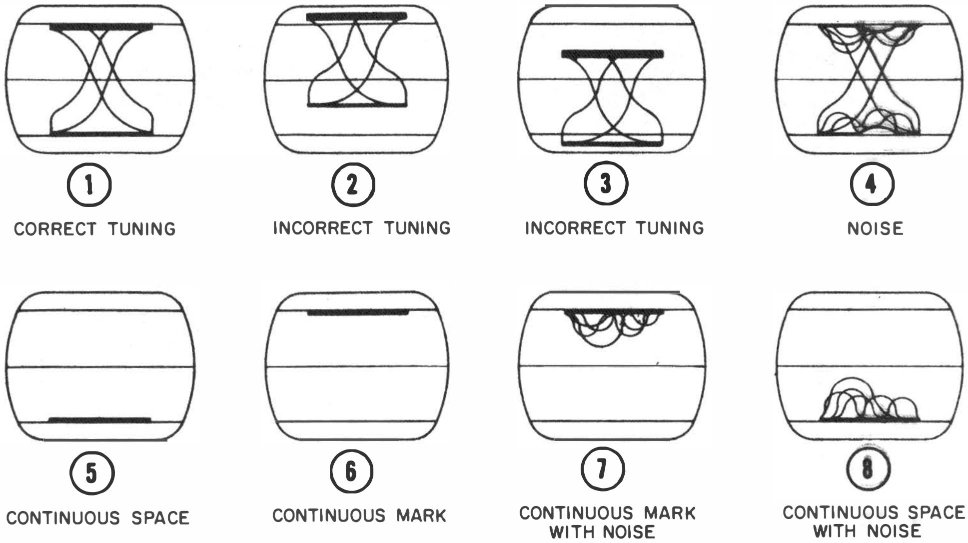
50.76

Figure 4-20.—Converter-comparator group AN/URA-17( ).

The SB-1210/UGQ is intended for use with cryptographic devices, whereas the SB-1203/UG is a general-purpose panel.

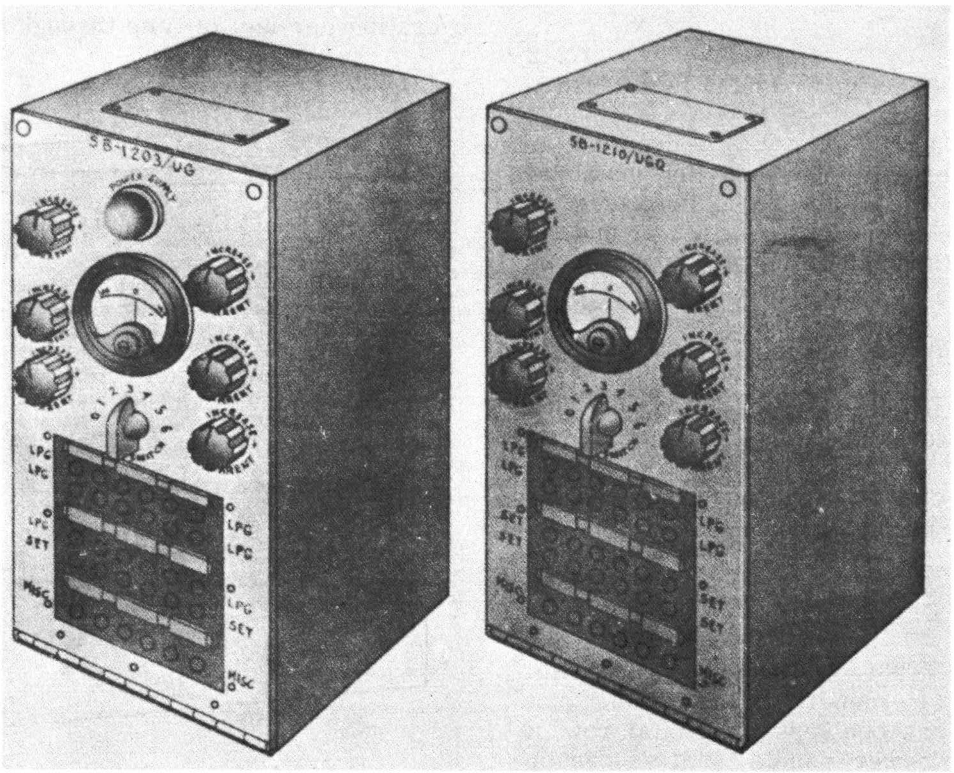
Each of the panels contains six channels, with each channel comprising a looping series circuit of looping jacks, set jacks, and a rheostat for adjusting line current. The number of looping and set jacks in each channel varies according to the panel model. Each panel includes a meter and rotary selector switch for measuring the line current in any channel. There are six miscellaneous jacks to which may be connected any teletypewriter equipment not regularly assigned to a channel.

If the desired teletype equipment is wired in the same looping channel as the radio adapter (keyer or converter) to be used, no patch cords are required. But, if the desired teletypewriter (for example, in channel 1) is not wired in the same looping channel as the



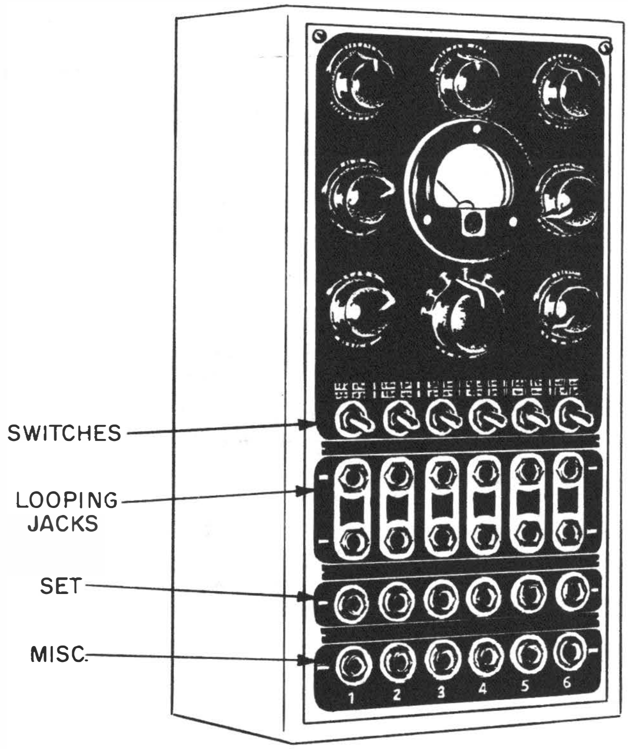
1.239.3

Figure 4-21.—Monitor oscilloscope patterns for frequency shift converters.



70.79

Figure 4-22.—Teletype patch panels SB-1203/UG and SB-1210/UGQ.



1.242
Figure 4-23.—Teletype panel TT-23( )/SG.

keyer or converter to be used (for example, channel 3), one end of the patch cord must be inserted in the set jack in channel 1, and the other end in either one of the two looping jacks in channel 3.

In any switching operation between the various plugs and jacks of a teletype panel, the cord plug must be pulled from the looping jack before removing the other plug from the set (machine) jack. Pulling the plug from the set jack first open-circuits the channel, causing all teletype messages in the channel to be interrupted.

Teletype Panel TT-23( )/SG

The model TT-23( )/SG teletype panel (fig. 4-23) is the forerunner of the panels just described. It has one less horizontal row of jacks than the newer panels, and, as can be seen in the illustration, it has a toggle switch incorporated in each channel. The purpose of the switch is to provide a means of disconnecting the local d-c supply when the necessary current is supplied by another source. Except for these differences, the TT-23( )/SG performs the same function and is operated in the same manner as the newer panels.

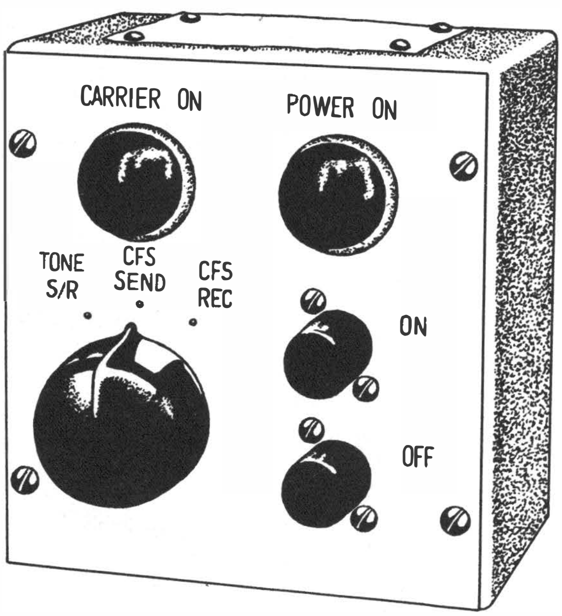
REMOTE CONTROL UNIT C-1004( )/SG

Another piece of equipment used with teletypewriter installations aboard ship is the C-1004( )/SG control unit shown in figure 4-24. This unit is mounted close to the teletypewriter keyboard and permits remote control of the radio transmitter. It has a transmitter power on-off switch, a power-on indicator lamp, a carrier-on indicator lamp, and a three-position rotary selector switch.

The TONE S/R switch position is used for both sending and receiving when using a tone shift keyer/converter. When using carrier frequency shift mode of operation, the operator must switch to CFS SEND position for transmitting and to CFS REC position for receiving.

MULTIPLEXING

The number of communication networks in operation per unit of time throughout any given



1.244.1
Figure 4-24.—Remote control unit C-1004( )S/G.

area is increasing constantly. In the past, each network was required to operate on a different frequency. As a result, all areas of the radio-frequency 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 main purpose of a multiplex system is to increase the message-handling capacity of teletypewriter channels and the transmitters and receivers associated with them. This increase in capacity is accomplished by the simultaneous transmission of several messages over a common channel.

Multiplexing can be accomplished in either of two methods. Frequency division multiplexing, for example, employs a number of tone channels slightly displaced in frequency. Each tone channel carries the 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 teletypewriter signal into a number of equal intervals and allots each interval to a separate teletypewriter circuit. Thus, the teletypewriter signals are, in effect, compressed in time for transmission. Receiving equipment at a distant station accepts the multiplex signals, converts them to mark-space signals (in effect, expands them in time), and distributes them in the proper order to a corresponding number of circuits.

MULTIPLEX EQUIPMENT

The Navy currently has only a limited number of multiplex equipments installed aboard ship. They are telegraph terminal groups AN/UGC-1( ) and AN/UCC-1(V). Both models are send-receive terminal sets used for long-range, high-frequency radio circuits. Of the two, the AN/UCC-1(V) is the most recently developed and employs the frequency division method of multiplexing. Model AN/UGC-1( ) uses the time division method.

TELEGRAPH TERMINAL SET AN/UGC-1( )

Model AN/UGC-1( ) telegraph terminal set (fig. 4-25) is a completely transistorized multiplexing equipment. The receiver group, transmitter group, and a common power supply are all housed in a single cabinet only 36 inches high.

A schematic representation of a multiplex installation employing the AN/UGC-1( ) is shown in figure 4-26. The frequency shift transmitter, the keyer, the radio receiver, the converter, the patch panels, and the teletypewriter equipment are included to show the complete send-receive system.

Teletypewriter signals are fed to the terminal equipment's transmitting group from two, three, or four separate circuits. The signaling speed can be 60, 75, or 100 wpm, but the speed must

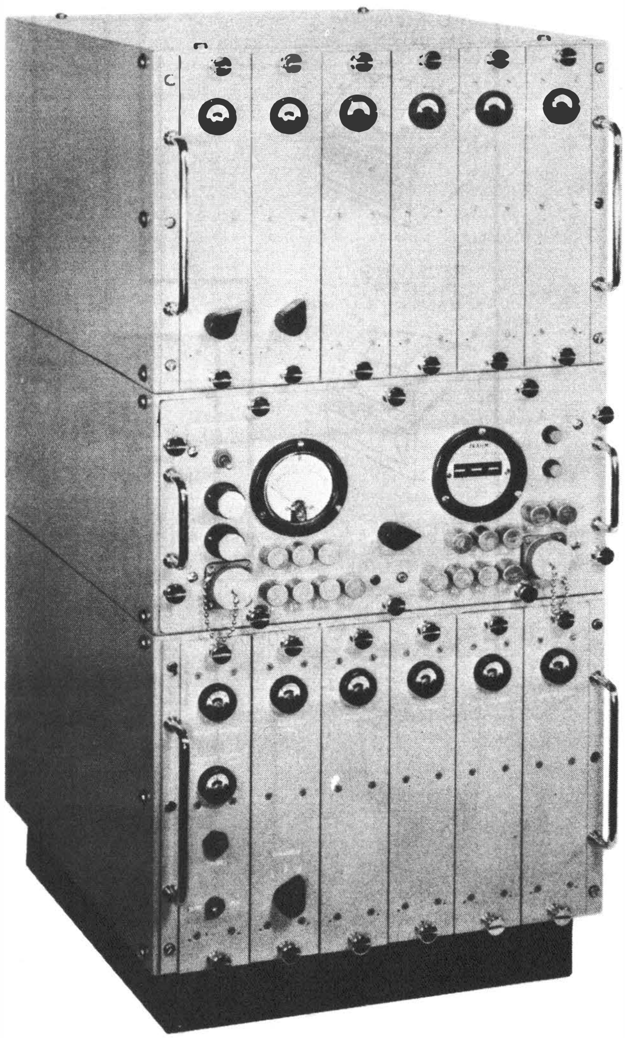


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Figure 4-25.—Telegraph terminal set AN/UGC-1( ).

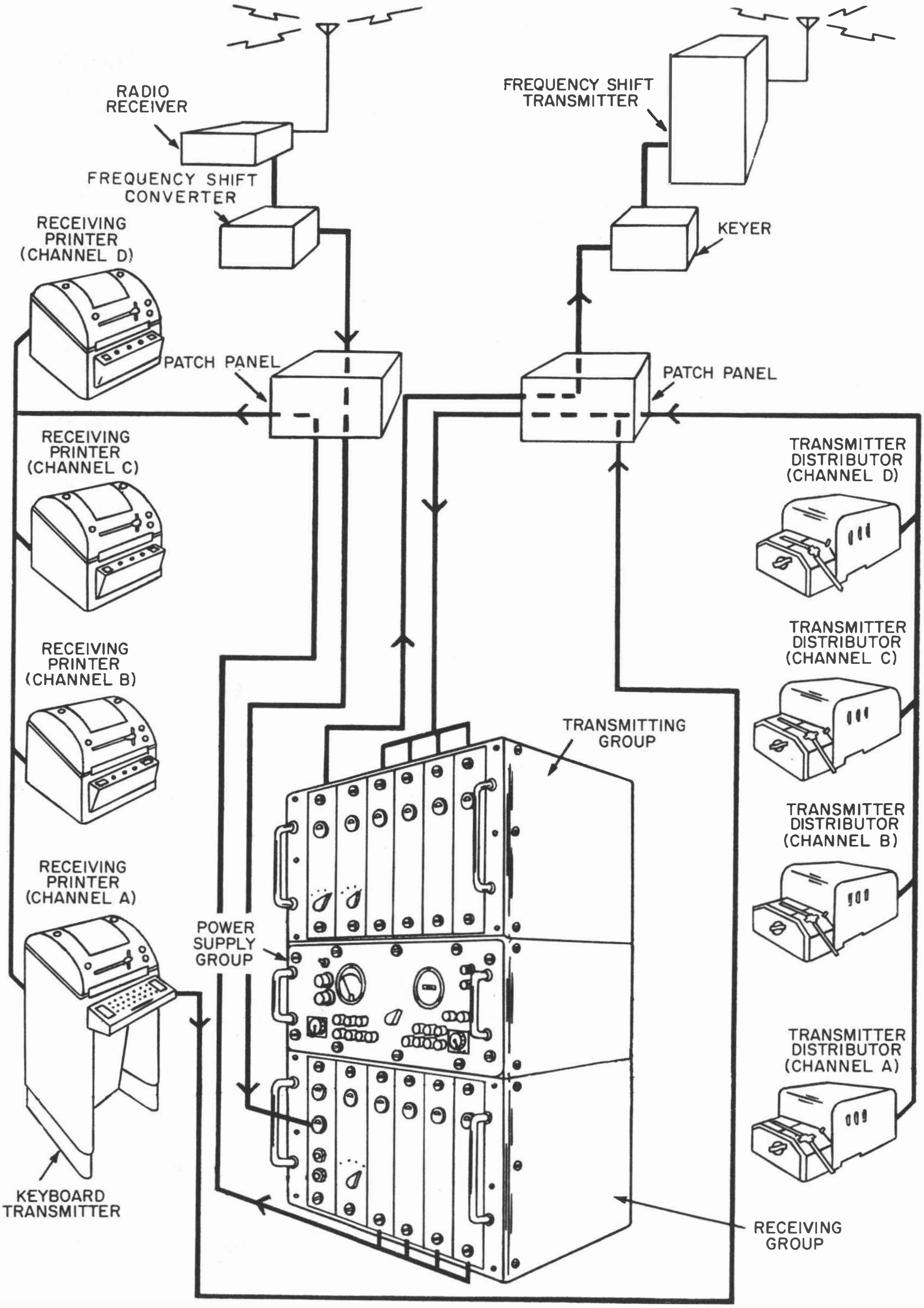

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Figure 4-26.—Multiplex installation employing AN/UGC-1( ) terminal equipment.

be the same for each circuit. In the transmitting group, the teletypewriter signals are converted to multiplexed signals that are arranged in sequential order for transmission over a single radio circuit. The multiplexed output of the transmitting group is fed through the patch panel and frequency shift keyer to the radio transmitter, where the frequency-shifted multiplex signal is placed on the air.

At the receiving station, the multiplex signals from the radio receiver are processed through the frequency shift converter. Then, they are patched to the receiving group in the AN/UGC-1( ). The receiving group converts the multiplexed signals back into standard teletypewriter signals and distributes the d-c marks and spaces to the proper teletypewriters.

TELEGRAPH TERMINAL SET AN/UCC-1(V)

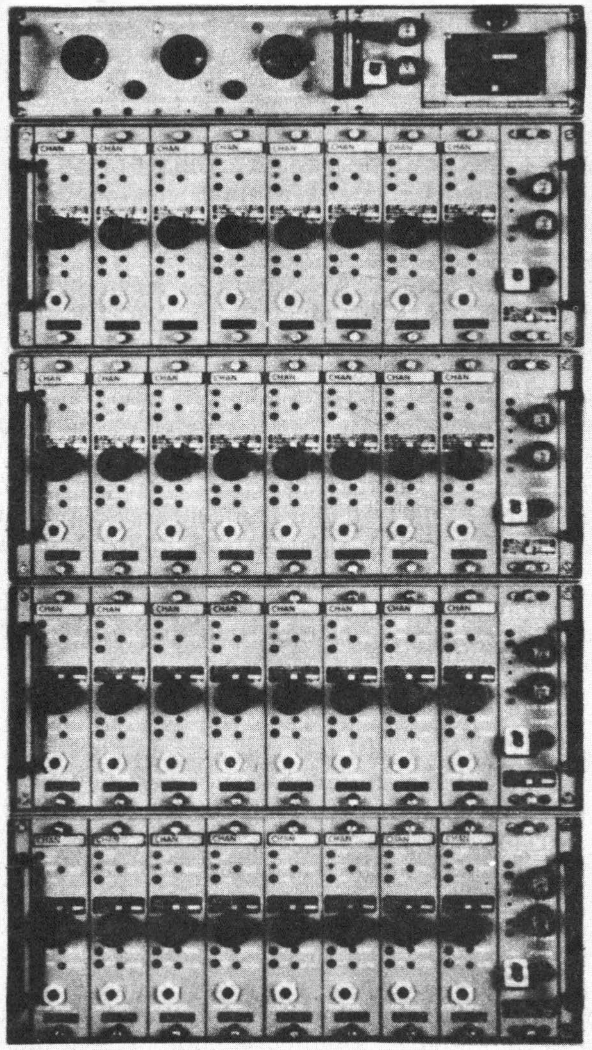
The AN/UCC-1(V), shown in figure 4-27, is a frequency division multiplex terminal equipment for use with radio (or wire) circuits. It is a completely transistorized equipment that provides up to 16 different voice-frequency tone channels. Each channel has its own keyer and one or more converters that will accept keying speeds of either 100 wpm or 200 wpm. Because of its light weight, small size, and high message-handling capacity, the AN/UCC-1(V) is suitable for installation on most types of ships.

When keyed by teletypewriter signals, the keyers generate one frequency representing a mark and another representing a space (frequency shift keying). The outputs from the different keyers then are combined in the multiplexer-demultiplexer (top unit in the illustration) for transmission over a single communication link.

For incoming signals, the converters reverse the process performed by the keyers. They accept a particular frequency shift signal from the multiplexer-demultiplexer and convert it to the d-c marks and spaces for operation of the teletypewriters.

FACSIMILE

Facsimile (FAX) is a method for transmitting still images over an electrical communication system. The images, called pictures or copy in facsimile terminology, may be



120.26
Figure 4-27.—Telegraph terminal AN/UCC-1(V).

weather maps, photographs, sketches, typewritten or printed text, or handwriting. The still image serving as the facsimile copy or picture cannot be transmitted instantly in its entirety. Three distinct operations are performed. These are (1) scanning, (2) transmitting, and (3) recording or receiving.

The scanning operation consists of subdividing the picture in an orderly manner into a large number of elemental segments. This process is accomplished in the facsimile transmitter by a scanning drum and phototube arrangement.

The picture to be transmitted is mounted on a cylindrical scanning drum, which rotates at a constant speed and at the same time moves longitudinally along a shaft. Light from an exciter lamp illuminates a small segment of the moving picture and is reflected by the picture through an aperture to a phototube. During the transmission of a complete picture, the light traverses every segment of the picture as the drum slowly spirals past the fixed lighted area.

At any instant, the amount of light reflected back to the phototube is a measure of the lightness or darkness of the tiny segment of the picture that is being scanned. The phototube transforms the varying amounts of light into varying electrical signals, which, in turn, are used to amplitude modulate the constant frequency output of a local oscillator. Then, the modulated signal is amplified and sent to the radio circuits.

Electrical signals received by the facsimile receiver are amplified and serve to actuate a recording mechanism that makes a permanent recording (segment by segment) on recording paper. The paper is attached to a receiver drum similar to the one in the facsimile transmitter. The receiver drum rotates synchronously with the transmitter drum. This action continues until the original picture is reproduced in its entirety. The recording mechanism may reproduce photographically with a modulated light source shining on photographic paper or film, or it may reproduce directly by burning a white protective coating from specially prepared black recording paper.

Synchronization is obtained by driving both receiving and transmitting drums with synchronous motors operating at exactly the same speed.

Framing (orienting) the receiver drum with respect to the transmitter drum is accomplished by transmitting a series of phasing pulses just before a picture transmission is to begin. The pulses operate a clutch mechanism that starts the scanning drum in the receiver so that it is phased properly with respect to the starting position of the scanning drum in the transmitter

FACSIMILE EQUIPMENT

The equipment necessary for radio facsimile operation and its relationship to other units in the various receiving and transmitting systems are illustrated by block diagram in figure 4-28. As shown in part A of the figure, the receiving system consists of a standard radio receiver, a receiver, a frequency shift converter, and a facsimile recorder. Part B shows two systems for transmitting facsimile signals. One, the upper row of blocks, is for long-range, carrier frequency shift transmission and consists of a facsimile transceiver, a keyer adapter, a frequency shift keyer, and a CW transmitter. The other, the lower row of blocks, is for short-range, audiofrequency shift transmission and employs a facsimile transceiver, a radio modulator, and a voice transmitter.

The equipment discussed in the remaining portion of this chapter is representative of that used in shipboard facsimile installations.

FACSIMILE TRANSCEIVERS TT-41( )/TXC-1B AND TT-66( )/TXC

Facsimile transceiver TT-41( )/TXC-1B (fig. 4-29) is an electromechanical-optical facsimile set of the revolving-drum type for both transmission and reception of page copy. Colored copy may be transmitted, but all reproduction is in black, white, and intermediate shades of gray. Received copy is recorded either directly on chemically treated paper, or photographically in either negative or positive form. The equipment transmits or receives a page of copy 12 by 18 inches in 20 minutes at regular speed (60 rpm), or in 40 minutes with half-speed (30 rpm) operation.

The TT-66( )/TXC facsimile transceiver, shown in figure 4-30, is a newer transceiver that performs the same functions as the TT-41( )/TXC-1B. Because they have different operating speeds, however, the two transceivers are not compatible. The newer set has selectable operating speeds of either 90 rpm or 45 rpm, whereas the older equipment operates at either 60 rpm or 30 rpm.

A facsimile transceiver (or transmitter) generates an amplitude-modulated signal, and the recorder is designed to operate on this type of signal. The signal generated by the

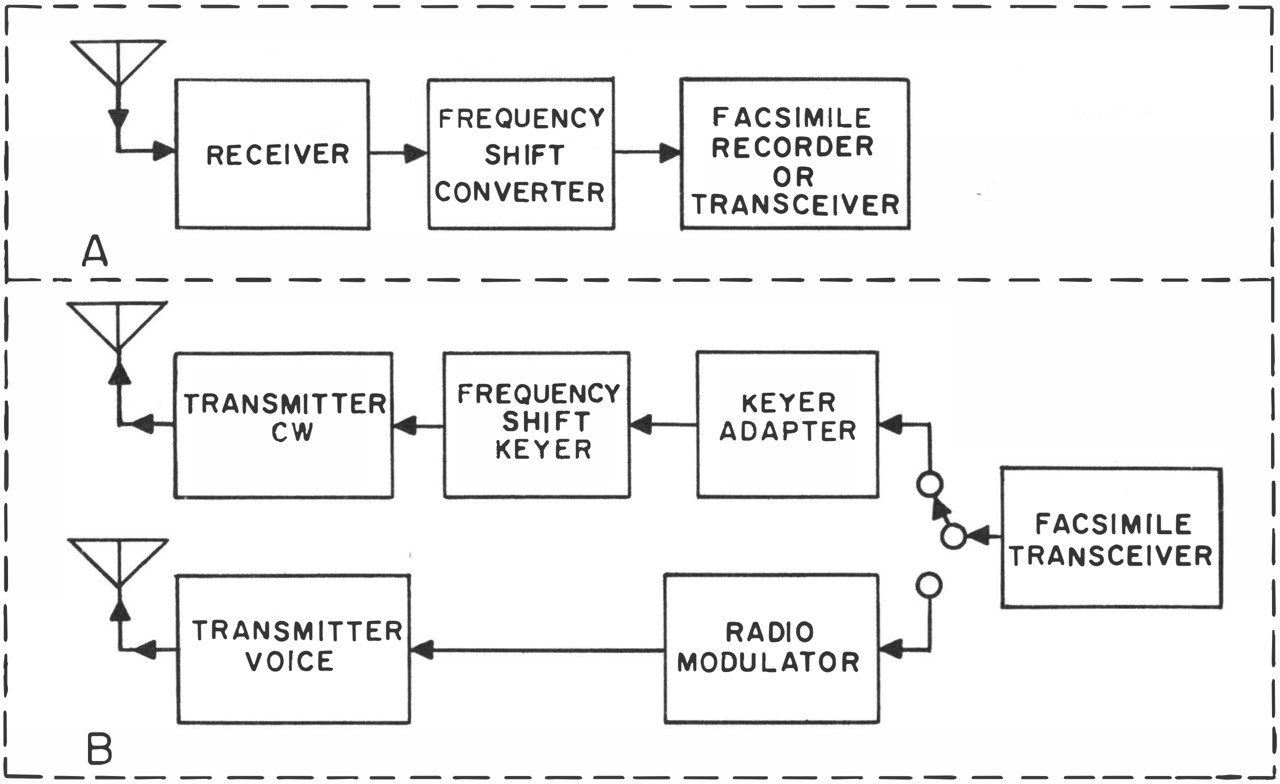


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Figure 4-28.—Radio facsimile systems.

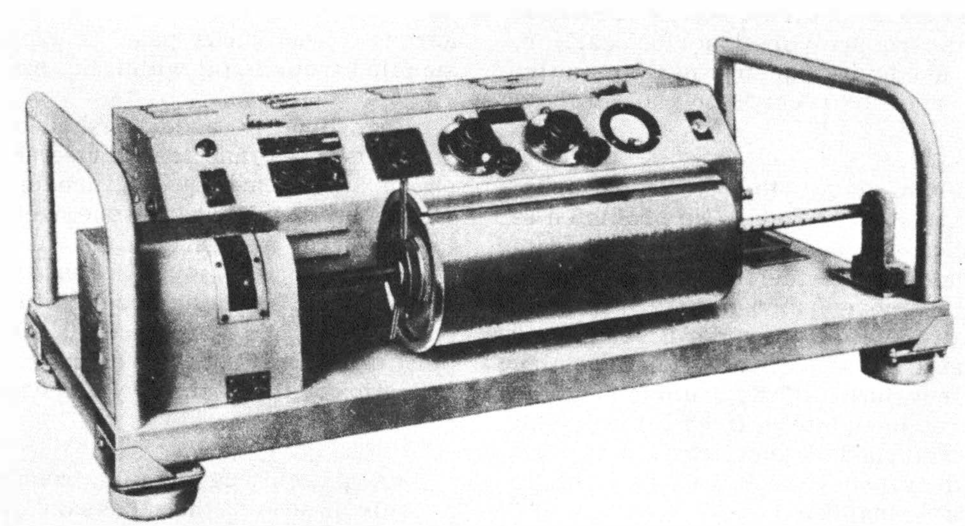

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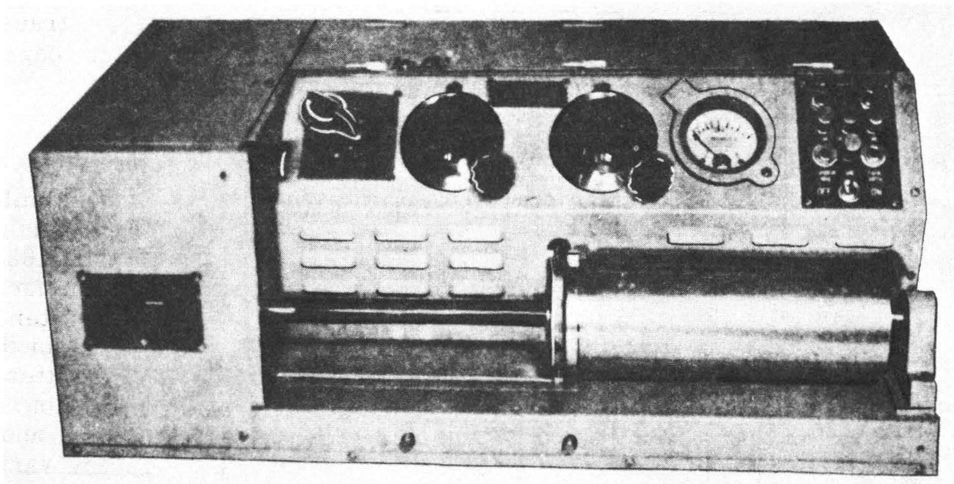
Figure 4-29.—Facsimile transceiver TT-41( )/TXC-1B.



120.27

Figure 4-30.—Facsimile transceiver TT-66( )/TXC.

transmitter is unsuitable, however, for transmission by means of radio. For this reason, it is necessary to use signal conversion equipment between the facsimile transmitter and the radio transmitter, and between the radio receiver and the facsimile recorder.

FACSIMILE RECORDER RD-92( )/UX

Facsimile recorder RD-92( )/UX, shown in figure 4-31, is used for direct stylus recording only. Unlike the transceivers described earlier, it cannot be used for transmitting facsimile, nor can it be used to receive on photographic film.

When receiving copy, the recorder drum rotates at a speed of 60 rpm. (No provision is made for multispeed operation.) As the drum rotates, a mechanical mechanism holding a stylus needle is moved across the drum to the right. The stylus needle records on paper fastened on the drum at the rate of one scanning line for each revolution of the drum. When the paper is covered completely, from left to right, the stylus is returned automatically to the left side of the drum so that it will be ready to record the next transmitted copy.

The model RD-92( )/UX recorder is used by the Navy to receive transmissions originating from the TT-41( )/TXC-1B. Usually, the recorder is installed aboard ships having a need for receiving complete weather maps: aircraft carriers, for example.

FACSIMILE RECORDER AN/UXH-2

A more modern facsimile recorder than the one just described is the model AN/UXH-2, shown in figure 4-32. Instead of recording on paper that is attached to a revolving drum, the AN/UXH-2 makes direct stylus recordings across a continuous page of paper. Paper is supplied from a roll within the machine.

Recording is accomplished by using three stylus needles that are carried across the page on a steel band. The needles are spaced on the band so that only one needle is touching the paper at any given time, and the speed at which this needle moves across the paper is the same as the scanning speed at the transmitter. Recording speeds can be at 60, 90, or 120 scans per minute, making this recorder compatible for operation with most Navy facsimile transmitters.

When receiving signals from a transmitter capable of sending the necessary control signals, the AN/UXH-2 can be left unattended. Upon receipt of the proper signals, it automatically phases, starts recording at the beginning of a transmission, stops when the transmission is complete, and compensates for changes in signal level during the recording.

KEYER ADAPTER KY-44( )/FX

For carrier frequency shift transmission, the amplitude-modulated audio signal from the facsimile transmitter must be converted to d-c keying voltages before being applied to the frequency shift keyer. This is the function of keyer adapter KY-44( )/FX shown in figure 4-33.

The output of the adapter is a d-c signal that varies in amplitude from 0 to 20 volts, depending on the frequency of the audio input signal. When the d-c signal is used to key a frequency shift keyer, such as the KY-75/SRT described earlier in this chapter, and when the frequency shift keyer, in turn, is controlling a radio transmitter, the end result is a transmitted carrier frequency shift signal similar to a radioteletype signal. As stated previously, this method of transmitting facsimile signals is used for long-range transmissions.

MODULATOR MD-168( )/UX

For transmission of facsimile signals by the audio frequency shift method, a radio modulator, such as the MD-168( )/UX (fig. 4-34), is required between the facsimile transmitter and the radio transmitter. The modulator converts the amplitude-modulated signal from the facsimile transmitter to constant amplitude frequency modulation, which varies at frequencies between 1500 and 2300 cycles per second. This frequency variation is used to modulate the radiotelephone transmitter. Modulator MD-168( )/UX can be employed with any transmitter capable of being voice modulated. In general, the audio frequency shift method is used for short-range transmissions.

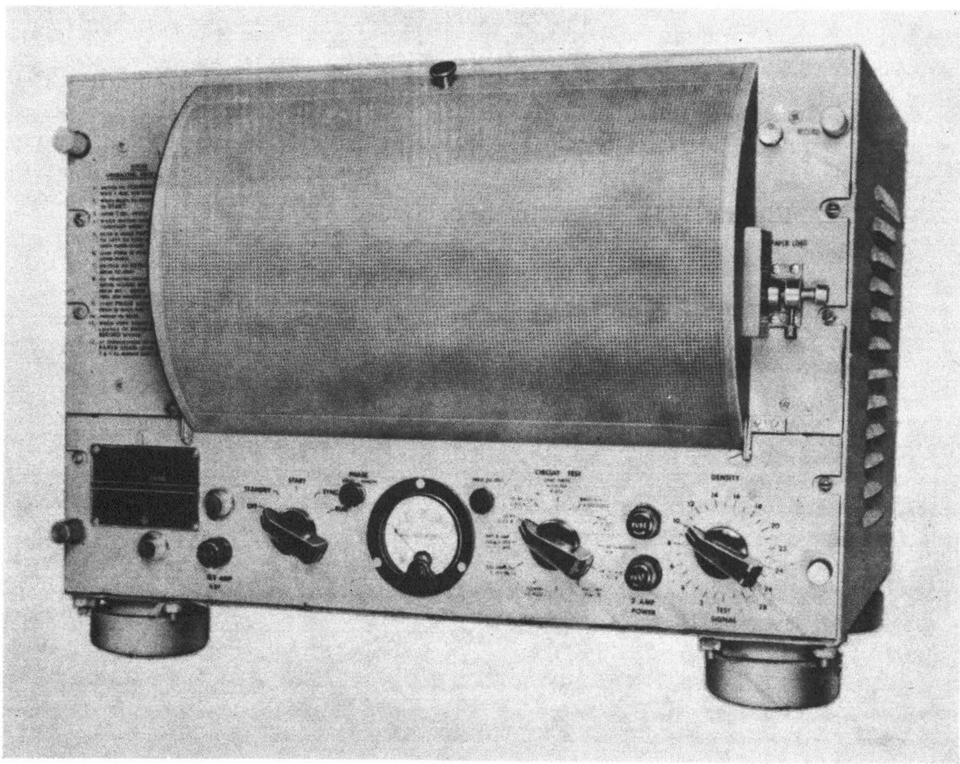


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Figure 4-31.—Facsimile recorder RD-92( )/UX.

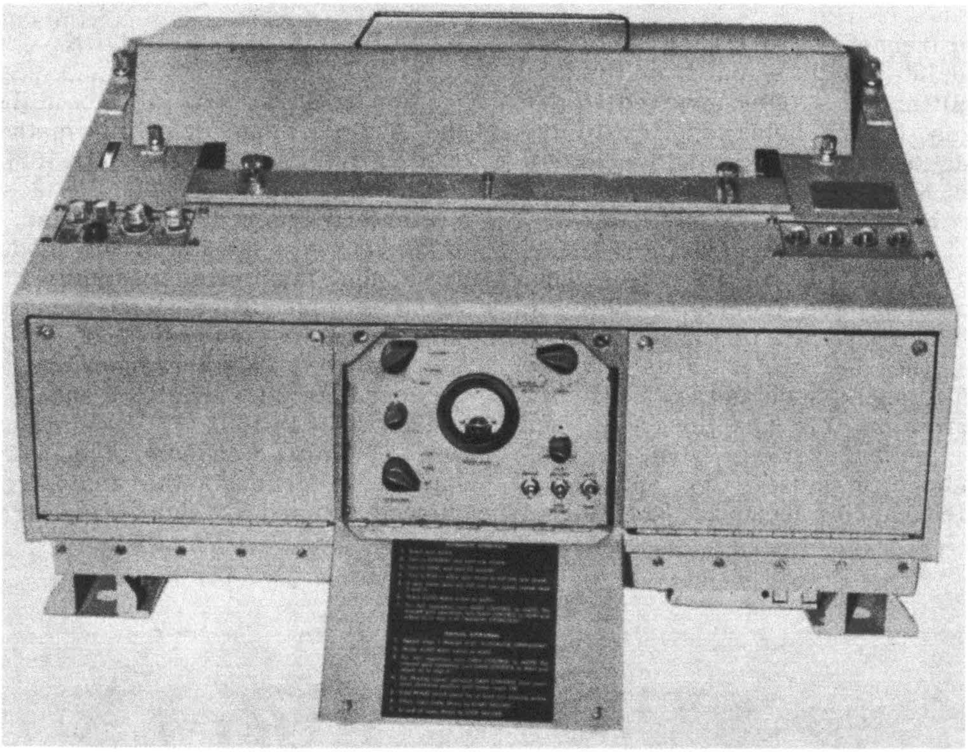

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Figure 4-32.—Facsimile recorder AN/UXH-2.

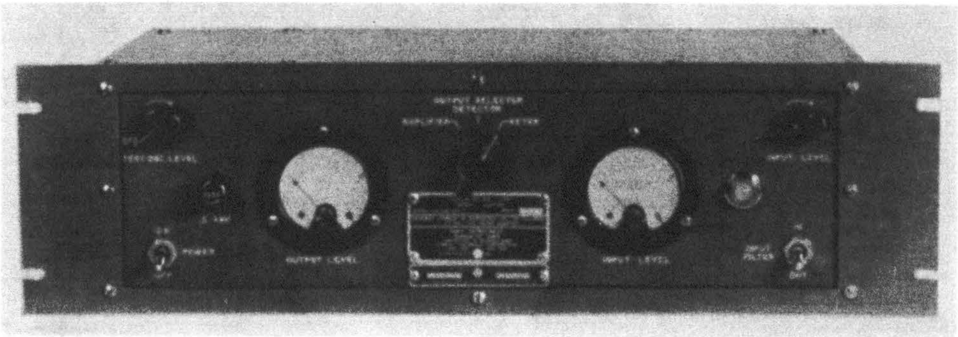

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Figure 4-33.—Keyer adapter KY-44( )/FX.

FREQUENCY SHIFT CONVERTER CV-172( )/U

With either the carrier frequency shift or the audiofrequency shift methods of transmitting facsimile signals, the output of the radio receiver at the receiving station is an audiofrequency shift signal of constant amplitude. The function of frequency shift converter CV-172( )/U (fig. 4-35) is to convert the receiver's output to an amplitude-modulated signal that varies between 1200 and 2300 cycles per second, which is the signal required for proper operation of the facsimile recorder.

The CV-172( )/U is not the only frequency shift converter used by the Navy in facsimile installations, but it is the one most commonly found aboard ship. Others you may encounter are models CV-97/UX and the CV-1066/UX. They all perform the same function.

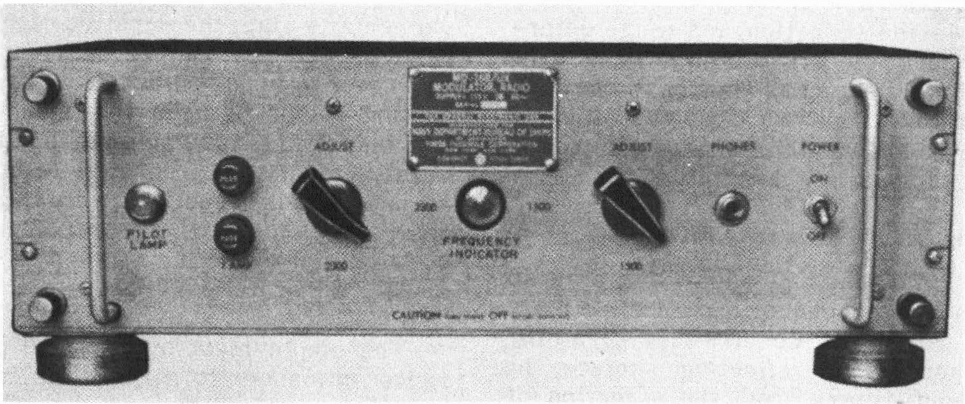

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Figure 4-34.—Modulator MD-168( )/UX.

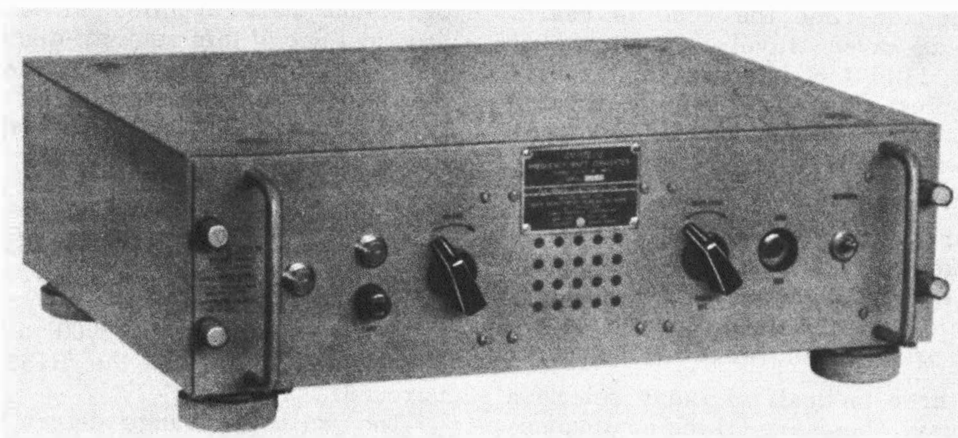

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Figure 4-35.—Frequency shift converter CV-172( )/U.

CHAPTER 5

RADAR

Radar (from the words radio detection and ranging) is one of the greatest scientific developments that emerged from War War II. It makes possible the detection and range determination of such objects as ships and airplanes over long distances. The range of radar is unaffected by darkness, but it often is affected by various weather conditions; heavy fog or violent storms, for example.

THEORY OF OPERATION

The basic principles of radar are similar to those of sound echoes or wave reflections. If a person shouts in the direction of a cliff or some other sound-reflecting surface, he hears his shout return from the direction of the cliff. Sound waves, generated by the shout, travel through the air until they strike the cliff. There they are reflected or bounced off, and some are returned to the originating spot. These reflected waves are the echo that the person hears.

Time elapses between the instant the sound originates and the time the echo is heard. Because sound waves travel through air at approximately 1100 feet per second, the distance of the reflecting surface from the shouter can be computed as $(1100)t/2$, where $t/2$ is one-half the elapsed time, corresponding to one-half the round trip distance out and back.

Most radar systems operate on a principle very much like that just described. The major difference is that radar utilizes radiofrequency electromagnetic waves, instead of sound waves, to detect the presence of reflecting surfaces.

At least three methods of radar detection are in use today. These are (1) the continuous-wave method, (2) the frequency-modulation method, and (3) the pulse-modulation method. This last method is the most common, and is the only one discussed in this text.

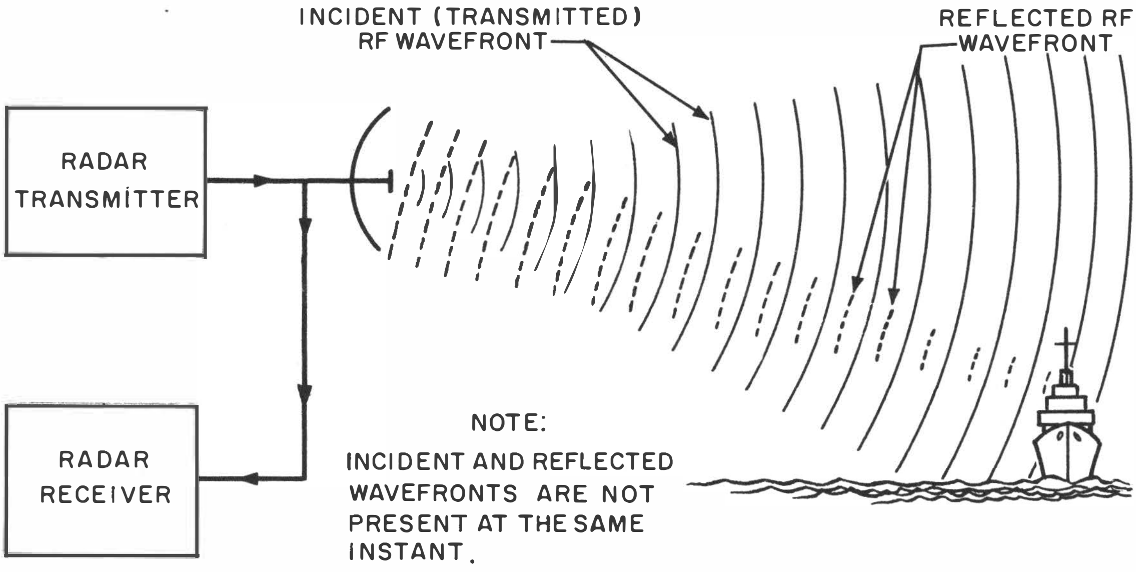
In the pulse-modulated method (fig. 5-1), the transmitter sends out short pulses of r-f energy at regular intervals. Depending on the particular radar, the duration of the transmitter pulse ranges between 0.1 and 5.0 microseconds. Each transmitting period is followed by a receiving period of relatively much longer duration than the transmitting period. The transmit-receive cycle is repeated many times per second, with the repetition rate depending on the design of the set.

RANGE DETERMINATION

The employment of radar to determine the range (distance) to a target is made possible by (1) our knowledge of the velocity of the transmitted radiofrequency energy in space, and (2) the measurement of the time required for the energy to reach a target and return.

Once radiated into space, radiofrequency energy travels at the speed of light. In terms of distance traveled per unit of time, it travels approximately 186,000 land miles per second, or 164,000 nautical miles per second. To make practical use of this velocity-distance relationship, it is necessary to consider distance in terms of yards and time in terms of microseconds (μs). Computing mathematically, we find that r-f energy travels 328 nautical yards in 1 microsecond. This means that approximately 6.18 microseconds are required for the energy to travel 1 nautical mile, or 2027 yards (6080 feet). For convenience, however, all Navy radar ranging (including equipment calibration) is based on a flat figure of 2000 yards (6000 feet) per nautical mile; and the 6.18 microseconds is rounded off to 6.1.

The action of range determination is explained with the aid of figure 5-2 and a target at a 20-mile range. Information obtained during the radar operation is presented visually on the face of a cathode ray tube (scope). The



72.58

Figure 5-1.—Pulse-modulated method.

tube face (screen) for certain types of indicators usually is covered with a translucent scale graduated from 0 to the maximum range (in yards or miles). In this instance the maximum range is 20 miles. A horizontal sweep voltage causes the cathode ray beam to trace across the screen beneath the scale. Scale readings indicate the actual target range.

In part 1 of figure 5-2, a radiofrequency pulse is transmitted and is just leaving the antenna. A small "pip" is produced at the zero-mile mark on the scope at the instant the radar energy is transmitted. The leading edge of this pulse serves as the reference from which target distance is measured.

In part 2, 61 μs later, the transmitted pulse has traveled 10 miles toward the target. The sweep trace, which is timed to show true range by indicating one-half the distance the r-f pulse has traveled, is now at the 5-mile mark.

In view 3 of figure 5-2, 122 μs after the transmission interval, the r-f energy has reached the target, 20 miles away; a relatively small r-f reflection, or echo, has started back. The scope trace is now at the 10-mile mark.

In part 4, 183 μs after transmission, the echo has returned half the distance from the target, and the scope is now at the 15-mile mark.

Finally, at part 5 of the illustration, 244 μs after transmission of the initial pulse, the echo has returned to the radar receiving antenna. This relatively small amount of r-f energy is amplified and applied to the vertical deflection system of the scope, and an echo pip of smaller amplitude than the initial pip is displayed at the 20-mile mark.

If two or more targets are in the path of the transmitted pulse, each returns a portion of the transmitted energy in the form of echoes. The target at the greatest distance away (assuming all targets are similar in size and type of material) will return the weakest echo.

BEARING DETERMINATION

Bearing (also called azimuth) is the direction of an object from the observer, expressed in degrees clockwise through 360° around the horizon. True bearing is measured from true north; relative bearing is measured from the heading of the ship. In radar applications, bearing (true or relative) of the target may be determined by concentrating the radiated energy in a narrow beam, and by knowing the beam direction when a target pip is picked up.

Radar antennas are designed to produce a single narrow beam of energy in one direction (fig. 5-3). The receiving beam pattern is the same as the transmitting pattern. The antenna and associated lobe of r-f energy are either rotated in the horizontal plane through 360° or "rocked" back and forth so that they sweep over a given area. When a target is encountered, a return signal is received. The antenna may then be positioned so that the received echo signal is maximum. The maximum signal strength indicates that the axis of the lobe passes through the target. The radar set is equipped with bearing indicators so that target bearing can be measured either from true north or with respect to the heading of a ship (or aircraft) containing the radar set.

The bearing of a target can be determined in several ways. When the single-lobe method is used, the sensitivity of the system depends on the angular width of the lobe pattern. If the signal strength changes appreciably when the antenna is rotated through a small angle, the accuracy with which the on-target position can be selected is great.

When the antenna lobe is rotated from position A to position B (shown in parts 1 and 2 of fig. 5-3), the increase in the signal strength received is small. Thus, the bearing of the target cannot be determined accurately. If the energy is concentrated in a narrower beam, as shown in part 3 of figure 5-3, the change in signal strength is greater as the antenna is rotated again from A to B, and a more accurate determination of bearing is possible.

ALTITUDE DETERMINATION

The remaining dimension necessary to locate completely an object in space can be expressed either as an angle of elevation or as an altitude. If one is known, the other can be calculated from one of the basic trigonometric ratios. A method of determining the angle of elevation and the altitude is shown in figure 5-4. Slant range (part A, fig. 5-4) is obtained from the radarscope indication as the range to the target. The angle of elevation is the same as that of the radar antenna (part B, fig. 5-4). Altitude is equal to the slant range multiplied by the sine of the angle of elevation.

In radar equipment with antennas that can be elevated, altitude determination by slant range is computed automatically by electronic means.

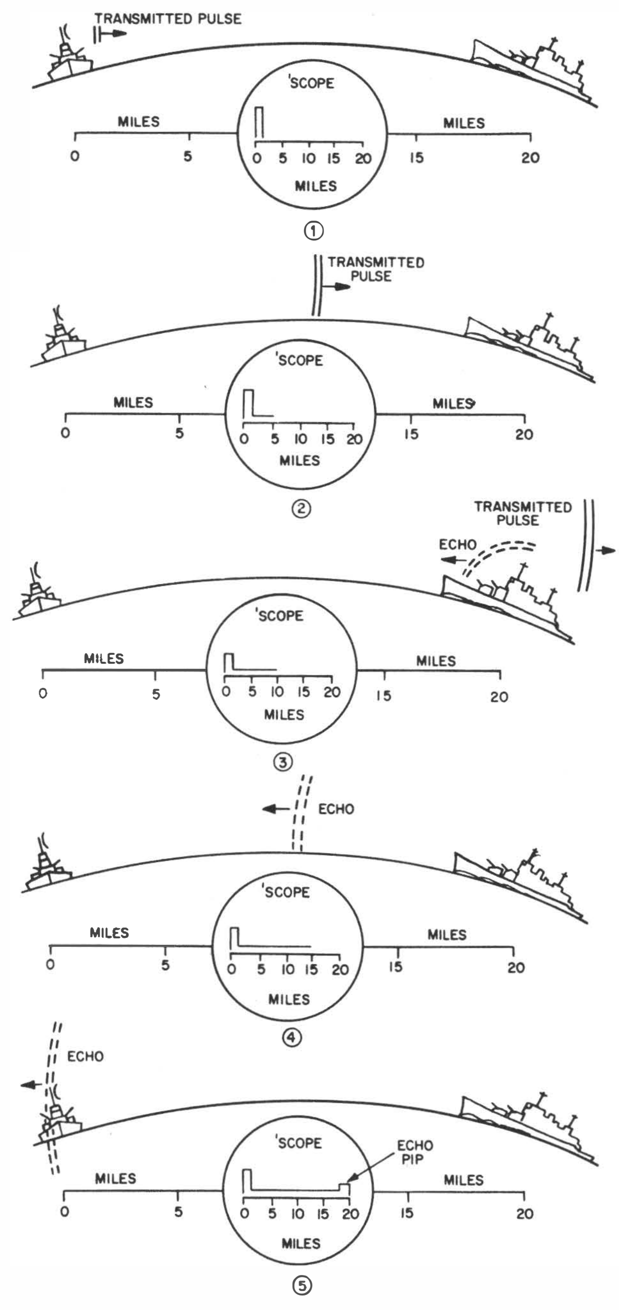


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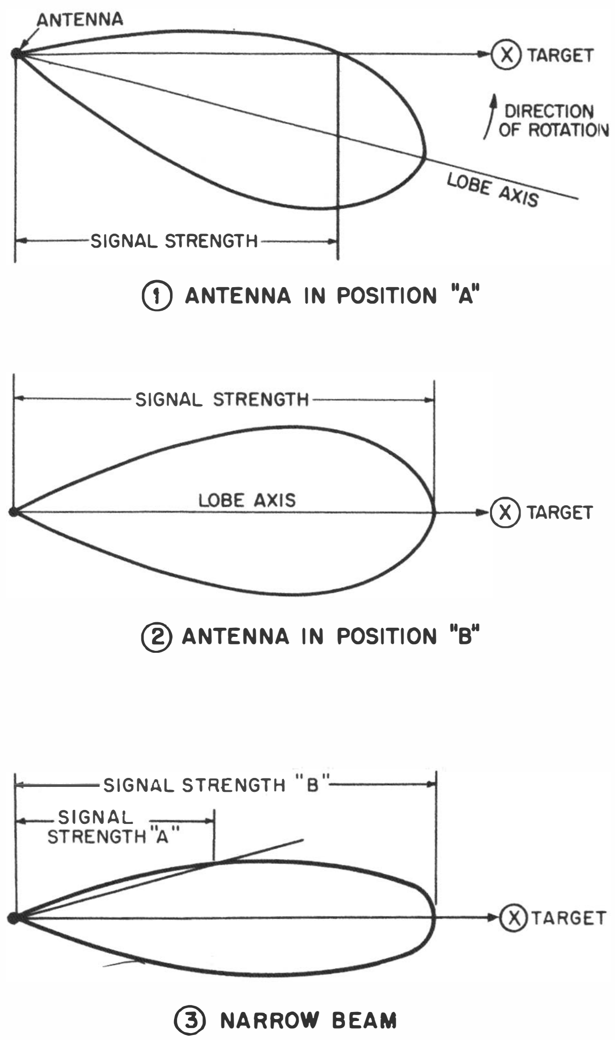
Figure 5-2.—Radar range determination.

BASIC PULSED RADAR SYSTEM

A block diagram of the basic units of a pulse-modulated radar system is shown in



20.284
Figure 5-3.—Radar determination of azimuth or bearing.

figure 5-5. The modulator produces the timing pulses that trigger the transmitter and indicator. These timing pulses are converted by the transmitter into high-power pulses of r-f energy at the assigned frequency. The use of one antenna for both transmitting and receiving is made possible by the duplexer. It directs the transmitter outgoing pulses to the antenna (away from the receiver) and the incoming echo pulses to the receiver (away from the transmitter). The antenna radiates the r-f energy as a directional beam, and receives the echo pulses only from the direction in which the antenna is pointing. The receiver amplifies the received echo pulses reflected from the target, and applies them to the indicator. There they are displayed on a cathode ray tube. Necessary power for the various radar functions is supplied by the power supply. A more detailed description of some of the individual blocks follows.

MODULATOR

The transmit-receive periods in a pulsed radar system are controlled by synchronizing signals generated in the modulator or synchronizer. Usually, the basic control device within the modulator is a very stable oscillator. The oscillator output is amplified, shaped as required, and fed as synchronizing pulses to the transmitting, receiving, and indicating sections.

The transmit period in a radar system is much shorter in duration than the receive period. Sufficient time must be allowed during the receive period (between transmissions) to

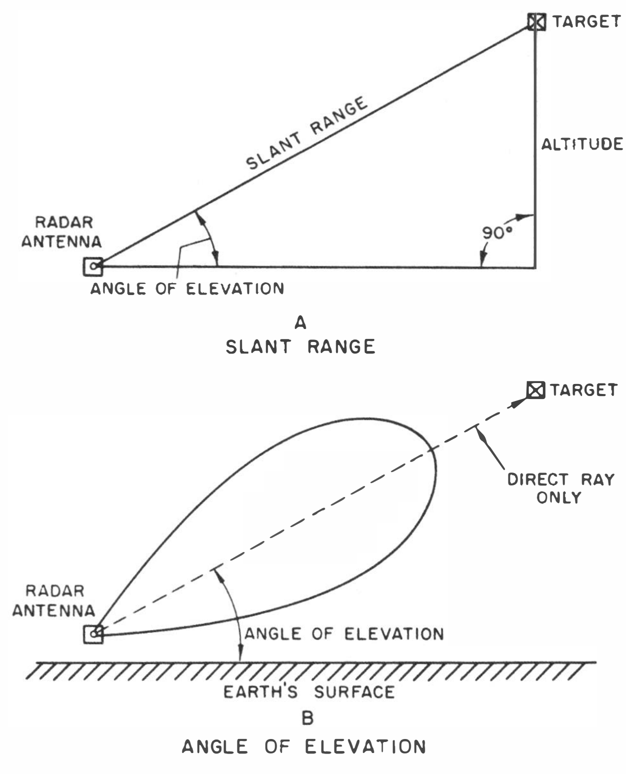


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Figure 5-4.—Radar determination of altitude.

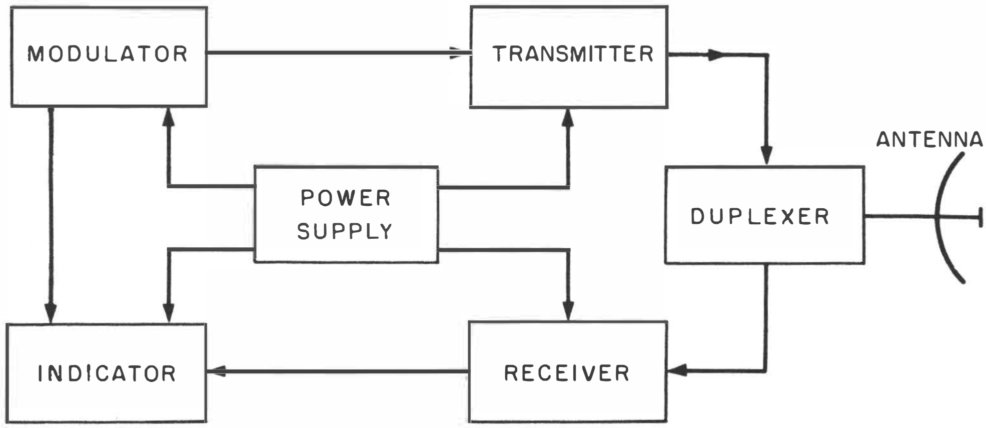

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Figure 5-5. —Block diagram of a pulse-modulated radar system.

ensure the return of echoes from the maximum desirable range of the system. Thus, the maximum range from which echoes can be received for a target of given size depends on the relationship of the time between transmission bursts (pulse repetition period) and the r-f power generated.

The relationship between pulse repetition rate (PRR) and maximum range is explained with the aid of the following example. Assume that sufficient power is transmitted to produce useful echoes from a target of appreciable size. The pulse repetition period is the reciprocal of the pulse repetition rate. Thus, PRP = 1/PRR. If the PRR is 250 pulses per second (PPS), the period is 1/250 = .004 sec or 4000 μs. Assuming further that the transmission period contained in this time period is of negligible duration, and by knowing that each mile traversed by the r-f energy requires approximately 6.1 μs to travel in each direction (or 12.2μs per mile), it is seen that the maximum range is 4000μs/12.2μs = 328 miles.

Although maximum range increases with a decrease in pulse repetition rate, it should be noted that the antenna system is rotated at a relatively rapid rate, and the beam of energy strikes a target for a relatively short time. During this time, a sufficient number of pulses must be transmitted and their echoes received to produce a visual indication of target presence. The most desirable pulse repetition rate, then, is a compromise between maximum range and indicator requirements.

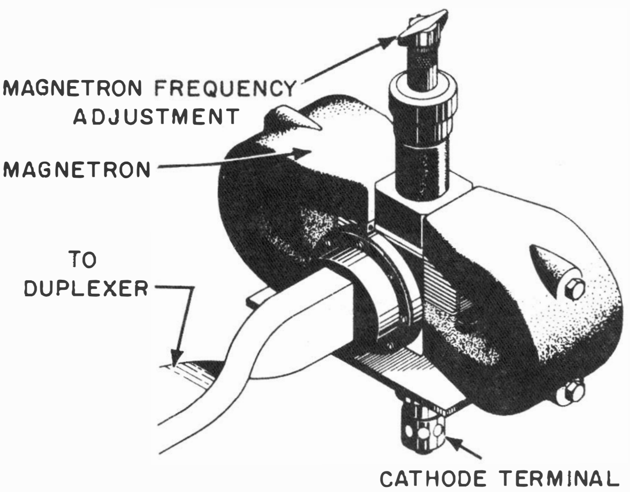
The minimum range at which a target can be detected is governed largely by the width (duration) of the transmitted pulse. If a target is so close to the transmitter that the echo is returned before the transmitter is turned off, reception of the echo is masked by the transmitted pulse. Hence, for short ranges, the transmitted pulse must be of short duration to permit the detection of close-in targets.

The choice of pulse repetition rate, pulse width, frequency, and transmitter power output is decided by these five conditions: (1) the tactical use of the system, (2) accuracy required, (3) range to be covered, (4) overall physical size, and (5) the most practical method of generating and receiving the signal.

TRANSMITTER

An outgoing radiofrequency pulse of extremely short duration is generated by the transmitter each time a keying pulse is received from the modulator. The frequency of the r-f pulse is high because the directivity of the radiated beam is greater at high frequencies. Moreover, the higher the frequency, the shorter the wavelength; hence, the smaller and lighter will be the antenna system components.

A special microwave oscillator tube, called a magnetron (fig. 5-6), frequently is used as the transmitting tube in radar systems. A pulse from the modulator, shaped and amplified to form a strong negative pulse, is



32.180

Figure 5-6.—Magnetron.

applied to the magnetron cathode. The presence of this pulse causes the tube to oscillate for the duration of the pulse. The frequency of the magnetron oscillations may approximate several thousand megacycles. Usually the peak power output ranges between 100 and 1000 kw but, because the short duration of the pulse results in a much lower average power, the components are relatively small.

In a radar system using a magnetron (fig. 5-7), the magnetron output is fed to the radar antenna through a duplexer and a waveguide. The duplexer consists of antitransmit-receive (ATR) and transmit-receive (TR) switches that prevent the high-powered r-f output of the transmitter from entering the receiver, but permit the returning signal to enter the receiver unimpeded. The duplexer and the waveguide physically connect the transmitter to the antenna.

Some radar transmitters are similar to radio (communication) transmitters. Figure 5-8 is a block diagram of a radar transmitter. Instead of the single magnetron, the radar transmitter consists of an electron tube oscillator, amplifiers, frequency multipliers, drivers, and power amplifiers. Although the stages and their purposes are the same as those in a communication transmitter, the peak power requirements are much higher in a radar transmitter, and it is necessary to use special power amplifier tubes. Klystrons and traveling wave tubes are examples of these tubes, but, because of their complexity, they are not treated in this text.

In the electron tube type of radar transmitter, frequency stability is ensured by using only the most stable type of oscillator-buffer arrangement, and by operating the oscillator at a submultiple of the transmitter output frequency. Frequency multipliers then are used to produce the desired output frequency. The driver stages increase the r-f power. The modulator supplies keying pulses to the final power amplifier stages, thereby controlling the duration and repetition rate of the transmitted pulses. Finally, as in the magnetron type of transmitter, the duplexer and the waveguide provide the physical connection between the transmitter and the antenna. Monitoring circuits along the waveguide produce information necessary for tuning the transmitter and receiver, as well as for various tests.

RECEIVER

The receiver used in a particular radar system depends on the design of the transmitter. In the system with the magnetron, the receiver (fig. 5-9) does not have r-f amplifiers preceding the mixer stage. The incoming signal (echo) is fed, via the duplexer, directly from the antenna to the mixer. In the mixer, the incoming signal is mixed (heterodyned) with an unmodulated r-f signal generated by the local oscillator. Heterodyning in the mixer produces the intermediate frequency, which, in turn, is fed through several i-f stages before it is detected. The detector output (called "video") is amplified in several stages before being fed to the indicator where a visual indication of the received echo is produced.

Another output from the mixer goes to the automatic frequency control (AFC) circuit. This circuit produces a d-c voltage proportional to the amount of error (if any) in the frequency of the i-f signal. The error voltage is applied to the local oscillator in such a manner that it changes the oscillator frequency until the mixer output (i-f) is on frequency. This action ensures a constant intermediate frequency, regardless of changes in the magnetron frequency or tendencies of the local oscillator to drift.

Some radar receivers (not illustrated) differ from the type just described in that they require the use of r-f amplifiers ahead of the mixer stage. Essentially, these receivers are of the conventional superheterodyne type.

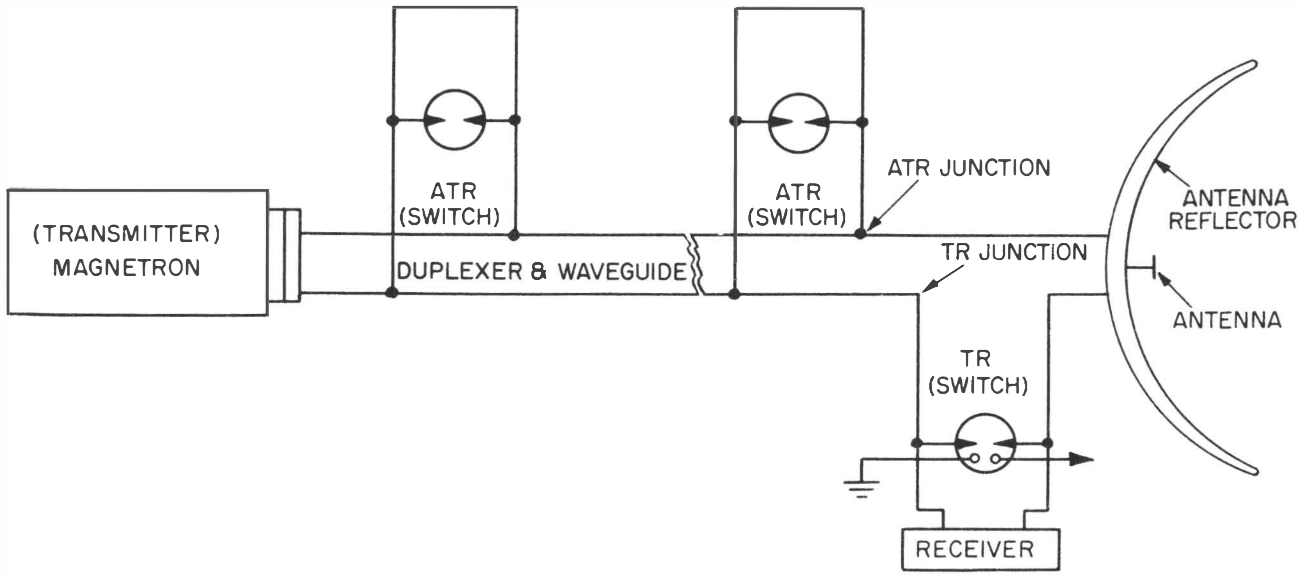


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Figure 5-7. —Transmitting section of pulsed radar system using a magnetron.

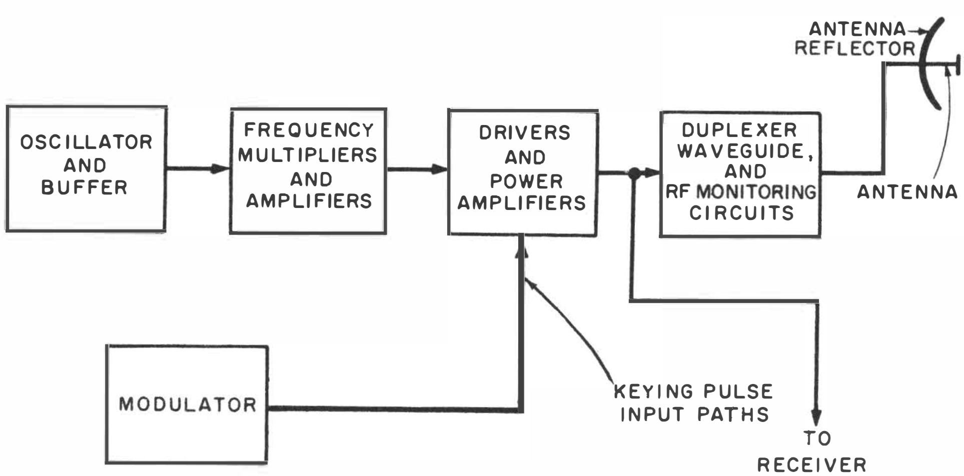

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Figure 5-8.—Transmitting section of pulsed radar system using oscillator, multipliers, and amplifiers.

INDICATOR

The purpose of the indicator is to present visually the information gathered by the radar set. In the early days of radar, the indicator was a part of the main radar console. With the increase in numbers and purposes of radar sets aboard ship, however, remote indicators (radar repeaters) became necessary.

A representative radar repeater is shown by block diagram in figure 5-10. The repeater consists of a scope (cathode ray tube), a power

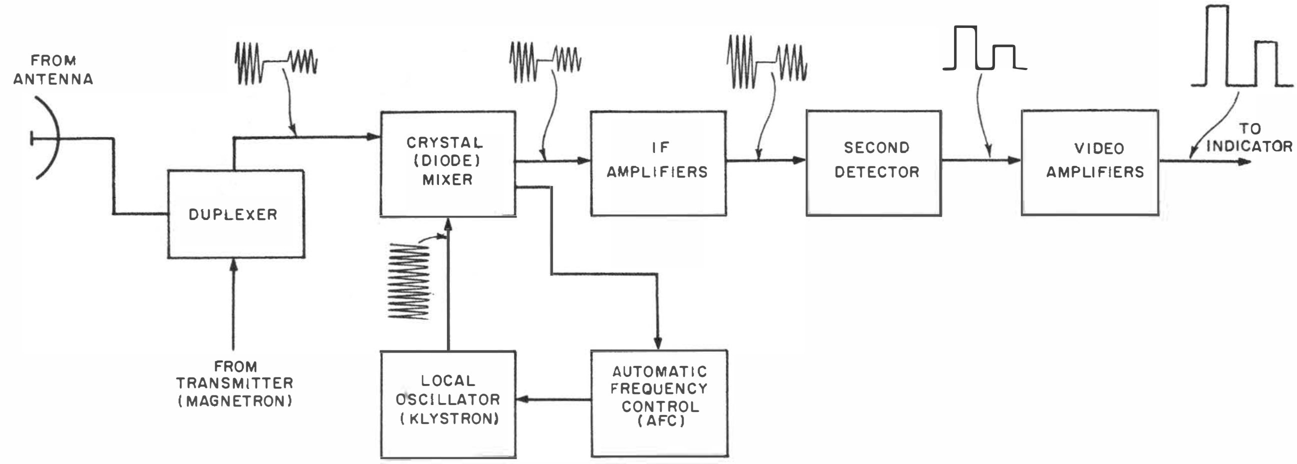

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Figure 5-9. —Radar receiver used in conjunction with a magnetron transmitter.

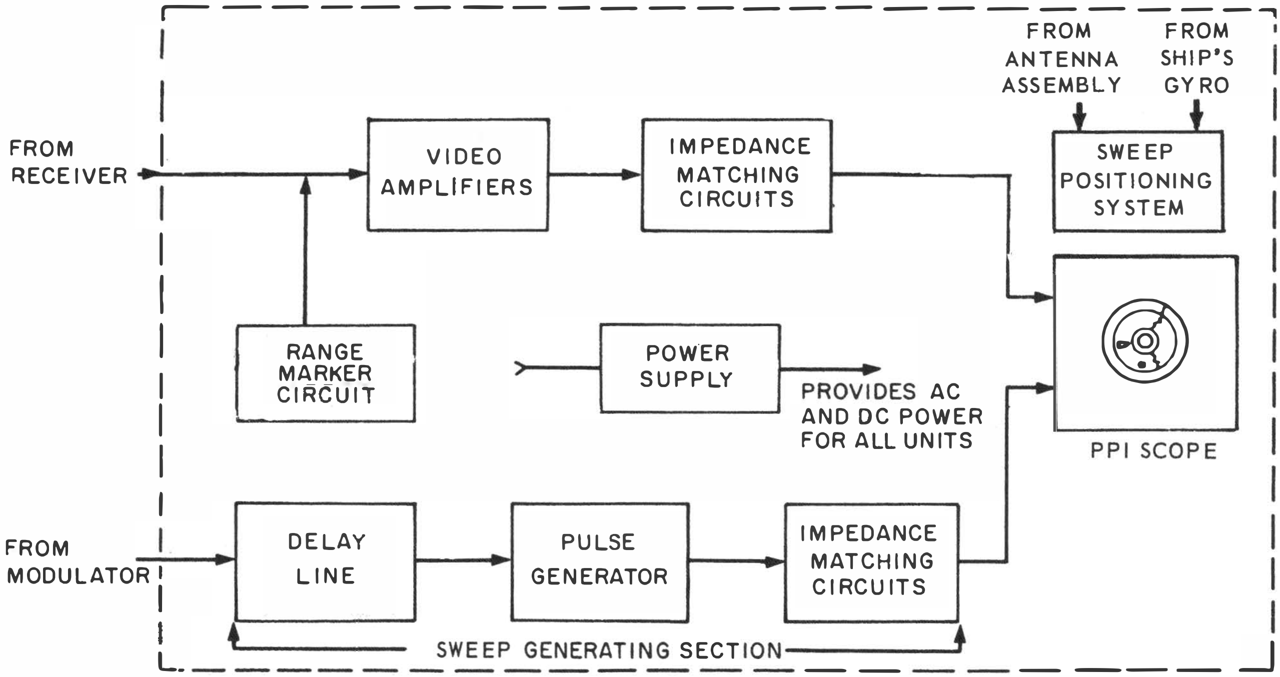

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Figure 5-10. —Radar indicator.

supply, video amplifiers, a sweep generating section, a sweep positioning system, impedance matching circuits, and a range marker circuit.

When the modulator sends a keying pulse to the transmitter, it also sends a triggering pulse to the indicator. This trigger pulse, processed through the sweep generating section of the indicator, appears on the face of the scope coincidently with the transmission of the r-f pulse from the antenna. In other words, the trigger pulse initiates the trace or sweep across the face of the scope, and the beginning of the trace indicates the time the radar signal is transmitted.

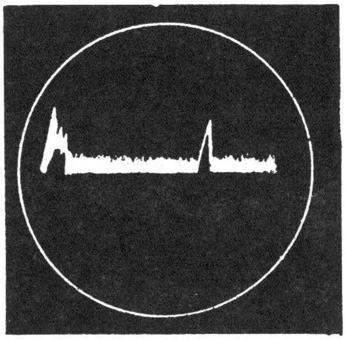
The target echo pulse (video) from the receiver is increased in amplitude by video amplifiers. It then is applied to the scope via impedance matching circuits. Depending on the type of presentation employed, the echo appears on the trace (or sweep) as a pip or a bright spot. As stated earlier, the time of appearance of the echo pulse is indicative of the target range.

Information from the ship's gyrocompass and the radar antenna assembly is applied to the indicator through a sweep positioning system. This system positions the sweep to a true bearing, and synchronizes the rotation of the sweep with the rotation of the antenna. Without true bearing data from the gyro, the position of the sweep indicates a relative bearing.

Range markers can be displayed on the screen to aid the operator in estimating the range of a target. In addition, most radar repeaters are equipped with a mechanical or electronic cursor that facilitates the accurate reading of bearing. Some radar repeaters also are equipped with a range strobe or bug that permits accurate measurement of range.

Types of Presentations

While the radar beam is systematically scanning the surrounding area, the results of each scan are presented on various scopes. Several types of scope presentations (or scans) are used to display the target information. Only the basic types are discussed here, however. In each type, the screen of the cathode ray tube is illuminated by an electron beam (spot), which moves swiftly across the screen, leaving a line of light (called the sweep or trace) in its wake. The manner in which the sweep appears on the screen depends on the type of presentation.



59.4

Figure 5-11.—A-scope presentation.

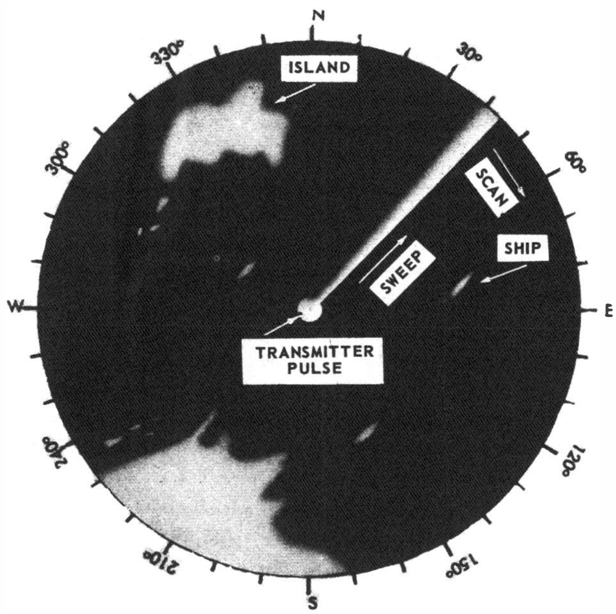
A-SCOPE.—Earlier types of scope presentations were identified by a single letter of the alphabet, such as the A-scope shown in figure 5-11. The A-scope is used to determine range only. Its screen has a short persistence; that is, it glows for only a short time after the illuminating spot is removed. The echo is presented on the screen as a vertical displacement of the horizontal trace, and the point at which the displacement occurs indicates the range to the target.

At one time, the A-scope presentation was the major type of display. For accurate measurements, however, the antenna had to be stopped and pointed directly at the target. This disadvantage was overcome by the development of the planned position indicator (PPI) type of display.

PPI SCOPE.—The PPI scope (fig. 5-12) presents both range and bearing information. Usually, this scope is employed in a radar system whose antenna is uniformly rotated around the vertical axis. The trace on the scope rotates in synchronization with the antenna.

Large numbers of pulses are transmitted for each rotation of the antenna. As each pulse is transmitted, the scan spot starts at the center of the screen and moves toward the edge of the screen along a radial line. Upon reaching the edge, the spot quickly returns to the center and begins another trace with the next transmitted pulse. The return trace of the spot is eliminated from the screen by a process called blanking.

When an echo is received, the intensity of the scanning spot increases considerably, and



53.109
Figure 5-12.—PPI presentation.

a bright spot remains at that point on the screen. The position of the radial line on which the echo appears indicates the target bearing. The distance of the target pip from the origin of the radial line indicates the target range.

Unlike the A-scope, the PPI scope has long persistence. Because of this characteristic, it is possible to produce a map of the surrounding territory on the scope face, making the PPI presentation useful as an aid to navigation. The PPI scope presentations also provide the observer with instantaneous changes of target positions in all directions.

RHI SCOPE.—Some radars are equipped with special antennas that enable altitude information to be obtained. The range height indicator (RHI) scope is used to display altitude data. (See fig. 5-13.)

Except for the type of information displayed, the RHI is similar to the PPI. On both scopes, the sweep pivots from one point, and target echoes are shown in bright relief against the background. The sweep on the RHI screen, however, does not go through 360°. Instead, the sweep is synchronized with an antenna that scans vertically through a few degrees and returns to a preset elevation.

An altitude cursor appears across the face of the RHI scope. The cursor, curved to conform to the earth's surface, can be moved up or down. The vertical movement of the cursor is recorded by an associated set of counters. With the cursor aligned so that it bisects the target, altitude is read on these counters. The slant range to the target is indicated along the baseline of the sweep.

Because bearings cannot be read from an RHI scope, the RHI operator usually works in conjunction with the PPI operator who coaches him onto the target on which altitude information is desired.

ANTENNAS

Instead of emitting radio waves in all directions, the radar antenna must send them out in a concentrated beam. One method of obtaining this directional effect is to arrange two or more dipoles so that radiation from the dipoles adds in some directions and cancels in other directions. (Dipoles are conductors that are one-half wavelength long at the carrier frequency of the radar.) When a reflector (either metal or another set of dipoles) is placed behind the dipoles, radiation occurs in one direction, and the resulting lobes of transmitted energy are similar to those shown in figure 5-14.

Another method of obtaining directivity in the emitted radar beam is to situate the open, flanged end (feed horn) of the waveguide so that the r-f energy is sprayed against the reflector. Then, the reflector is shaped so that the beam is concentrated as desired.

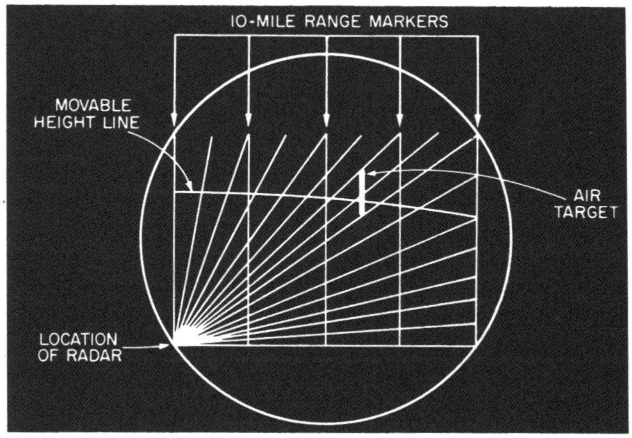


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Figure 5-13.—RHI presentation.

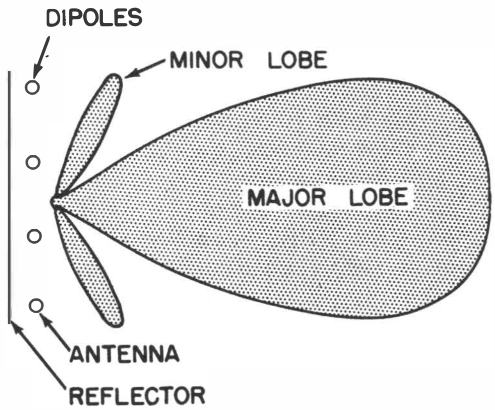

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Figure 5-14.—Directivity of radar beams.

Many types of antennas are used with military radar systems, and they vary in appearance considerably. Although the radiating element actually is the antenna, the entire antenna array is implied when the term "antenna" is used in this text.

BEDSPRING ARRAY

The bedspring array (fig. 5-15), so called because of its resemblance to a bedspring, is used with air-search radars. It consists of a stacked dipole array with an untuned reflector. The more dipoles that are used or stacked in one dimension (horizontal, for example), the more narrow the beam of radiated energy becomes in that same plane. Consequently, the size of the antenna is not the same for all installations.

Because of its relatively large size, the bedspring array is being replaced by antennas of a more compact design.

PARABOLOIDAL ANTENNA

The paraboloidal (or parabolic) antenna, shown in figure 5-16, consists of a dipole or feed horn radiator and a parabolic or dish-type reflector. This type of antenna produces a narrow beam, the degree of whose concentration is determined by the size and shape of the reflector.

Because the lobe produced by the parabolic antenna is narrow and sharp, its chief function is with fire control and special-purpose radars. It is not used with most shipboard air-search or surface-search radars, because the roll of the ship could cause the very narrow vertical beam to miss a target.

BARREL STAVE ANTENNA

With a simple modification to the reflector, the parabolic antenna becomes the barrel stave antenna. (See fig. 5-17.) Essentially, the barrel stave reflector is a parabolic reflector with the top and bottom cut away, leaving only the center part of the reflecting surface.

The lobe produced by the barrel stave reflector still is narrow horizontally. But, because there is no surface to restrict its vertical height, the lobe becomes a high vertical beam suitable for surface-earth. The height of the lobe is great enough to prevent the roll of the ship from causing a target to go undetected.

BILLBOARD ARRAY

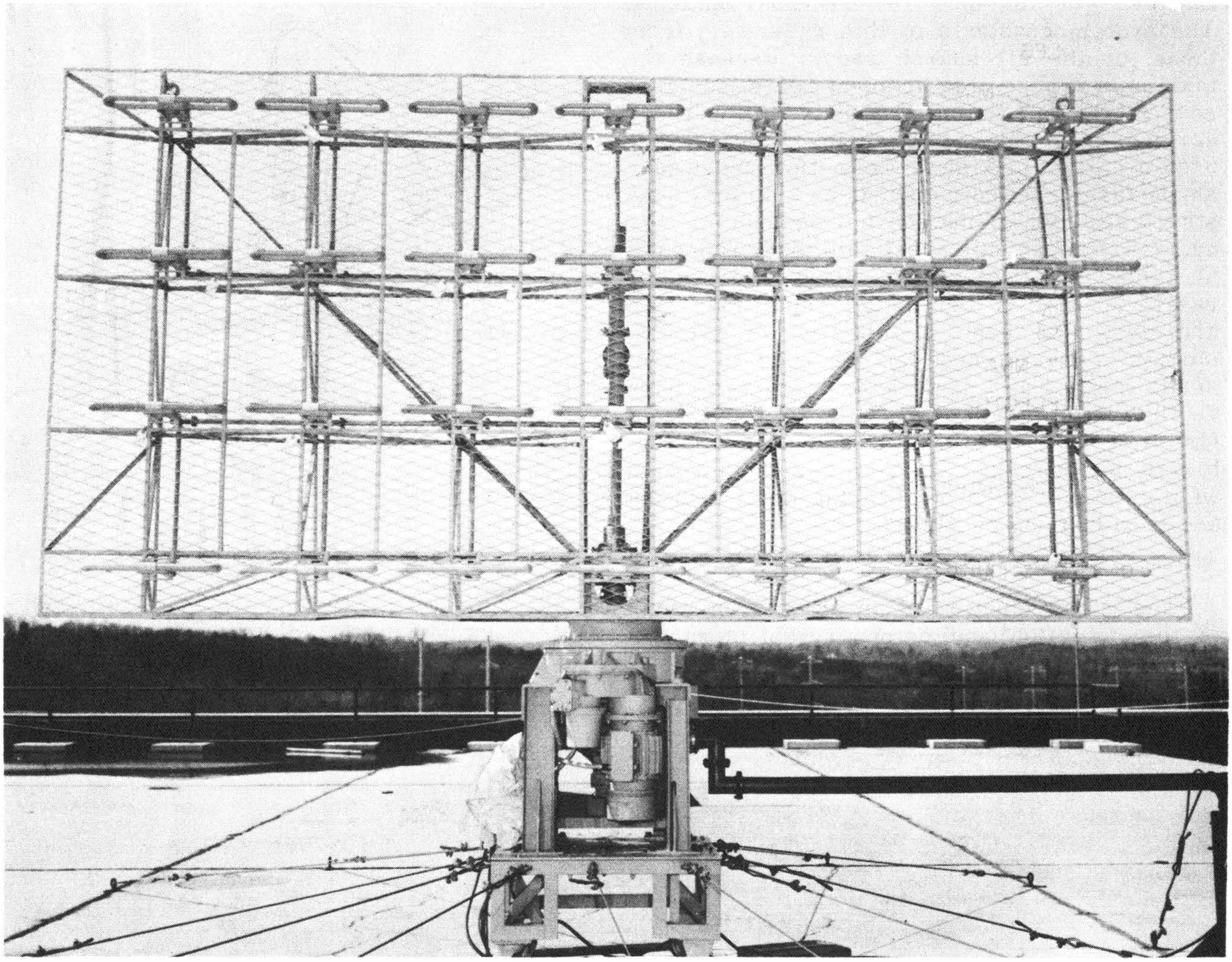
A billboard or fixed array is one in which an antenna or antenna system is placed in front of a large plane-reflecting surface. Such an antenna is shown in figure 5-18. The reflecting surface may consist of rods (joined at the end), mesh, or a solid sheet of conducting material.

Because of their large size and weight, fixed array installations presently are limited to larger ships. The installation consists of four billboard antennas built into the superstructure so that each antenna covers a 90° sector around the ship. This type of installation ordinarily is used with air-search radars.

RADAR FREQUENCY BANDS

Frequency ranges within the UHF and SHF bands are broken into narrower bands of frequencies. They are designated by letters, as P, S, L, X, and K. These bands are further subdivided by subletters and/or numbers, as S_a, S_1, X_{bl}, X_c, and so forth. For example, say the S-band covers a total frequency range from 3000 mc to 4000 mc. Then 3000-3200 mc might be designated the S_a-band, 3200-3500 the S_b-band, and 3500-4000 mc the S_c-band.

In applying these designations, the descriptive information concerning frequency of operation of a radar equipment would state "Frequency range: S_a-band," instead of the actual frequency in figures. The frequency ranges of each radar band are contained in other



33.109

Figure 5-15.—Bedspring array.

publications; hence, they are not given here. In many instances the operating frequencies of certain equipments are classified, for which reason any discussion of the frequencies should be cautious.

RADAR FUNCTIONS AND CHARACTERISTICS

No single radar set has yet been developed to perform all the combined functions of air-search, surface-search, altitude-determination, and fire control because of size, weight, power requirements, frequency band limitations, and so on. As a result, individual sets have been developed to perform each function separately.

Most of the radar sets that are designed for a specific purpose, such as surface-search, have certain system constants or general characteristics in common. The remainder of this chapter is devoted to a brief discussion of the functions and characteristics of various radar and radar ancillary systems.

SURFACE-SEARCH RADARS

The principal function of surface-search radars is the detection and determination of accurate range and bearing of surface targets and low-flying aircraft while maintaining 360° search for all surface targets within line-of-sight distance of the radar antenna. The system constants of this radar vary from those of the air-search radar. Because the maximum range requirement of a surface-search radar is limited mainly by the radar horizon, very high frequencies (X-band) are used to give maximum reflection from such small target-reflecting areas as ship masthead structures and submarine periscopes. Narrow pulse widths permit short minimum ranges, a high degree of range resolution, and greater range accuracy. High pulse repetition rates are used for best illumination of targets. Medium peak powers can be used to detect small targets at line-of-sight distances. Wide vertical beam widths are used to compensate for pitch and roll of own ship and to detect low-flying aircraft. Narrow horizontal beam widths permit accurate bearing determination and good bearing resolution.

AIR-SEARCH RADARS

The chief function of an air-search radar is the detection and determination of ranges

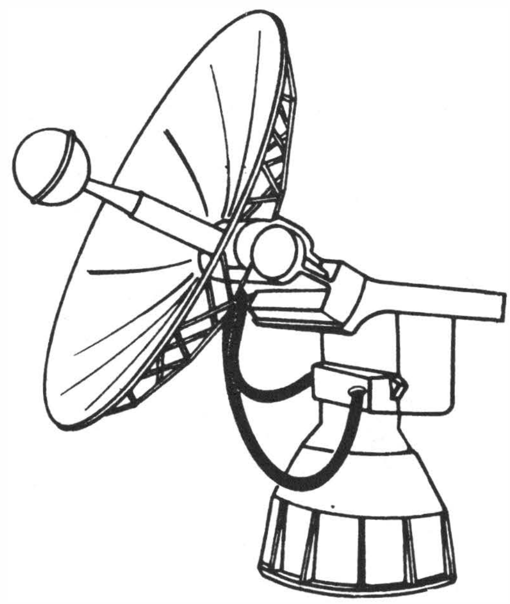


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Figure 5-16.—Parabolic antenna.

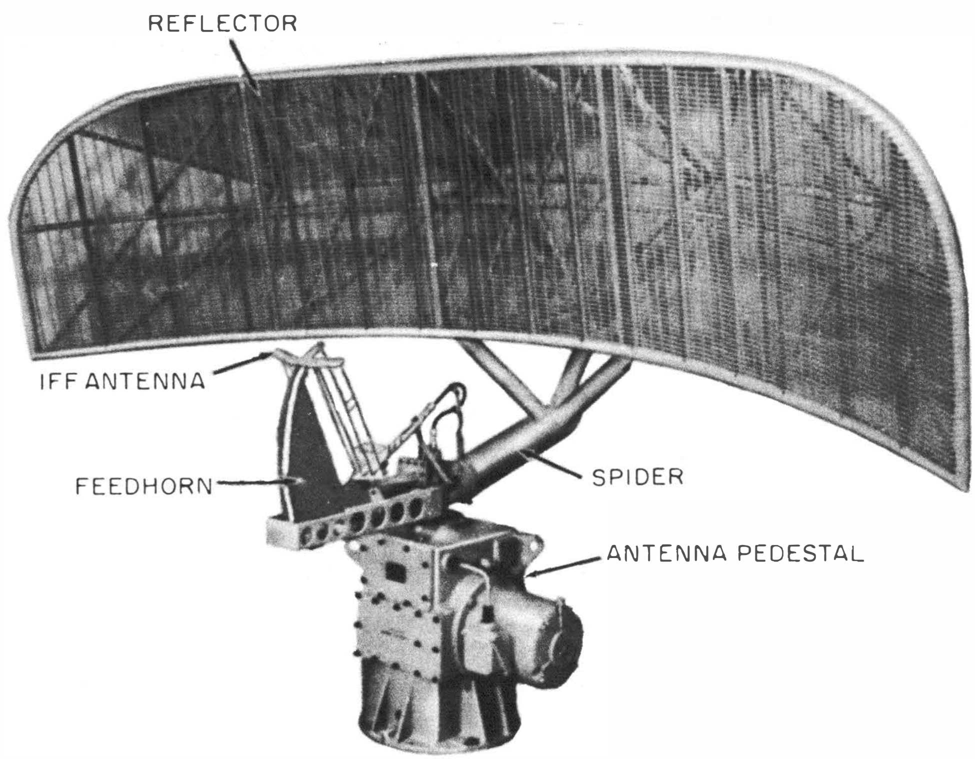

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Figure 5-17.—Barrel stave antenna.

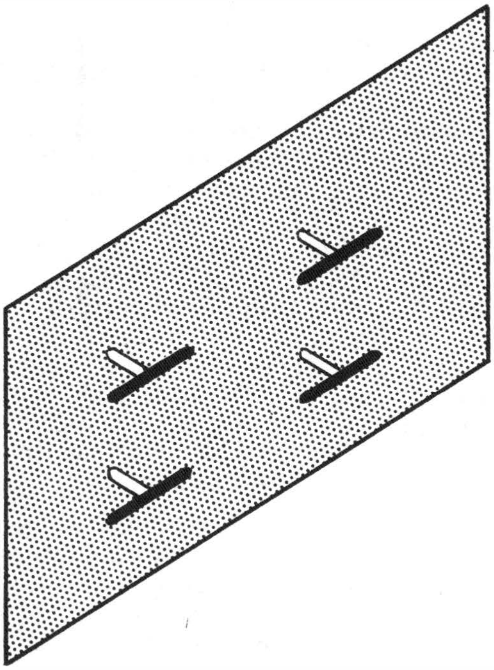

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Figure 5-18.—Billboard array.

and bearings of aircraft targets at long ranges (greater than 50 miles), maintaining complete 360° search from the surface to high altitude. System constants must be selected with this function in mind. Low frequencies are chosen (P- or L-band) to permit long-range transmissions with minimum loss of signal. Wide pulse widths (2 to 4 microseconds) increase the transmitting power and are used to aid in detecting small targets at greater distances. Low pulse repetition rates are selected for greater maximum measurable range. High peak power permits detection of small targets at long ranges. Wide vertical beam width is used to ensure detection of targets from the surface to relatively high altitude and to compensate for the pitch and roll of the ship. Medium horizontal beam width gives fairly accurate bearing determination and bearing resolution while maintaining 360° search coverage.

ALTITUDE-DETERMINING RADARS

The function of the altitude-determining radar is to find the accurate range, bearing, and altitude of aircraft targets detected by air-search radar. Its antenna must be tilt-stabilized to provide a stable reference for altitude determination. High frequencies (S-band) are chosen as a compromise between the long-range capabilities of lower frequencies and the narrow beam-forming characteristics of higher frequencies. Narrow pulse widths (1 microsecond) are chosen to permit good range resolution. High pulse repetition rates (600 to 1000 PPS) permit detection of small aircraft targets at medium ranges (30 to 50 miles). High peak power permits the detection of small aircraft targets at medium ranges while using narrow pulse width. Narrow vertical and horizontal beam widths (1° to 3°) are selected to permit accurate bearing and position angle determination and good bearing and elevation resolution.

FIRE CONTROL RADARS

The principal function of fire control radars is the acquisition of targets originally detected and designated from search radars, and the determination of extremely accurate ranges, bearings, and position angles of targets. Antennas must be tilt-stabilized to compensate for pitch and roll of own ship. Very high frequencies are chosen (X-band and K-band) to permit the formation of narrow beam widths with comparatively small antenna arrays, detection of targets with small reflecting areas, and good definition of all targets. Pulse widths (0.1 to 3 microseconds) provide a high degree of range accuracy, short minimum range, and excellent range resolution. Repetition rates (1500 to 2000) afford maximum target detection while using narrow pulse widths. Because very long ranges are not required, low peak power permits the use of smaller components by keeping the average power low. Narrow vertical and horizontal beam widths (0.9° to 3°) provide accurate bearing and position angles and a high degree of bearing and elevation resolution.

MISSILE GUIDANCE RADARS

In general, missile guidance radars operate on the same principles as the air-search, altitude-determining, and fire control radars just described. Although used for missile or target tracking in several missile guidance systems, the chief application of radar is in the beam-rider guidance system.

The beam-rider system is highly effective for use with short-range and medium-range surface-to-air and air-to-air missiles. For missiles of longer range, a beam-riding system may be used during the midcourse phase of flight, while the missile still is within effective range of the beam-transmitting radar. As it approaches the limit of beam-riding range, the missile switches over to some other form of guidance.

Two types of beam-rider systems are possible. In the simplest type, a single radar with a narrow lobe is used for both target tracking and missile guidance. In the other, one radar is used for tracking, while another generates the very narrow guidance beam. The single-radar system has the advantage of simplicity, but it is not nearly as effective as the two-radar system.

In the two-radar system, a computer is used between the radars, and the missile guidance radar is controlled by the computer. The computer takes target information—speed, range, and course—from the tracking radar, and computes the course that must be followed by the missile. The output of the computer controls the direction of the guidance radar antenna, and points the guidance beam toward the point of target interception. Because the computer receives information constantly, it is able to alter the missile course as necessary to offset evasive action or changes in course by the target.

AEW RADARS

Airborne early warning (AEW) systems are used extensively in the Navy. These systems are special shipboard and aircraft radar equipment that work together as a single unit.

The purpose of the AEW system is to extend the normal radar horizon by placing the radar set in an airplane, and relaying the radar information to the AEW ship for presentation on the ship's indicator. Thus, targets can be seen at considerable greater distances than is possible with standard shipboard radar sets. For example, a plane at a 1000-foot altitude will have a minimum radar detection range of 55 miles on a target 50 feet high. If the plane is relaying radar information to a mother ship 50 miles away, then the ship has an effective search range of 105 miles in the plane's direction. If a relay is directly over a mother ship at 5000 feet, the ship has an effective 360° search range of 100 miles.

IFF SYSTEM

Although technically not a radar equipment, an electronic system that is employed with radar permits a friendly craft to identify itself automatically before approaching near enough to threaten the security of other naval units. This system is called identification, friend or foe (IFF). It consists of a pair of special transmitter-receiver units. One set is aboard the friendly ship; the other is aboard the friendly unit (ship or aircraft). Because space and weight aboard aircraft are limited, the airborne system is smaller, lighter, and requires less power than the shipboard transmitter-receiver. The airborne equipments are automatic, and operate only when triggered by a signal from a shipboard unit.

The IFF systems are designated by MARK numbers. In order to avoid confusion between IFF systems and fire control systems, the IFF mark number is a Roman numeral (Mk III), whereas the fire control number is an Arabic numeral (Mk 29).

The IFF system operates as follows: An air-search radar operator sees an unidentified target on his radarscope. He turns on the IFF transmitter-receiver, which transmits an interrogating or "asking" signal to the airborne transmitter-receiver. The interrogating signal is received by the airborne unit, which automatically transmits a characteristic signal called an identification signal. The shipboard system receives the signal, amplifies it, decodes it, and displays it on the radarscope or on a separate indicator scope. When the radar operator sees the identifying signal and identifies it as the proper one, he knows that the aircraft is friendly.

If the aircraft does not reply when interrogated, however, or if it sends the wrong identifying signal, then the ship must assume that the target is an enemy, and defensive action must be taken. The IFF equipments comprise the interrogator-responder and the identification set (transponder).

The interrogator-responder performs two functions. It transmits an interrogating signal, and it receives the reply. The transponder also performs two functions. Not only does it receive the interrogating signal, but it replies automatically to the interrogating signal by transmitting an identifying signal. The two types of interrogation are direct and indirect. Interrogation is direct when the interrogating signal that triggers the transponder is a pulse from the radar equipment. Interrogation is indirect when the interrogating signal is a pulse from a separate recognition set operating at a different frequency from that of the master radar.

Early IFF systems used direct interrogation. Direct interrogation proved unsatisfactory, however, because the transponder was required to respond to radars that differed widely in frequency. Later IFF systems, consequently, make use of indirect interrogation within a special frequency band reserved for IFF operation.

CHAPTER 6

RADAR EQUIPMENT

The modern warship has several radars. Each radar is designed to fulfill a particular need, but it also may be capable of performing other functions. For example, most height-finding radars can be utilized as secondary air-search radars; in emergencies, fire control radars have served as surface-search radars. To familiarize you with some of the capabilities and limitations of radars and radar accessories, this chapter is devoted to describing the characteristics and uses of various shipboard radar equipment.

Because there are so many different models of radar equipment, the radars and accessories described herein are limited to those common to a large number of ships in the active fleet, and to those that are replacing older equipment currently installed in the fleet.

SURFACE-SEARCH RADARS

As you learned in the preceding chapter, the principal function of surface-search radars is the detection of surface targets and low-flying aircraft and the determination of their range and bearing. The most common surface-search radar in use today is the AN/SPS-10( ). It is described in the next topic.

AN/SPS-10( )

Designed for installation aboard DDs and larger ships, the AN/SPS-10( ) is a medium-range, two-coordinate (bearing and range) surface-search and limited air-search radar. Its maximum range when detecting surface targets is greater, normally, than the optical horizon as viewed from the antenna reflector. (The optical horizon in miles equals 1.22 times the square root of the antenna reflector height in feet.) Actual detection range depends on a number of conditions, including antenna height, target size and composition, weather, and the like. In some instances, targets have been detected at distances exceeding 100 miles.

The AN/SPS-10( ) operates in the frequency range 5450 to 5825 mc, with a peak power output of 285 kw. Its magnetron is tunable over the entire frequency range. This feature is desirable so that its operating frequency can be changed to minimize interference from other radar sets operating at the same frequency.

Two pulse widths are available. The long pulse (1.3 μsec) gives a longer range than the short pulse (0.25 μsec). In addition, the pulse repetition rate (PRR) can be varied between 625 and 650 pulses per second (PPS).

The antenna used with the AN/SPS-10( ) is a horn-fed, truncated parabolic reflector, which rotates in a clockwise direction at an average speed of 16 rpm. Radiated signals have a beam width of 1.5° in the horizontal plane and between 12° and 16° in the vertical plane.

The major units of the AN/SPS-10( ) are shown in figure 6-1. These units are typical of those employed in most surface-search radar systems.

AN/SPS-5( )

The AN/SPS-5( ) radar set is an improved version of the older model AN/SPS-4( ), which it replaced aboard most ships of DE size and smaller. Classed as a medium-range surface-search radar, the AN/SPS-5( ) has a tunable magnetron that permits selection of any operating frequency between 6275 and 6575 mc. (Later models of the AN/SPS-5 have a frequency range of 5450 to 5825 mc.) Power output varies between 170 and 285 kw, depending mostly on the operating frequency selected. A pulse length of 0.37 μsec is used as a compromise between long and short ranges. The antenna is similar to that of the AN/SPS-10( ).

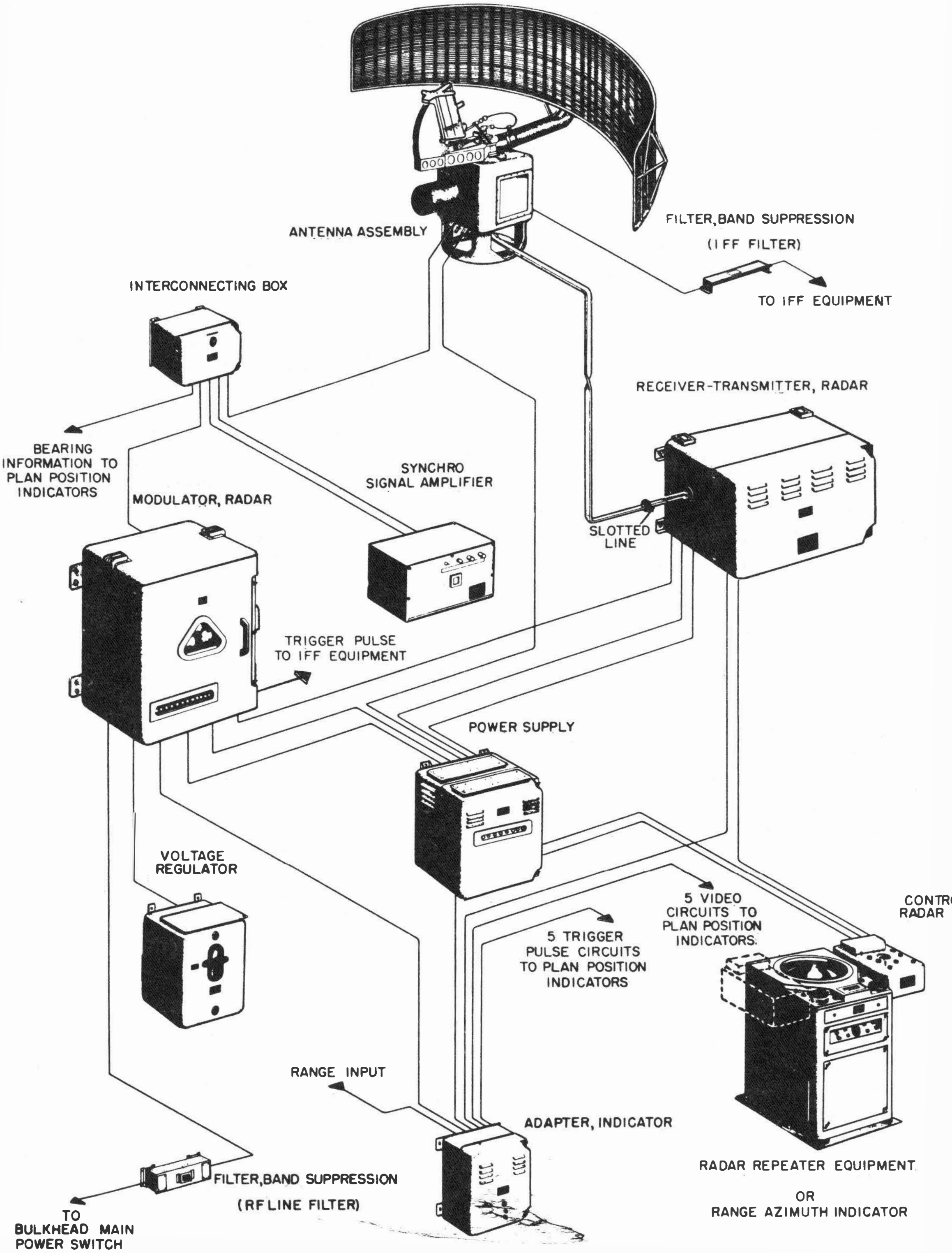

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Figure 6-1.—Radar Set AN/SPS-10( )—relationship of units.

AN/SPS-21( )

The AN/SPS-21( ) is a short-range, compact surface-search radar designed principally for installation aboard small ships. It also is installed on some of the larger auxiliary ships for use as a close-range navigational radar. Being a short-range equipment (75 yards to 16 miles), the set has a narrow pulse width of 0.2 μsec and a low power output of 10 kw. Its operating frequency is selectable within the frequency range 5500 to 5600, and it employs a parabolic antenna that radiates a beam 2° wide in the horizontal plane and 15° high in the vertical plane.

AN/SPS-35( )

Another small-ship, short-range surface-search radar is the AN/SPS-35( ). This set operates at frequencies between 9335 and 9405 mc with a power output of 7 kw. The duration of the transmitted pulse is 0.2 μsec. Its beam width is 2.2° in the horizontal plane, and 16° in the vertical plane.

AN/SPS-36

The AN/SPS-36 is a nonmagnetic, short-range surface-search radar for use on minesweepers. Its effective range is from a minimum of 25 yards to a maximum of 16 miles. Operating in the frequency range 9350 to 9400 mc with a power output of 7 kw, this equipment transmits a beam covering 2° horizontally and 28° vertically. Pulse length is either 0.15 μsec or 0.5 μsec, depending on the range scale selected.

AN/SPS-41

Currently installed on several ships of the auxiliary type, the AN/SPS-41 surface-search radar has an effective detection range of 25 yards to 32 miles. It operates on a fixed frequency (9375 mc) with a peak power output of 10 kw. Beam coverage is 1.8° in the horizontal plane and 20° in the vertical plane. A pulse length of 0.1 μsec is used for distances 4 miles and less; for longer distances, 0.4 μsec.

AN/SPS-46( )

The AN/SPS-46( ) radar set is a surface-search and navigational equipment presently installed on a limited number of amphibious ships. This equipment is capable of detecting targets at distances ranging from 25 yards to 32 miles. It operates in the frequency range 9345 to 9405 mc, and has a peak power output of 7 kw. The transmitted signal has a horizontal beam width of 2.2° and a vertical beam width of 15°.

AIR-SEARCH RADARS

The primary function of air-search radars is the long-range (greater than 50 miles) detection of aircraft targets and the determination of their ranges and bearings. These radars search 360° in azimuth from surface to high altitudes.

In the ensuing paragraphs are discussed the characteristics of three air-search radars—the AN/SPS-6( ), AN/SPS-12( ), and AN/SPS-28( ) radar sets. Other air-search radars currently installed aboard Navy ships are models AN/SPS-17( ), AN/SPS-29( ), AN/SPS-32, AN/SPS-37( ), AN/SPS-40, and AN/SPS-43( ). For security reasons, characteristics and operational features of these latter six models are not discussed in this text.

AN/SPS-6( )

Radar sets AN/SPS-6, -6A, -6B, and -6C are high-power (500 kw), long-range search radars and are used extensively throughout the fleet for detecting, ranging, and tracking both conventional and jet aircraft. Except for having different parabolic-type antenna reflectors that vary the vertical coverage afforded, the four sets are identical. Vertical coverage ranges from 10° for the original set to 30° for the last model. For all four models the horizontal beam width is 3.5°.

The AN/SPS-6( ) is capable of tracking aircraft at low altitudes. It also is suitable for limited surface tracking and navigation. This radar excels, however, in detecting targets of small reflective surface at high altitudes. Jet aircraft are detected at altitudes up to 40,000 feet and at distances as far out as 60 miles. Large conventional aircraft flying at high altitudes normally are picked up in the range of 70 to 140 miles, whereas smaller targets (such as fighters) are detected when they are between 60 and 80 miles away.

This equipment is tunable to any operating frequency within the range of 1250 to 1350 mc, and provides a choice of pulse lengths (1 or 4 μsec).

AN/SPS-12( )

The AN/SPS-12( ) is another air-search radar operating in the frequency range 1250 to 1350 mc with a peak power output of 500 kw. Its operating features, characteristics, and capabilities are similar to those of the AN/SPS-6( ). It differs from the AN/SPS-6( ) mainly in that it has a more sensitive receiver and a larger antenna, and is designed for installation on large ships.

AN/SPS-28( )

Radar set AN/SPS-28( ), shown in figure 6-2, is a medium-range (30 to 50 miles) air-search radar installed on DDs and smaller ships. This radar has a frequency range of 215 to 225 mc, which is somewhat lower than the frequencies covered by the radars discussed previously. It has a peak power output of 300 kw and a fixed pulse length of 4 μsec. The radar uses a bedspring-type antenna that has a horizontal beam width of 18° and a vertical beam width of 27°.

HEIGHT-FINDING RADARS

Because height-finding radars supply height, bearing, and range information, they are known as three-coordinate radars. Currently, six different models of three-coordinate radars are designated either standard or planned standard shipboard equipment. They are the AN/SPS-8( ), AN/SPS-30, AN/SPS-33, AN/SPS-39( ), AN/SPS-42, and AN/SPS-48 radar sets. Of these sets, the AN/SPS-8( ) predominates in number of installations. Fortunately, it is an unclassified equipment, thus it can be discussed in this text; the others are classified.

Most radars present only range and bearing, so their beams are narrow in azimuth and broad in the vertical plane. Altitude information, however, depends on knowing the exact angular position of the radar beam above the horizon when it is enveloping a target. For this reason, the beams of height-finding radars are quite narrow vertically, as well as narrow in the horizontal plane.

The beams of height-finding radars must be independent of the ship's movements. Stabilization is accomplished by means of antenna stabilizing systems. These systems are discussed later in this chapter.

AN/SPS-8( )

Radar sets AN/SPS-8, -8A, -8B, -8C, and -8D are high-power, shipboard, height-finding radar systems, designed principally for fighter aircraft direction. They present target height, slant range, bearing and beacon (IFF) information on remote radar repeaters and the model VL range-height indicator. (See fig. 6-3 for relationship of units.) These radars are found on large ships (cruisers and carriers mostly) and many destroyer radar picket ships.

The operational characteristics of the AN/SPS-8 series vary slightly with the different models. Bearing in mind this variation, some of the characteristics of the original AN/SPS-8 are: frequency in the X-band, peak power 650 kw, pulse width 1 or 2 μsec, PRR 500 or 1000 PPS, vertical beam width 1.1°, and horizontal beam width 3.5°. Antenna rotation rates are 1, 2, 3, 5, or 10 rpm. The antenna may be made to scan any sector from 30° to 200° vertically, or it may be trained manually. Antenna elevation scan rates are 300, 600, and 1200 rpm. Maximum range using 1-μsec pulse is 83 miles; with 2-μsec it is 165 miles. Minimum range is approximately 4500 yards.

FIRE CONTROL AND MISSILE GUIDANCE RADARS

Electronic equipment in the fire control and missile guidance systems is closely related to mechanical and optical equipment both physically and electrically. Although the use of radar is merely a part of a whole fire control or missile guidance problem, only the radar is discussed in this text.

Among the radars used for gun fire control are radar sets Mk 25, Mk 34 (also designated AN/SPG-34), Mk 35, AN/SPG-48, AN/SPG-50, and AN/SPG-52. Of these sets only the Mk 25 and Mk 34 are described.

Missile guidance radars currently installed in the fleet are models AN/SPG-49, AN/SPG-51, AN/SPG-55, AN/SPQ-5, and AN/SPW-2. The security classification of these equipments prohibits any discussion in this text of their operational characteristics. They are listed here for the purpose of making the reader aware of their existence and use.

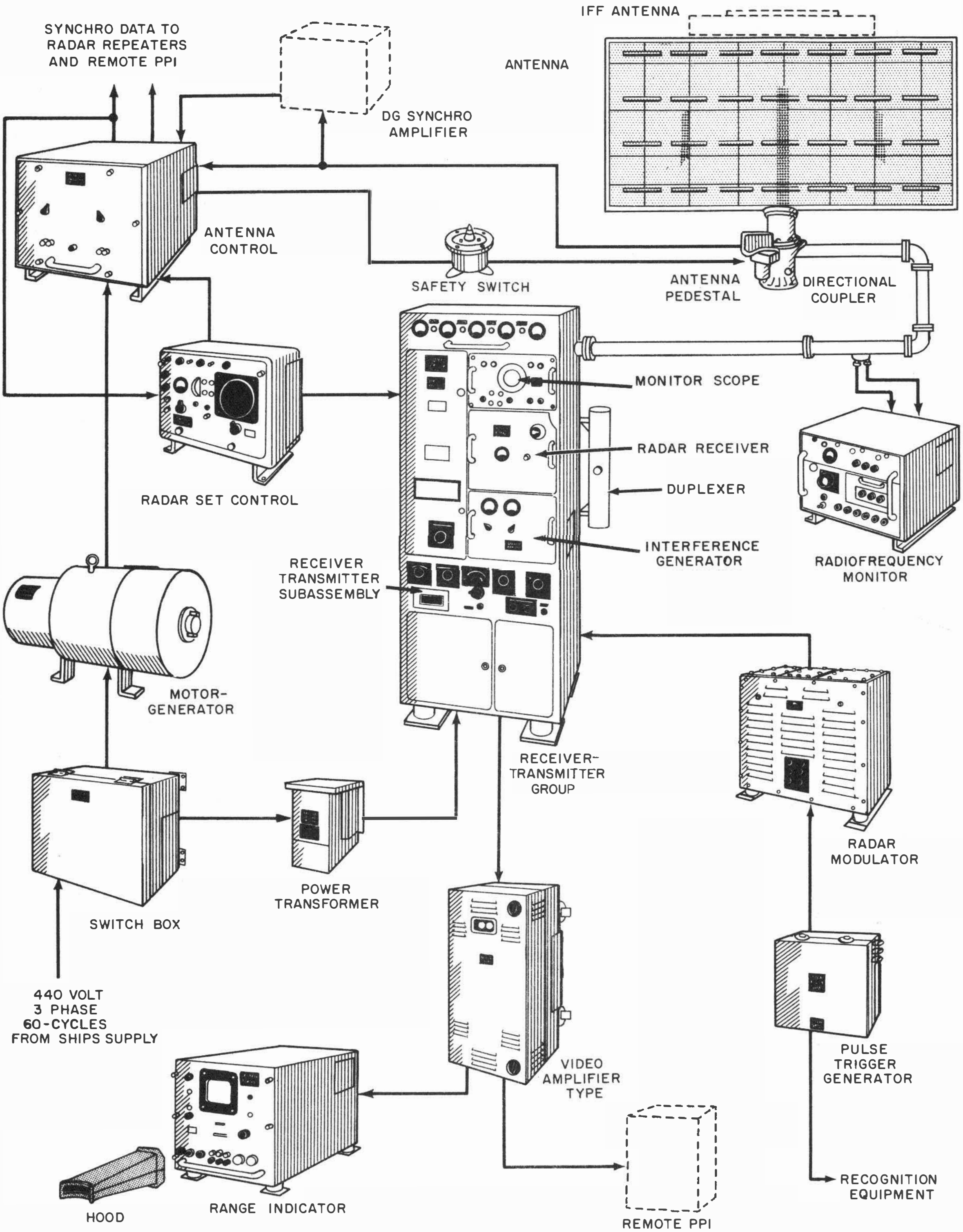

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Figure 6-2.—Radar Set AN/SPS-28( )—relationship of units.

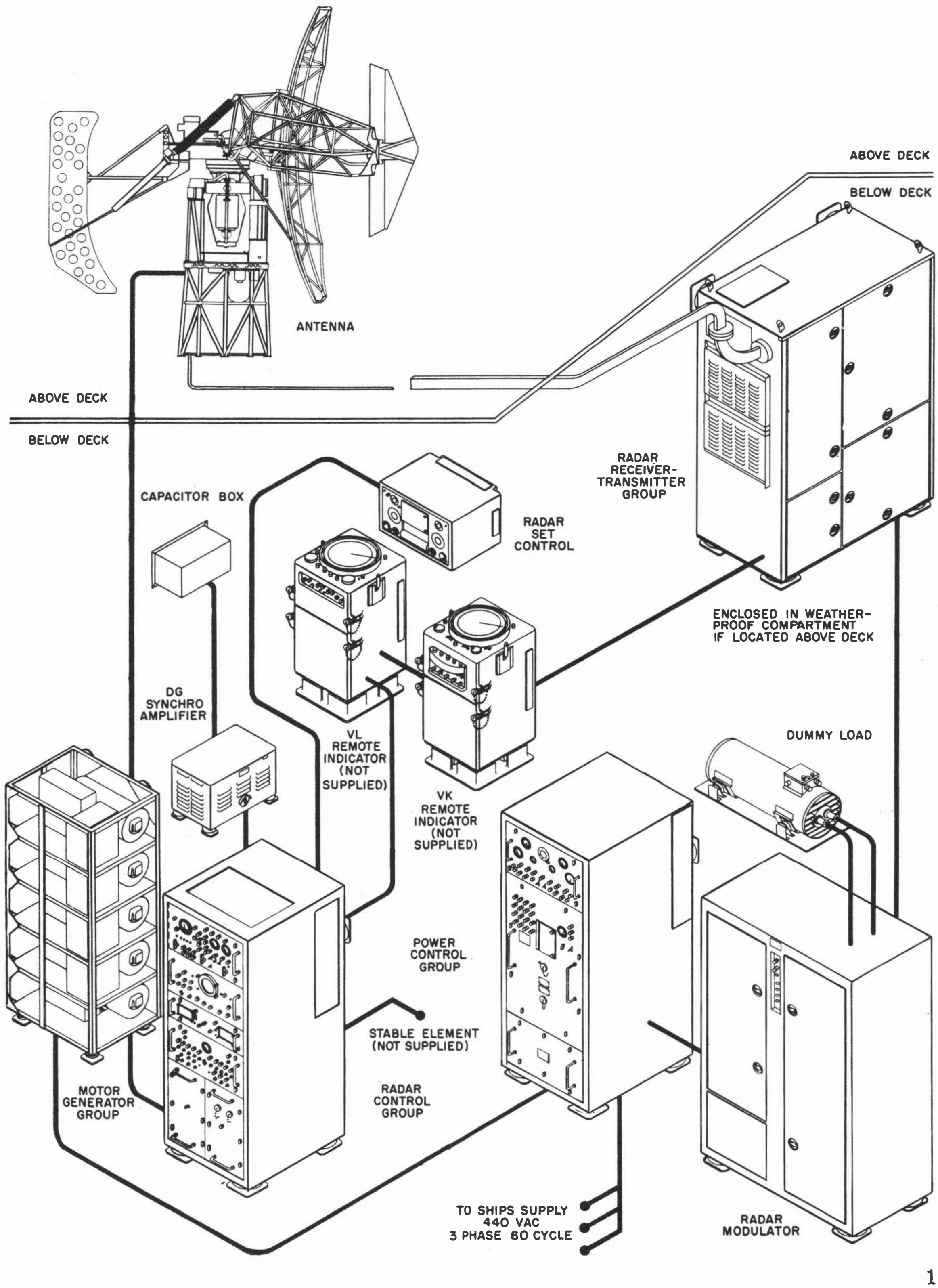

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Figure 6-3. —Radar Set AN/SPS-8( )—relationship of units.

MARK 25 MOD-( )

The Mk 25 radar (fig. 6-4), an extremely accurate equipment, is capable of tracking either surface or air targets. It is used principally in 5-inch 38-caliber gun fire control systems, but serves equally well for controlling guns of other calibers.

This equipment operates on X-band frequencies, with a peak power output of 50 kw and a pulse width of 0.2 μsec. Its accuracy in bearing is ±0.1°; range in yards is ±15 yards to ±0.1 percent of the range; and elevation is ±0.1°.

Early models of the Mk 25 had a maximum range of 50,000 yards. Those now in use can track targets at distances up to 100,000 yards.

MARK 34 MOD-( )

Another fire control radar capable of tracking either surface or air targets is the Mk 34. It was designed for heavy machinegun batteries, but its most common use today is in the Mk 63 fire control system that controls our 3-inch guns. When used in this system, the radar usually is listed as the AN/SPG-34.

Operating on X-band frequencies, with a peak power output of 32 kw and a pulse width of 0.5 μ sec, the Mk 34 can track targets at distances greater than 30,000 yards. Its maximum range, however, is considerably less than the range of the Mk 25.

The antenna for this radar may be found on the gun platform itself (Mk 63 system) or on a separate director.

AUXILIARY EQUIPMENT

The equipment covered in the remainder of this chapter is used with the various radars we have discussed. In some instances, this auxiliary equipment is in a system that facilitates the use of radar; in others, it is in the radar system itself.

REPEATERS

As the tactics of warfare became more sophisticated, there was more and more evidence that the information obtained from radar would have to be displayed at any one of several physically separated stations. The size and weight of the relatively bulky and complex radar console made it unsuitable for remote installations. The need was for a smaller and lighter general-purpose unit, capable of accepting inputs from more than one type of radar. To fulfill this need, the present-day remote indicator (repeater) was developed.

Several types of radar repeaters currently installed on Navy ships are described in the following seven topics.

VL-( ) Remote Indicator

The model VL-( ) remote indicator, illustrated in figure 6-5, is used for displaying radar information from any vertical-scanning height-finding radar. The indicator is of the RHI type, with a 12-inch display tube, but only a 10-inch viewing surface is used to present a vertical sector scanned by the radar. It can cover from 5° below the horizontal to 90° above. An expand control allows the 11° sector normally scanned by the radar to be expanded on the scope to about four times its normal size.

Range scales available are 20, 40, 80, or 200 miles with radar centered, or a 20- to 40-mile delayed range scale. The range accuracy is ±1 percent of total scale. Altitude accuracy depends on the parent radar.

Because the VL-( ) indicator has no provisions for presenting azimuth information, it normally is used in conjunction with other radar repeaters.

AN/SPA-4( ) Remote Indicator

The AN/SPA-4( ) range-azimuth indicator (fig. 6-6), a remote PPI type of repeater, is used chiefly for surface search and station keeping. It utilizes a 10-inch, flat-face cathode ray tube to show range and azimuth of a target. It is a self-contained unit designed for operation with any standard Navy search radar system having a pulse repetition frequency between 140 and 3000 PPS. This repeater may be employed to select radar information from any one of several radar systems. A variable (rubber) range control is incorporated, whereby the range may be varied continuously from 1 to 300 miles.

AN/SPA-8( ) and -9 Remote Repeaters

The AN/SPA-8, -8A, -8B, -8C, and -9 are general-purpose PPIs employed with shipboard radars to display range and bearing information. These repeaters can be used as master

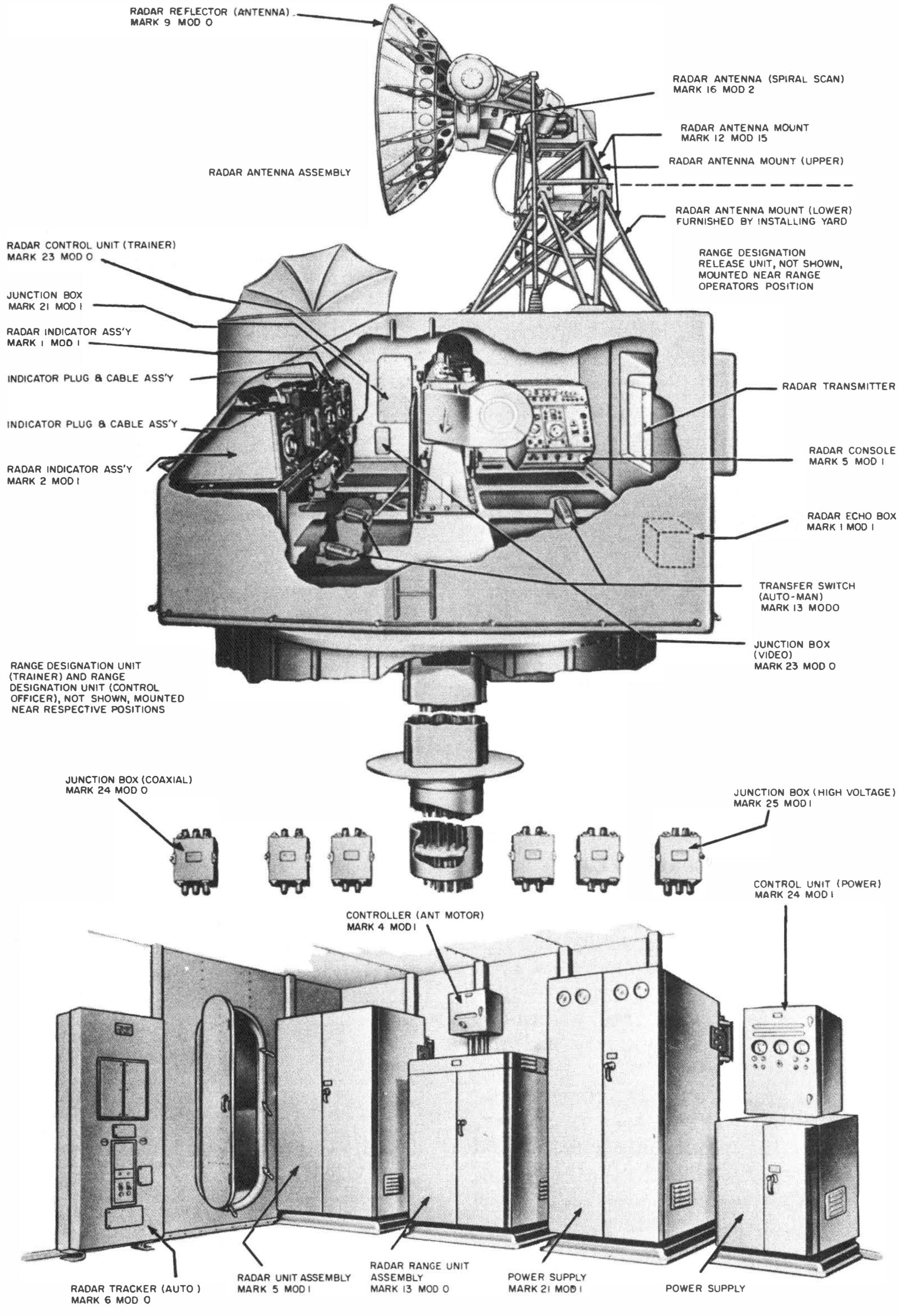

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Figure 6-4.—Mark 25 radar system.

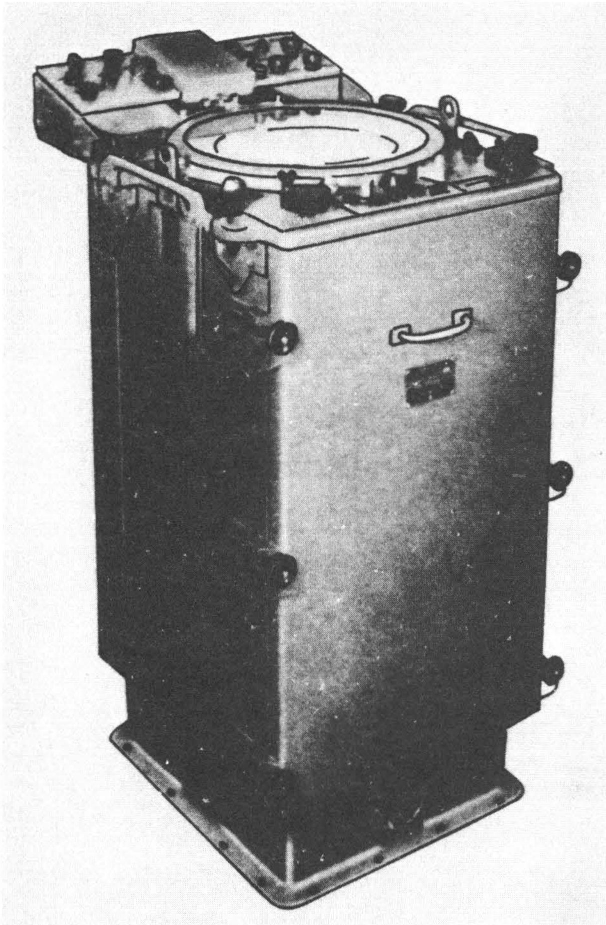

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Figure 6-5.–Radar repeater VL-( ).

or remote PPI indicators, as relay search repeat indicators, or as radar relay search tracking indicators. Frequently they are utilized as tracking and repeat indicators with the shipboard section of the airborne early warning (AEW) system.

This equipment features (1) continuous-range sweep variation without loss of target, (2) time sharing of the electronic cursor and range sweeps or the strobe and range sweeps, and (3) sweep and cursor offcentering, which make target identification possible without geographic distortion. All these features are incorporated in the indicators. The AN/SPA-9 is used for tracking, whereas the AN/SPA-8 cannot be used for tracking but is used for a repeater (sometimes called a slave.) The AN/SPA-8A, -8B, and -8C are single indicators used either for tracking purposes or as slaves.

The AN/SPA-8A (fig. 6-7) is representative of the -8 series. Some of its special features follow.

1. Manual offcentering: Any target within 250 miles may be centered on the scope.
2. DRA offcentering: Information from the ship's dead reckoning analyzer (DRA) may be fed to the repeater. This DRA information cancels own ship's motion, and shows all targets (including own ship) moving on their true courses.
3. Electronic cursor and range strobe: Provided with a centered or offcentered electronic cursor and range strobe. Origin of offcentered

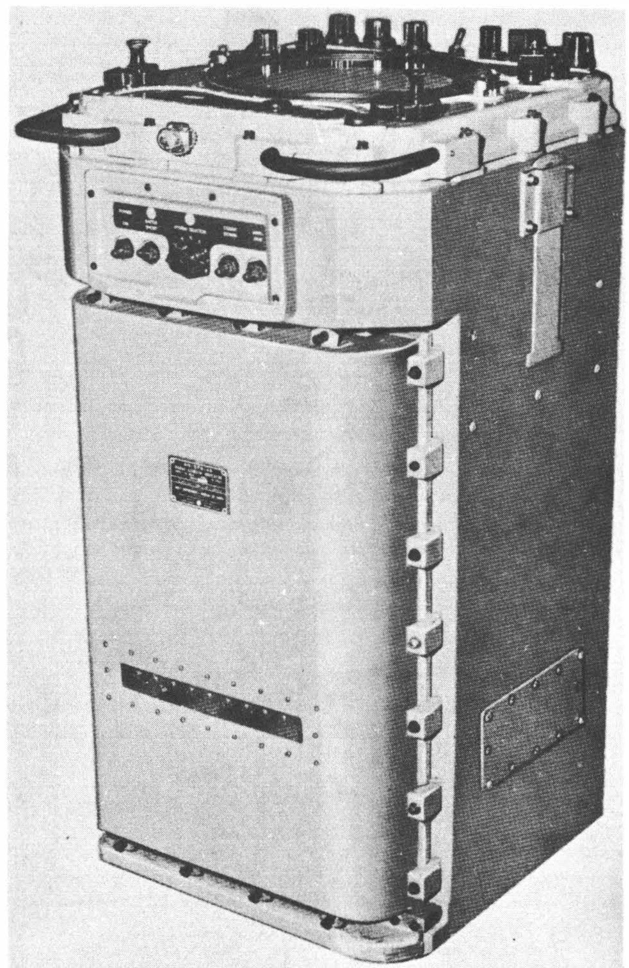

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Figure 6-6.–Range-azimuth indicator AN/SPA-4( ).

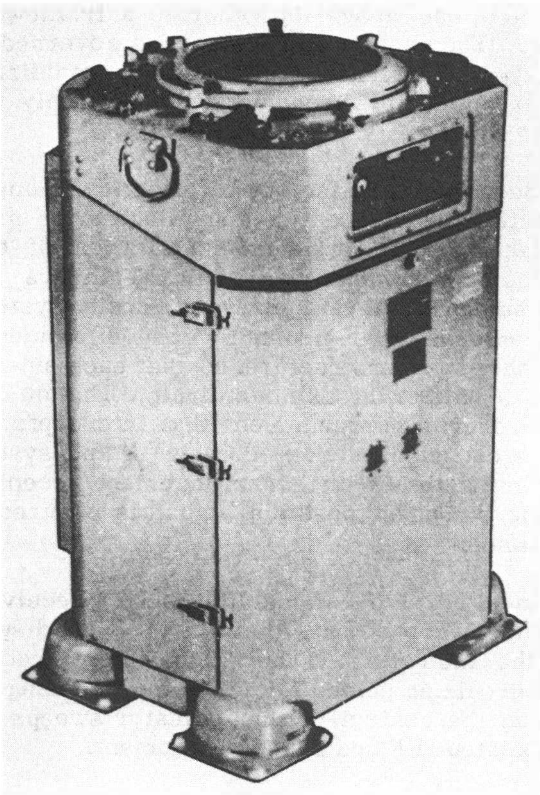

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Figure 6-7.—Azimuth-range indicator AN/SPA-8( ).

cursor and strobe may be controlled independently from sweep by tracking cranks.

4. Range scale: Rubber range, 4 to 300 miles, continuously variable, with a choice of six different scale spacings between range rings.

5. Tracking cranks: Used to position origin of strobe or electronic cursor. The tracking cranks may be locked so that the repeater can be used as a final (repeat) AEW indicator.

AN/SPA-18 Remote Indicator

The AN/SPA-18 is a small, compact, remote PPI that presents range and bearing information on a 7-inch CRT. It is designed for installation on small ships where space is limited. The unit is sealed in a sprayproof cabinet, and can be mounted in unprotected areas either on the bulkhead or on a shelf.

This repeater has a continuously variable range scale of 2 to 30 miles. It can be operated with any standard Navy search radar having a PRR of 57 to 3000 PPS.

AN/SPA-31 Remote Indicator

The AN/SPA-31 radar repeater is similar in size, appearance, and operational capability to the model VL-( ) repeater discussed previously. It is a range and height indicator that presents visually the scalar distance between a reference point and a target, and the vertical distance between a reference point and a target.

The repeater uses a 12-inch CRT with a 10-inch viewing surface, and provides a choice of four range scales: 20, 40, 70, or 160 miles.

AN/SPA-33( ) Remote Indicator

The AN/SPA-33( ) remote indicator, seen in figure 6-8, may be operated either as a general-purpose PPI or as a part of an AEW system. It has practically the same controls and capabilities as the AN/SPA-8( ). At first glance they look alike, but a closer check shows that the AN/SPA-33( ) has two joysticks in place of the range and bearing cranks on the AN/SPA-8( ). The joystick on the left is for the cursor origin; the one on the right is for the range strobe and cursor bearing line. Another difference between the two repeaters is that the AN/SPA-8( ) has provision for a DRA input, whereas the AN/SPA-33( ) does not.

AN/SPA-34 Remote Indicator

The AN/SPA-34 remote indicator (fig. 6-9) incorporates into a single console the desirable features of the AN/SPA-8( ) and the AN/SPA-33( ). Depending on the mode of operation selected, it functions as a general-purpose PPI, as an AEW tracking indicator, or as an AEW repeat indicator. Because of its size and weight, the AN/SPA-34 is installed only on ships of DD size and larger.

Additional Remote Indicators

Other remote indicators designated as standard shipboard equipment are the AN/SPA-25 (a transistorized PPI), the AN/SPA-50 (a large-screen PPI), the AN/SPA-58 (similar to AN/SPA-8A), the AN/SPA-59 (comparable to AN/SPA-33), and the range-height indicators AN/SPA-40 and -41.

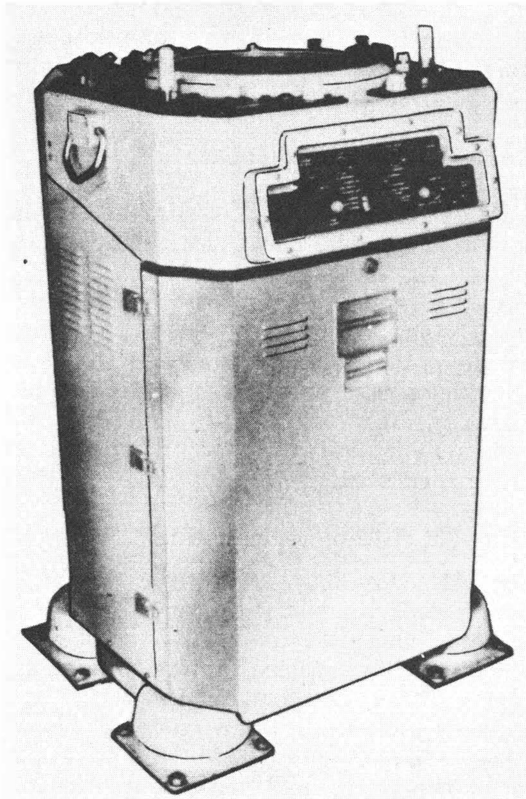

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Figure 6-8.—Azimuth-range indicator AN/SPA-33( ).

AEW TERMINAL EQUIPMENT

The purpose of the AEW system is (1) to obtain an extended radar horizon by operating search radar equipment in an aircraft at high altitude, and (2) to make available to surface ships in the vicinity the extended radar and IFF information thus obtained. This action is accomplished by transmitting to the surface craft radio signals containing the radar and IFF information. From these signals the original display at the airborne radar is reproduced on the shipboard indicators.

Two radio receiving sets and a video decoder currently used in shipboard AEW installations are the AN/SRR-4, the AN/WRR-1, and the KY-71/UPX. A description of each follows.

Radio Receiving Set AN/SRR-4

One or two radio receivers, a video decoder, and a data converter make up the AN/SSR-4 radio receiving set. These units are mounted one above the other in a framework rack. The number of receivers is governed by the type of antenna available. If an omnidirectional antenna is used with the set, only one radio receiver is required.

Because a satisfactory location for an omnidirectional antenna is unavailable on most surface ships, the usual installation of this equipment includes two radio receivers and two antennas operating as a diversity system. The antennas are mounted on opposite sides of the ship's superstructure so that each antenna covers half of the azimuth circle. The antenna and receiver arrangement that intercepts the strongest signal takes control of the system automatically. With this arrangement, reception of the strongest possible signal is assured at all times.

In either type of installation, the receivers provide video outputs that are used for display on the indicators. They also supply decoded synchronizing pulses for further processing and use in the control of the indicator sweeps and associated IFF and beacon equipment.

Radio Receiving Set AN/WRR-1

The AN/WRR-1 radio receiving set is a refinement of the AN/SRR-4. Although the two sets perform the same functions, they have somewhat different components. The AN/WRR-1 consists of a signal generator, a radio receiver, a signal converter, and a power supply mounted one above the other in the same equipment cabinet.

For diversity operation, the AN/WRR-1 employs a single receiver and two directional antennas. Each antenna covers half of the azimuth circle. The antenna that intercepts the strongest signal is connected automatically to the receiver by means of an antenna switching device.

Video Decoder KY-71/UPX

The KY-71/UPX is a video decoder used in conjunction with the shipboard AEW equipment. Radar data and the identification information (IFF) are transmitted on a common link, and it is the function of this unit to separate the data into separate circuits.

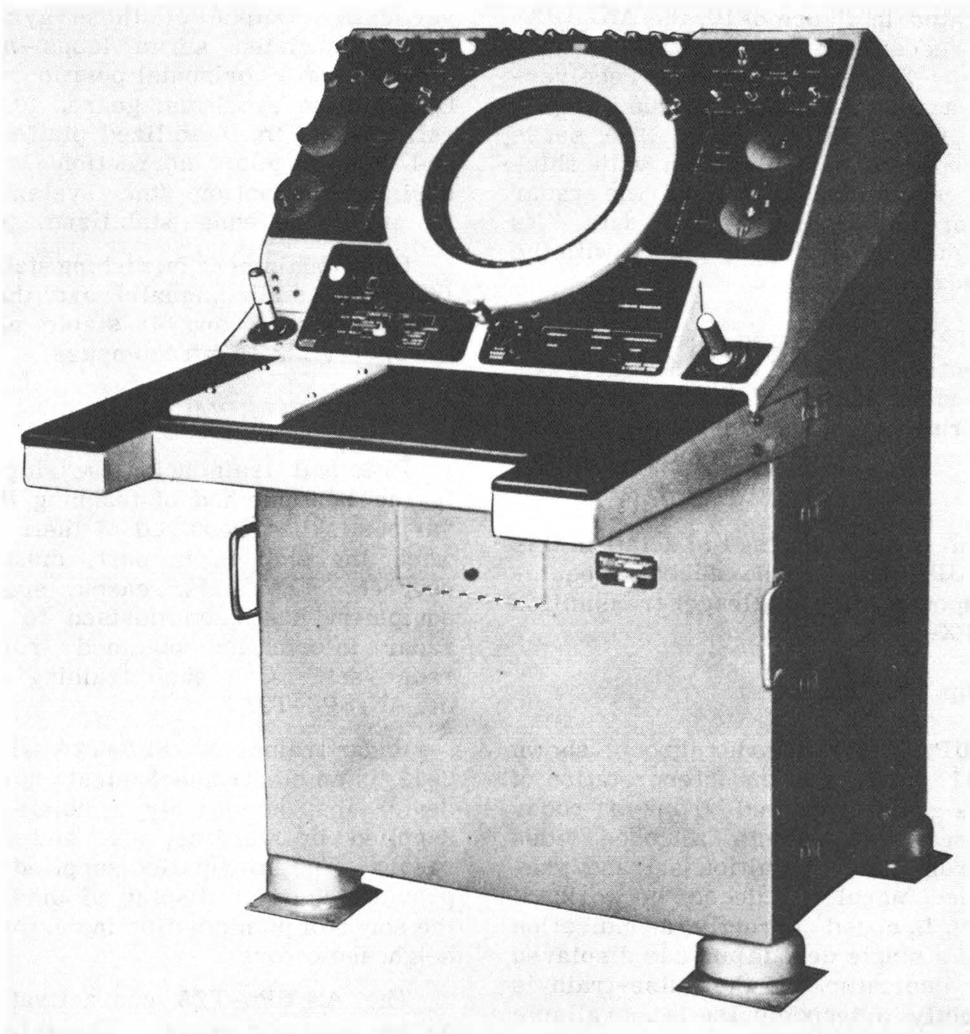

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Figure 6-9.—Indicator group AN/SPA-34.

By using this unit in conjunction with other standard identification data distribution accessories, an operator may display the identification data with or without the radar information. He also may display radar information without the identification data. Simultaneously, the other operators are able to select and display identification and/or radar data as they desire.

IFF EQUIPMENT

Today's high-speed aircraft present a critical problem in detection, identification, tracking, and evaluation. When enemy aircraft are approaching, they must be detected and identified at the greatest possible distance in order to provide ample time for initiating appropriate action.

Among the various models of IFF equipment currently installed aboard ships are the AN/UPX-1( ), AN/UPX-11, AN/UPX-12( ), AN/UPX-17, AN/UPA-24( ), and AN/UPA-38( ). Of these six models, only the AN/UPX-1( ) and the AN/UPA-24( ) are discussed in this text.

Radar Recognition Set AN/UPX-1( )

As illustrated in figure 6-10, the AN/UPX-1( ) radar recognition set consists of four major units. These units are a receiver-transmitter, a coder-decoder, a video amplifier, and a radar set control. The set is designed to operate in conjunction with shipboard radar equipment. It uses the radar display for presentation of its IFF data. Its antenna is either integral to or slaved with the associated radar antenna.

The AN/UPX-1( ) is used chiefly for challenging unidentified radar targets. It also can be used to further identify friendly targets as specific aircraft or ships, thereby providing additional security and useful tactical information.

Although it is not discussed in detail in this text, the AN/UPX-12( ) is the shipborne equipment that responds to the challenges transmitted by the AN/UPX-1( ).

Decoder Group AN/UPA-24( )

The AN/UPA-24( ) decoder group, shown in figure 6-11, facilitates the interpretation of coded IFF signals received from a radar recognition set. It selects a coded video pulse-train from the recognition set and presents the coded signal to a decode network. If the pulse-train is coded correctly, an indication in the form of a single decode pulse is displayed on the radar indicator. If the pulse-train is coded incorrectly, a decode pulse is unavailable for presentation.

The AN/UPA-24( ) permits the presentation of the coded or decoded IFF signal alone, the radar signal alone, or the radar signal mixed with either coded or decoded IFF signals. It also provides the means for controlling the operation of the recognition set.

ANTENNA STABILIZATION DATA EQUIPMENT

The AN/SSQ-14 stabilization data set is a vital link in establishing a stabilized antenna platform. It supplies a synchro signal indication of the angular displacement of the ship's deck, with respect to the horizontal, as the ship pitches and rolls. Two gyro units, one associated with pitch and the other with roll, are mounted on a horizontal platform, their output axes vertical. Output of these gyro units—with their associated servo loops—maintain this platform in a horizontal position. By means of transmitting synchros, geared to the pitch and roll axes of the stabilized platform, the pitch and roll angular correction is sent to the desired destination (the system that keeps the radar antenna stabilized, for example).

Other equipment furnishing stabilization data (roll and pitch signals) are the AN/SSQ-4, Mk 8 (Mods 2 and 4) stable elements, and the Sperry Mk 19 gyrocompass.

TRAINING EQUIPMENT

Practical training on the ship's equipment is the best method of teaching Radarmen the various skills required of their rating. But, when the ship is in port, most radars are secured. For this reason, special training equipment has been devised to simulate the radar information obtained from the actual radar set. One such training equipment is the AN/SPS-T2A.

Radar trainer AN/SPS-T2A, shown in figure 6-12, is an electromechanical analog computing device that completely simulates radar data supplied by surface, air, and height-finding radars. The information supplied by the trainer provides a radar display of moving targets on the scope of plan position indicators and range-height indicators.

The AN/SPS-T2A can activate six targets on an indicator scope. These targets can be made to travel at speeds between 0 and 300 knots for surface targets, and between 0 and 3000 knots for air targets. Targets can be controlled on any course within the 360° of azimuth. They can be made to travel from the center of the scope to a maximum of 250 miles. Air targets can be made to climb and dive at rates of 0 to 25,000 feet per minute, and they can be made to fly at altitudes between 0 and 100,000 feet. In addition, the trainer simulates own ship movements at speeds to 500 knots on any course. Travel distance of own ship is limited to 250 miles from origin.

The AN/SPS-T2A is considered an excellent device for training air controllers and for training new men in plotting and tracking radar contacts.

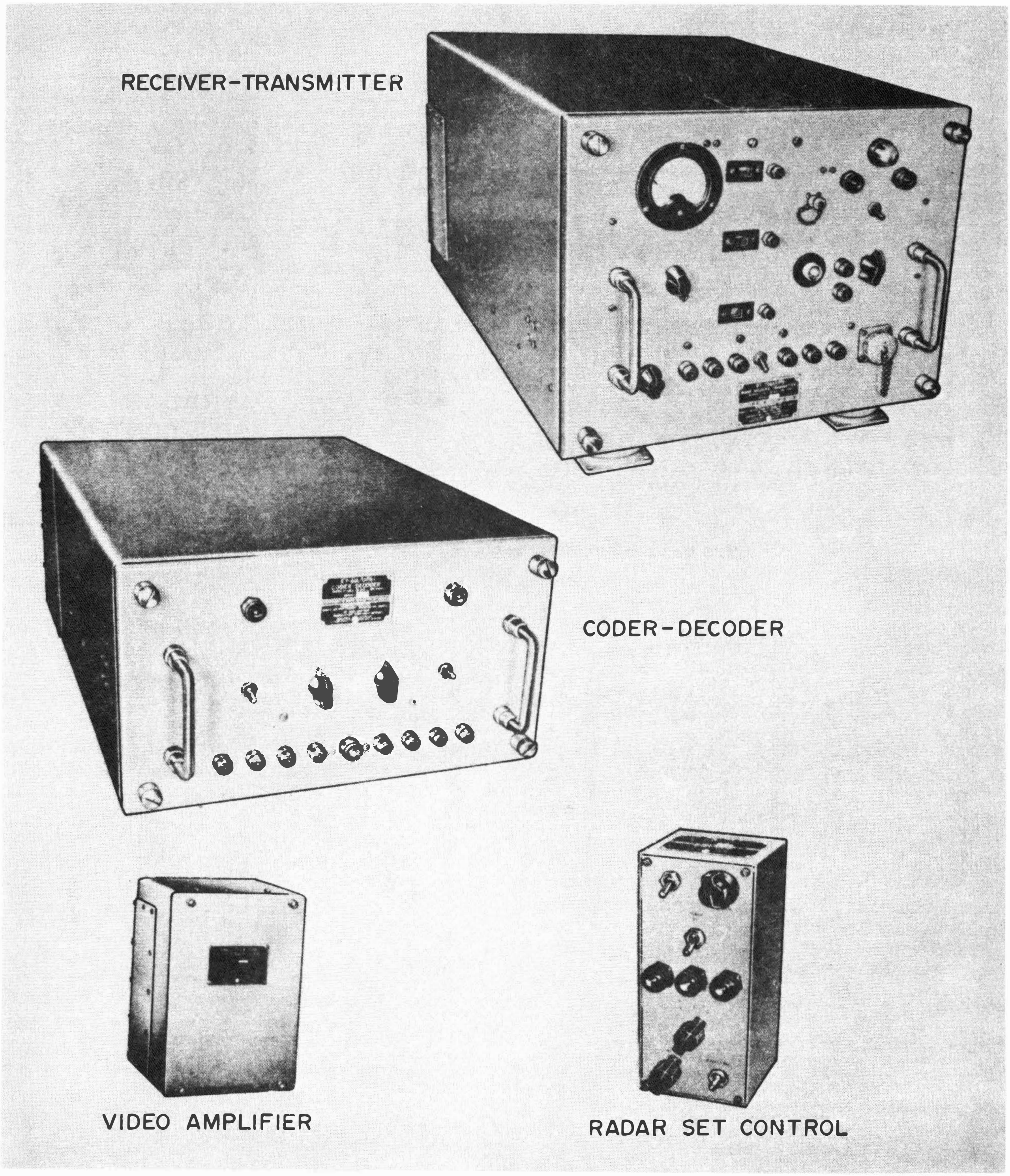

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Figure 6-10.—Radar Recognition Set AN/UPX-1( ).

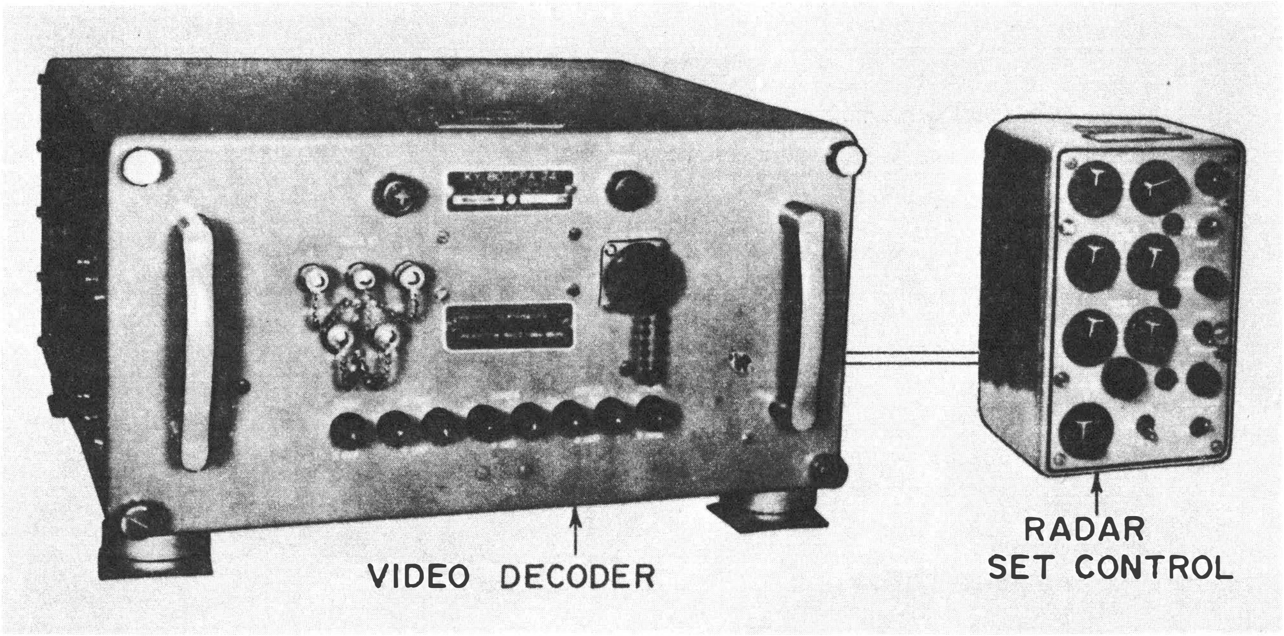

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Figure 6-11.—Decoder Group AN/UPA-24( ).

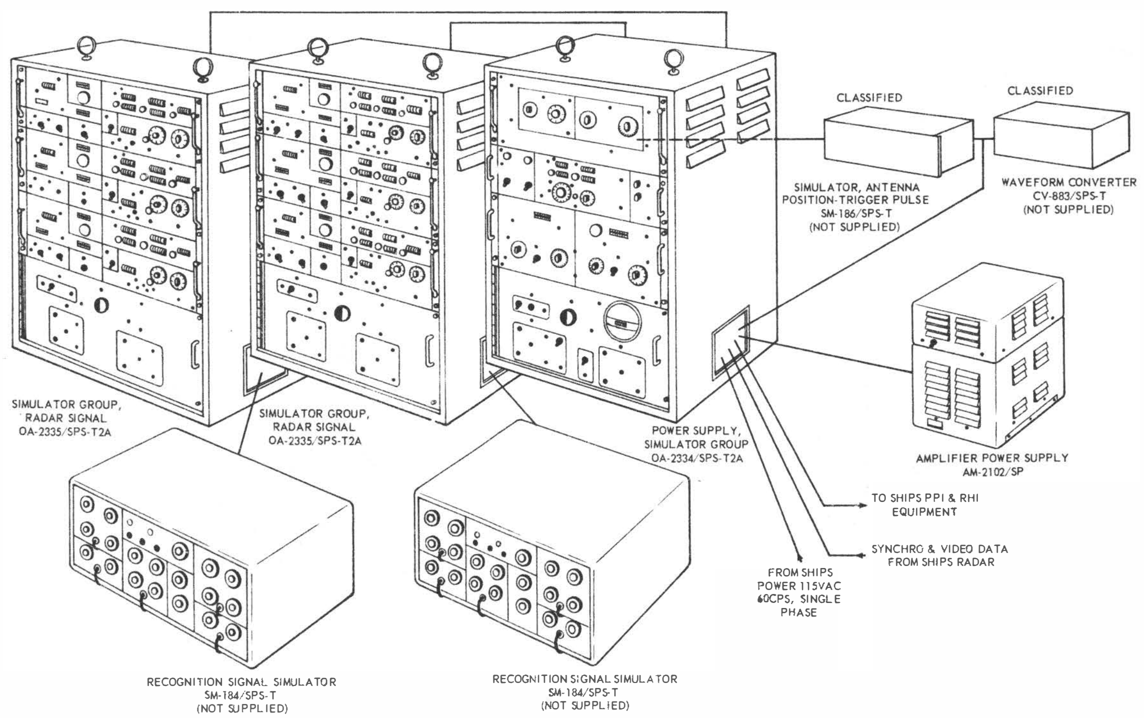

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Figure 6-12.—Radar Trainer AN/SPS-T2A.

CHAPTER 7

SONAR

In sonar (formed from the initial letters of sound navigation and ranging), sound energy is utilized for detecting and tracking and the ranging of underwater objects such as submarines. The sonar equipment may be of an active nature, transmitting sound energy into the water and then obtaining bearing and range information from returning target echoes; or it may be of a passive nature, depending on sound originating from the target (such as screw cavitation, machinery noise, and the like) for bearing information.

Before discussing the various sonars, let's briefly review some of the basic principles of sound.

SOUND

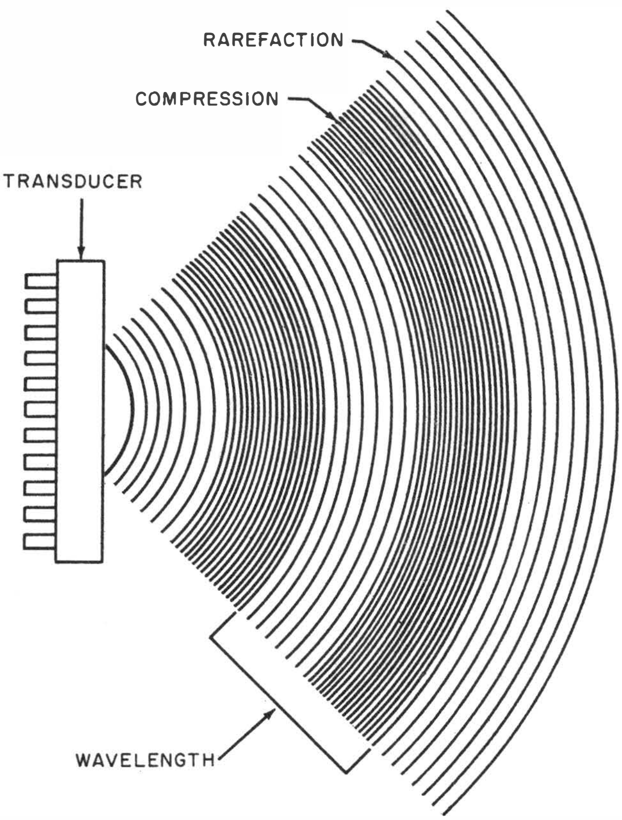
Everything you hear is a sound. This statement does not mean, however, that when you hear nothing there is no sound, because many sounds are beyond the frequency range of the human ear.

Sound is divided into three frequency groups. They are (1)` subsonic or infrasonic—those frequencies below the audiofrequency range; (2) ultrasonic or supersonic—those frequencies above the audiofrequency range; and (3) sonic—those frequencies within the audiofrequency range. As stated in chapter 2, the audio range is from approximately 15 to 20,000 cps. The actual range of frequencies that the human ear can detect varies with the individuals themselves.

To make use of sound, it is necessary to have a sound source, a medium for the sound to travel through (sound does not travel in a vacuum), and a detector to pick up the sound so that information can be obtained from it.

GENERATION AND TRANSMISSION OF SOUND

Any object that vibrates back and forth disturbs the material surrounding it, whether that material is a liquid, a solid, or a gas. The object that vibrates is the sound source. It may be a bell, a loudspeaker, or (as illustrated in fig. 7-1) a sonar transducer.



4.221

Figure 7-1.—Producing sound waves.

The transducer contains a diaphragm that is made to vibrate at the frequency of an applied voltage. When the diaphragm moves out, the medium next to it is compressed. As the diaphragm moves back, the particles in the medium move apart, causing a rarefaction or low-pressure area next to the diaphragm. When the diaphragm moves out again, a new compression is produced. The out-and-in movement of the diaphragm continues, and the alternate compressions and rarefactions spread in a series of waves called compression waves. Compression waves, propagated through a medium, are sound waves.

The number of sound waves created each second is the same as the frequency of the vibrating body. The speed at which these compressions travel outward depends upon the nature of the material or medium surrounding the body. In water, sound travels at approximately 4800 feet per second.

TRANSDUCERS

Knowledge of the design and function of the transducer is the key to understanding the principles of sonar, whether of the modern scanning type or the obsolete searchlight type. (Both types are discussed later.) First of all, we know that the transducer converts outgoing signals from electrical to acoustical energy, and incoming signals from acoustical to electrical energy. Signals are converted by either the magnetostrictive or piezoelectric process.

MAGNETOSTRICTIVE PROCESS

Magnetostriction is a process whereby changes occur in metals when they are subjected to a magnetic field. If a nickel tube is placed in a magnetic field, for example, it changes length as a result of the magnetostrictive effect.

In the searchlight type of transducer, several hundred nickel tubes are arranged in a circle and mounted on one side of a metal plate called a diaphragm. Each tube is wrapped with a coil of wire. When direct current (called polarizing current) is passed through the coils, a magnetic field is produced, causing the tubes to shorten. When an alternating current is impressed over the direct current, the tubes shorten and lengthen with each cycle of the alternating current.

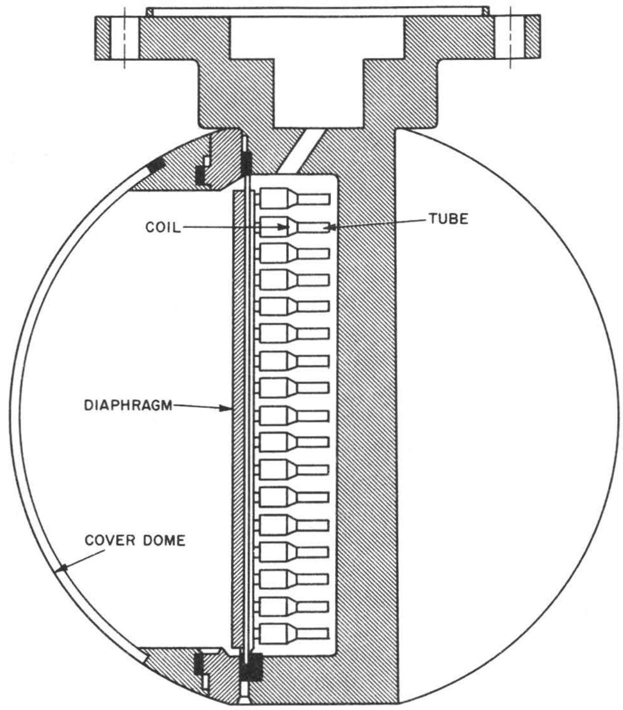


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Figure 7-2.—Searchlight magnetostrictive transducer.

This action causes the metal plate, upon which the tubes are mounted, to vibrate and produce sound energy. In other words, when an alternating current of 20-kc frequency is applied, the diaphragm vibrates at 20,000 cps, and a sound wave of that frequency is produced and transmitted into the water. The searchlight type of magnetostrictive transducer is illustrated in figure 7-2.

Transducers normally employed with scanning sonars operate on the principle of magnetostriction. Instead of nickel tubes, the elements of the transducer have nickel laminations pressed in a thermoplastic material. Permanent magnets are so mounted that they provide energy for polarizing the nickel. A scanning transducer containing 48 of these elements, arranged in a circle to give 360° search in azimuth, is shown in figure 7-3.

Most common types of operational scanning sonar transducers are magnetostrictive. Except for variations in dimensions, they are

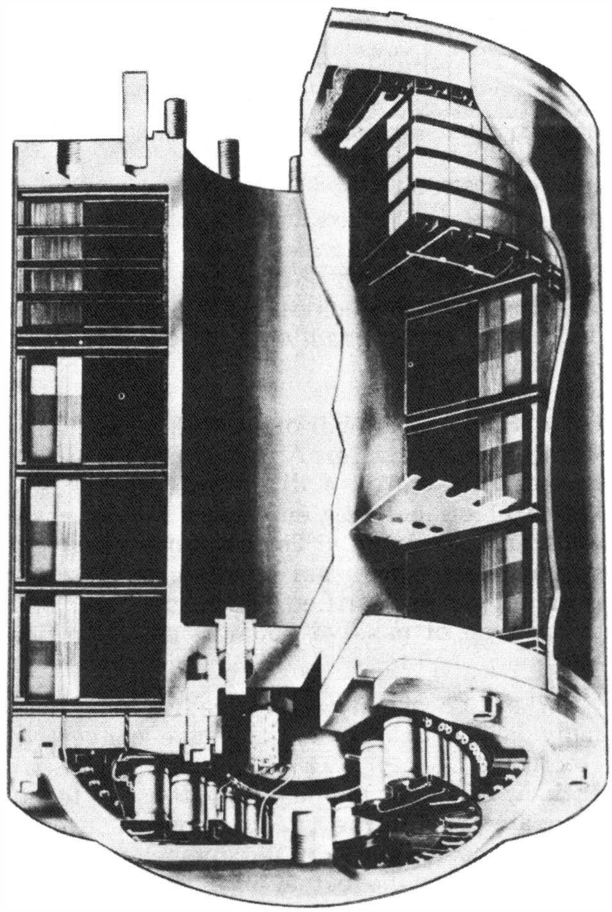

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Figure 7-3.—Scanning magnetostrictive transducer.

similar in design. Physical dimensions vary according to the operating frequency and power output desired.

Electrically, the magnetostrictive scanning sonar unit acts as two independent transducers housed in a common container. One of the independent units is the search section. The other is the maintenance of close contact (MCC) section. The search section is made up of 48 vertical staves. Each stave consists of nickel laminations and a polarizing magnet. The staves are electrically independent of one another. The MCC section, located above the search elements, is used whenever it is desired to transmit the sound pulse at a downward angle of approximately 30°.

PIEZOELECTRIC PROCESS

The piezoelectric type of transducer functions in the same manner as a magnetrostrictive transducer, except that crystals replace the nickel tubes and lamination. These crystals are of various materials: ammonium dihydrogen phosphate (ADP), quartz, tourmaline, and Rochelle salt. The ADP crystals are used more often than the others.

Earlier searchlight transducers are similar to the magnetostrictive transducer in that several hundred crystals are stacked close together to form the diaphragm. One end of the crystal is attached to a bakelite-covered steel plate; the other end is allowed to vibrate freely. The free ends of the crystal block comprise the transmitting and receiving sound units. The entire arrangement of crystals is connected electrically to give the effect of a single large crystal. When an electric current of the desired frequency passes through the crystals, they change size as a unit, thus causing a vibration. When outside energy is received, it exerts mechanical pressure on the crystals, and the pressure in turn produces an electrical current. This transducer has no single resonant frequency, as does the magnetostrictive transducer, and it operates well over a band of frequencies. Although some of these crystal tranducers still are in service, they are rapidly becoming of academic interest only.

Nearly all transducers now being built are of the ceramic type. The overwhelming majority are of barium titanate, containing various additives chosen for the particular application. These ceramic compounds exhibit the piezoelectric effect, so that their operation is fundamentally the same as the crystal types. Ceramic transducers have high sensitivity, high stability with changing temperature and pressure, and relatively low cost. Their greatest advantage lies in the mechanical properties of the material, which allow construction of almost any reasonable shape or size.

TYPES OF SONAR

Two general types of sonar are employed in submarine detection. They are referred to as active and passive sonars.

The active sonar is a transmitting (pinging) and receiving apparatus. It is capable of transmitting underwater sounds that strike targets and are returned in the form of echoes. The echoes so returned are received and presented in a manner to indicate the range and bearing of the target.

Passive sonars do not transmit sound. They merely listen for sounds produced by the target to obtain accurate bearing and estimated range information.

Active sonars normally are associated with surface ships, whereas passive sonars are used by submarines. Submarines also have active sonars. Integrated sonar systems aboard ASW vessels often employ passive equipment in conjunction with active equipment to obtain target depth information.

PASSIVE SONAR

Passive sonar depends entirely upon the target's noise as the sound source. So efficient is passive sonar that sounds many miles away may be identified and their source tracked.

An electroacoustic transducer, called the hydrophone (fig. 7-4), is used to detect underwater sounds. The hydrophone contains either a ceramic material or a metal alloy that reacts to mechanical stress. When subjected to stress, such as that caused by sound waves striking the hydrophone, the material vibrates or undergoes a change in size. These vibrations or changes in size cause a small voltage output from the hydrophone. The frequency of the output voltage is essentially the same as that of the received sound waves.

Passive sonars at one time used the single line hydrophone system, which was trained physically to obtain bearing information. Today's passive sonars utilize a hydrophone array,

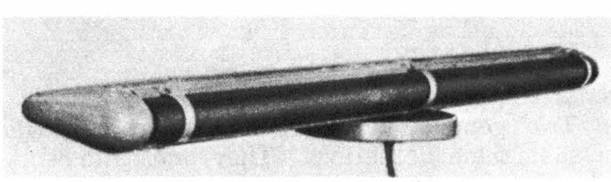

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Figure 7-4.—Hydrophone.

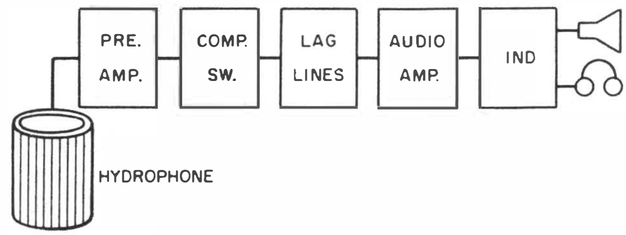

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Figure 7-5.—Block diagram of array type of passive sonar.

consisting of a number of hydrophones connected together in a circle. Although the array is not trained physically, a directional effect is obtained electrically by employing a compensator or scanning switch. The switch is rotated and positioned by the sonar operator at the control console. A simplified block diagram of the array type of passive sonar is shown in figure 7-5.

When the sound waves are received by the individual hydrophones, they are converted to electrical energy. The electrical signal from each hydrophone in the array then is fed to a separate preamplifier. After amplification, the signals are collected by the compensator switch as it samples the output of each preamplifier. From the switch, the collected signals enter the lag lines. The position of the switch indicates the direction from which signals are being received.

The circular arrangement of the hydrophones causes the signals to be out of phase with one another at the output of the preamplifiers. For the signals to be usable, they must be placed in phase with one another. This action is accomplished in the lag lines by delaying the first received signals a proportional amount until the last received signals catch up. Once the signals are in phase, they are additive. As a result, we have a strong signal to feed to the audio amplifier.

From the audio amplifier, the signal is fed to the indicator, and there it is presented both visually and audibly.

ACTIVE SONAR

The major components of a typical active sonar system are similar to those seen in

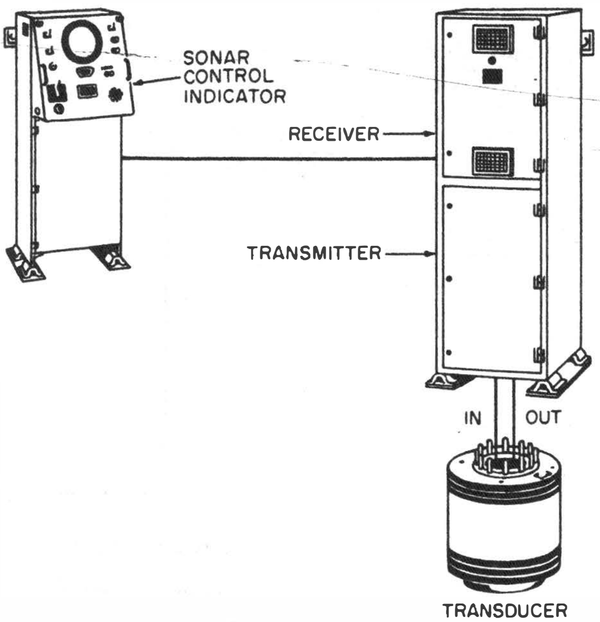

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Figure 7-6.—Typical active sonar system.

figure 7-6. In this set the sonar transmitter consists of a high-frequency audio oscillator and an amplifier. The transmitter feeds a short, powerful pulse to the transducer for transmission into the water. The signal pattern is transmitted in 360° of azimuth.

The transducer converts electrical signals into sound waves. It also changes the received sound echoes back to electrical signals.

Another important part of the active sonar system is the sonar receiver. It functions much the same as the conventional superheterodyne receiver. In this unit the small, high-frequency electrical signals resulting from the echo are amplified and turned into audio signals that can be heard through a loudspeaker. The sonar receiver also feeds the amplified echo signal into the various video indicating devices, such as the cathode ray tube (CRT) on the control indicator.

Searchlight Sonar

Earlier active sonars utilized a searchlight principle for transmitting sounds. Like the searchlight, the transducer had to be trained to a particular bearing in order to transmit a sound beam on that bearing. The sound beam was narrow in bearing width (about 5°), consequently the echoes were received from only a small sector of the surrounding sea. Search procedures called for the operator to transmit, train the transducer, and listen for returns (in steps) while searching the area around the ship. This type of operation was necessary because only limited power could be generated for sonic transmission, and all of this power had to be concentrated into a single sector for achieving maximum ranges. (The scanning sonar in widespread use today develops tremendous power—enough to be transmitted 360° in azimuth simultaneously.)

The main disadvantage of the searchlight type of sonar was the length of time required to scan the area around the ship. For example, it was possible for a submarine to slip by undetected on the port side while the operator was searching on the starboard side. Maintaining contact with a target that had a rapidly changing bearing required a high degree of proficiency on the part of the operator. Another disadvantage was that searchlight equipment had only an audio presentation, whereas today's scanning sonars have a video presentation in addition to the audio information.

Scanning Sonar

Modern ASW ships are equipped with scanning sonar. By means of a CRT, scanning sonar provides indications of all underwater objects around the ship. Its sound pulse spreads out in all directions simultaneously instead of being limited to a narrow sector as are searchlight sonars. The equipment receives the echoes and sounds coming from all directions, then displays the information on the CRT and its remote indicators.

Recently developed scanning sonars have an additional capability known as rotational direction transmission (RDT). This feature permits the transmission of a directional beam throughout 360°, thereby providing maximum possible ranges. While transmitting in this manner, however, the equipment continues to receive the echoes and sounds coming from all degrees of azimuth.

FUNCTIONS OF SCANNING SONAR SYSTEM

The functions of the principal components in a scanning sonar system are understood best by breaking them down into three basic operations: transmission, reception, and presentation. In the following discussion, refer to the

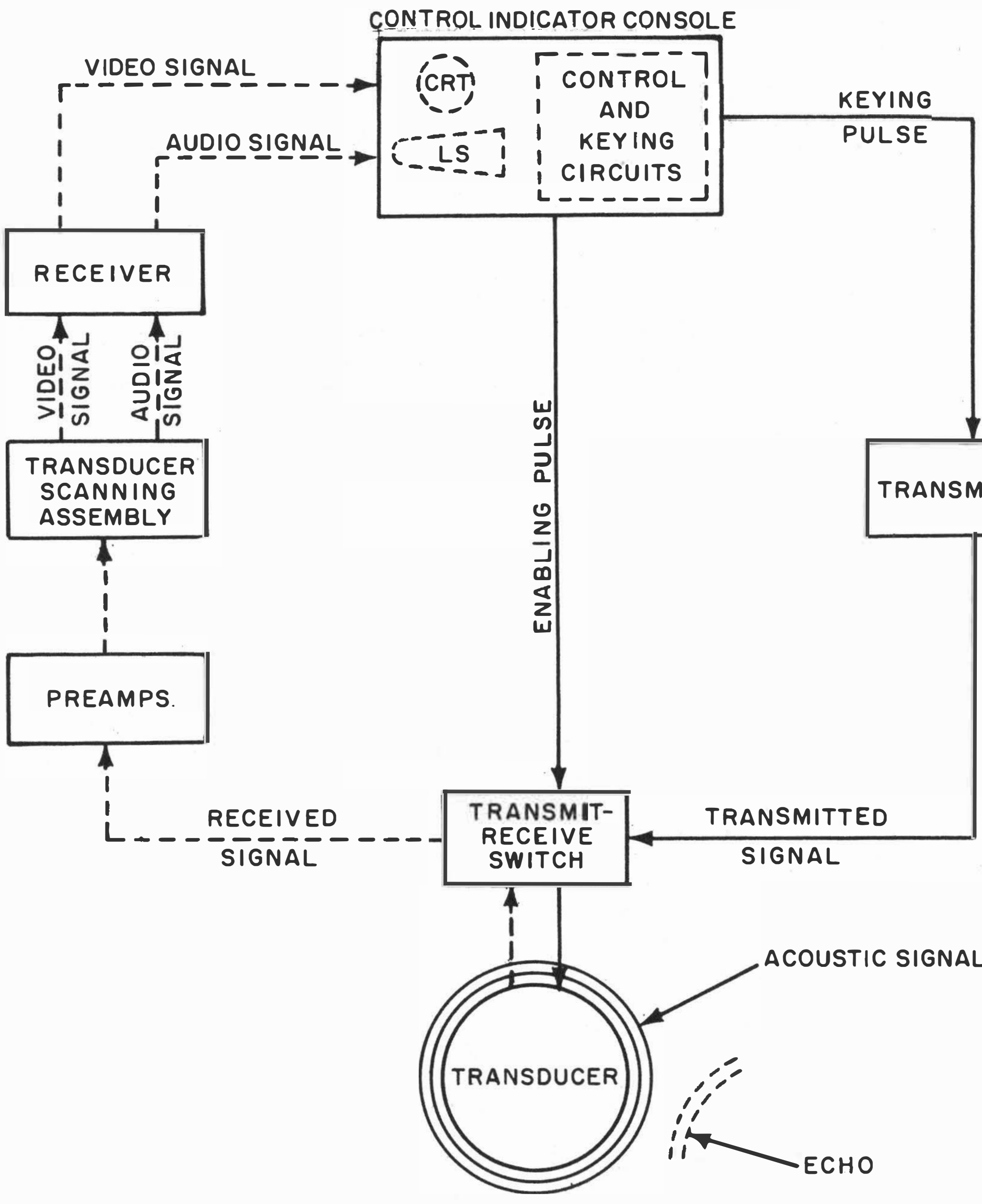

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Figure 7-7.—Block diagram of scanning sonar system.

block diagram in figure 7-7. This illustration shows the keying pulses and transmitted output signals in solid lines; returning echo signals are indicated by dotted lines.

TRANSMISSION

Initiating keying pulses is an automatic function of the keying circuits in the sonar control indicator. The time between pulses, as well as the duration of each pulse, is determined by the position of the controls on the indicator console.

A pulse originating in the keying circuits is sent simultaneously to the transmit-receive switch and to the transmitter. When this pulse is received by the transmit-receive switch, the transducer is switched from the receiver circuits to the transmitter circuits, and it remains connected there until the outgoing signal is transmitted. Then, the transmit-receive switch automatically reconnects the transducer to the receiver circuits.

In the sonar transmitter, the keying pulse triggers the audio oscillator. The signal generated by the oscillator is amplified to the required power level, and then is delivered to the transducer via the transmit-receive switch. The signal is applied simultaneously to all of the transducer elements (staves), and a sound pulse is emitted in all directions.

The acoustical wave released into the water by the transducer continues outward, ever expanding as it goes. When this wave strikes an object capable of reflecting the sound, a small portion is reflected back to the transducer.

RECEPTION

When a portion of the transmitted signal is returned to the transducer, it is converted to an electrical signal for use by the equipment. After conversion the signal is fed to a preamplifier (via the transmit-receive switch) for amplification to a usable energy level. Each stave of the transducer has its own preamplifier. The outputs of the preamplifiers are sent to the transducer scanning assembly for distribution to the receiver. The transducer scanning assembly contains a video scanning switch and an audio scanning switch.

The video scanner rotates continuously, thereby sampling the echoes from each element of the transducer, giving an effect similar to what would be produced by a rapidly rotating and highly directional transducer. The received signal appears at the receiver input as a single to the audio channel of the receiver.

The audio scanner does not rotate continuously. It is positioned as desired by the sonar operator. In this manner, audio signals can be received from any particular direction. The output from the audio scanning switch is applied to the audio channel of the receiver.

In the receiver, the video and audio signals are detected and amplified, as necessary, for presentation in the control indicator console.

PRESENTATION

For the returning echo to be of any value, it must be presented in such a manner that the information it represents can be interpreted.

Before entering the receiver, the returning echo is converted from acoustical energy to electrical energy in the transducer, then is sent to the video scanning switch. The rotation of this switch is synchronized with the sweep presentation, and the echo appears as a brightening of the sweep on the CRT at the bearing from which it originated. The sweep, seen on the CRT as an expanding circle, is adjusted to expand at a rate proportional to half the speed of sound in water. This adjustment is necessary because the transmitted pulse must travel to the target and return.

For a target 2000 yards away, as an example, the sound must travel a distance of 4000 yards. By adjusting the sweep on the CRT to travel at half the speed of sound, the sweep reaches a point equivalent to 2000 yards from the center of the scope at the same time the sound energy returns to the transducer. This energy, or echo, produces a brightening on the scope at a distance from the scope center. The distance can be measured to find the range to the target.

The audio signal is sent from the receiver to the loudspeaker or headset. Together with the CRT information, the audio intelligence is utilized in ascertaining the nature of the target.

A line called the cursor is printed on the scope after each sweep. Because of the long persistency of the cathode ray tube, the target echo remains visible for a short time to determine range and bearing. The operator can control the direction (bearing) and length (range) of the cursor with the bearing and range handwheels. By placing the tip of the cursor on the target, he can read the target's true bearing and range from the dials located on the sonar control indicator.

Various switches and controls also are located on the sonar control indicator. Their purpose is to give a better target presentation. These switches and controls are explained in the equipment technical manual supplied with each sonar equipment.

DEPTH-SOUNDING SONAR (FATHOMETER)

Because it can detect objects and measure distances under water, sonar equipment is ideally suited for measuring water depths. Until relatively recent years, the lead line was the principal means of performing this task. The modern method of sounding with echoes is more efficient, however.

Usually, depth-sounding sonars are called fathometers. They operate on the same principle as submarine-detecting sonars but, because of the reduced power requirement, they are much smaller in size and have fewer components. A representative block diagram of a depth-sounding sonar system is shown in figure 7-8.

When the system is keyed (either automatically or manually), a pulse is generated in the transmitter. The pulse is amplified and applied simultaneously to the transducer and the receiver circuit. The transducer converts the signal to acoustical energy and transmits it downward into the water.

The returned bottom echo is converted by the transducer to electrical energy and applied to the receiver. The received signals are amplified and presented on the recorder or the cathode ray tube indicator.

When recording, a stylus starts across the recorder chart (electrosensitive paper) simultaneously with emission of the pulse. The stylus moves at a constant velocity, marking the paper twice—once at the top of the chart when the pulse is transmitted, and again when an echo returns. These markings provide two points spaced in proportion to the depth of water beneath the transducer.

Visual indication of water depth is provided by a circular sweep on the face of a small cathode ray tube. An engraved translucent shield in front of the CRT furnishes a scale. The transmitted pulse and the echo appear as beams of light, perpendicular to the circular sweep, behind the calibrated scale. With the transmitted pulse always appearing at zero on the scale, the position at which the echo appears indicates the depth of the water.

LIMITATIONS OF SONAR

The range of sonar is limited by certain conditions that weaken and distort the sound beam as it travels outward. The same conditions have similar effect on the echo returning from an underwater object. Echo ranging is not possible if the sound beam and the echo are weakened excessively in their travel through the water. Nor is it possible if the sound beam is distorted on the way out so that it does not strike the underwater object, or if the echo does not strike the transducer on the way back.

The conditions or factors that limit the maximum range at which underwater targets may be detected include—

1. Pulse power;
2. Target composition and aspect;
3. Transmission loss;

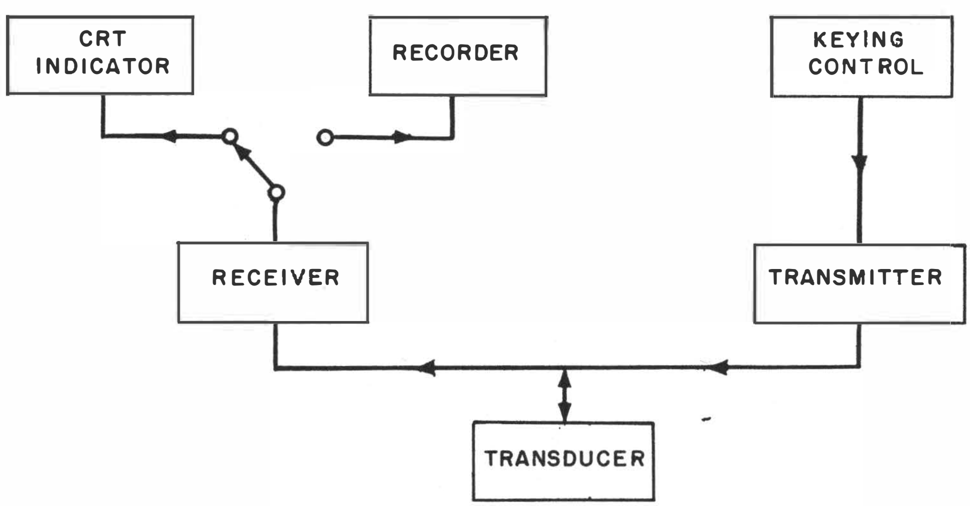

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Figure 7-8.—Block diagram of depth-sounding sonar system.

4. Ambient noise;
5. Refraction of the sound beam;
6. Water temperature;
7. Pressure;
8. Salinity; and
9. Other interference.

In sea water, temperature is the principal factor governing sound conditions. If a cross section or a profile of the sea's temperatures can be taken, a normal condition might show a layer of water from the surface to varying depths of uniform temperatures or of only slight temperature change (isotherm). Next, there would be a region of water that has a relatively large temperature difference—the higher difference at the top, decreasing markedly with depth (thermocline). For the remainder of the measured depth, the temperature would decrease slightly with depth.

The thermocline can play havoc with a pulse of acoustical energy. As the transmitted sound pulse reaches the thermocline, it can be affected in one of two ways.

First, the thermocline can prevent passage of the pulse, and it is reflected back to the surface. Then, targets beneath the thermocline may possibly be undetected. This is one of the reasons submarines seek the cover of such thermoclines and sometimes evade detection by surface ships or aircraft.

Second, the thermocline can allow passage of the sound pulse but alter its direction considerably in doing so. This change is called refraction. If a sound pulse, for instance, enters a thermocline at an angle at 30° from the sea's surface, it is possible for the angle to be altered to 70° or more while traveling through the thermocline, and change again as it emerges. The result of this refraction can be a distorted path of sound travel that affects the accuracy of sonar.

SONAR ACCESSORIES

In many instances, it is difficult to categorize an equipment as an accessory because of its role in the overall sonar system. For example, the remote indicator seldom is thought of as an accessory. It is not essential to the operation of the basic sonar system, consequently it is an accessory. Another example is the towed vehicle used with variable depth sonar (VDS). Without the vehicle, the sonar has no variable depth capability, but it still functions as a conventional scanning sonar; hence the vehicle is an accessory.

All sonar accessories are not as integrally associated with a system as those mentioned in the preceding paragraph. The bathythermograph, for instance, is isolated from any sonar system. The information obtained from the bathythermograph is necessary, however, for the effective utilization of sonar.

The foregoing accessories are among those described and illustrated in the next chapter.

CHAPTER 8

SONAR EQUIPMENT

PASSIVE SONAR

Because passive listening sonars are used principally aboard submarines and at harbor defense activities, they are not discussed in detail in this text, which is oriented toward electronic equipment installed aboard surface ships.

ECHO RANGING

Echo ranging equipments for detecting and tracking sonar targets may be divided into two basic types: searchlight and scanning. The main difference between the two types is in the design of their transducers.

Sonar sets of the searchlight type use a directional transducer to concentrate an outgoing pulse of sound into a narrow beam. (See part A, fig. 8-1.) Target bearing is determined by training the transducer for maximum echo strength. The only response is audio, and a thorough underwater search is a slow, step-by-step process.

Scanning-type sonars utilize a transducer consisting of many elements. The elements remain fixed in their locations but are switched rapidly into use by a switching system. As illustrated in part B, of figure 8-1, the signal transmitted from the transducer consists of a thin cylinder of sound that travels equally in all directions. The cylinder becomes larger and larger as it travels outward, but its thickness (or pulse length) remains constant.

SEARCHLIGHT SONAR

Searchlight sonars are used in harbor defense and may be found aboard ships of the Reserve Fleets; few, if any, remain on ships of the operating forces. Because of their limited application, they are not discussed in detail in this text. If the need arises for additional information on this type of sonar, you will find the subject covered thoroughly in the instruction manuals that accompany searchlight sonar models QGB and QJB.

SCANNING SONAR

Scanning sonar solved the problem of reducing the large amount of time required to search a given area by means of searchlight sonar. For example, a circle 1000 yards in radius can be searched in approximately 1.25

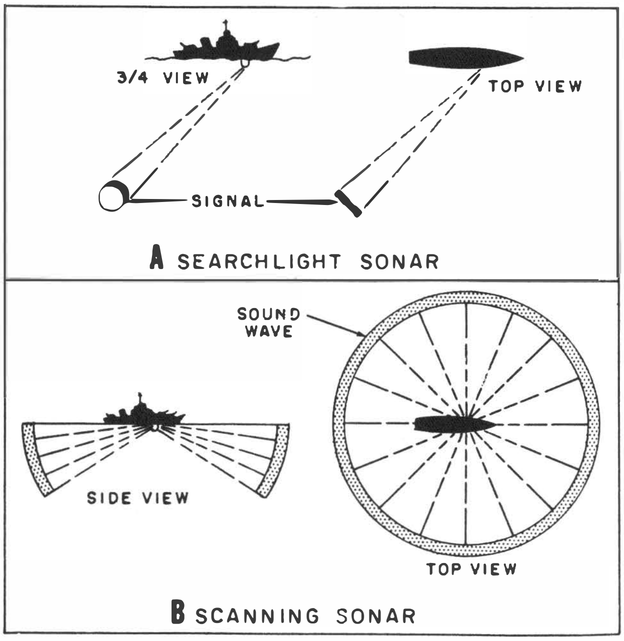

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Figure 8-1.—Nature of the sonar signal for searchlight and scanning sonars.

seconds with a scanning sonar, whereas the same operation takes at least 60 times as long with a searchlight sonar. An additional advantage of the scanning sonar is that it presents a complete and continual picture of all underwater objects and all noise sources within its range. Thus, the operator is able to keep track of many targets at the same time. (See fig. 8-2.)

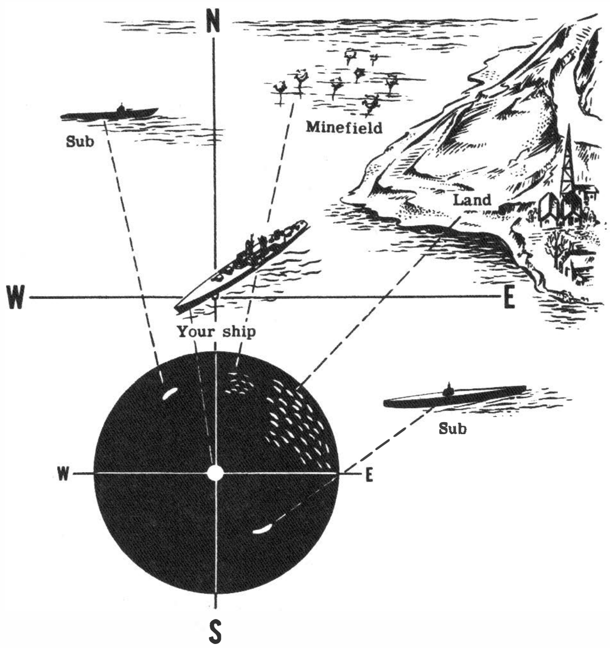

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Figure 8-2.—Scanning sonar presentation.

Information presented by a scanning sonar is displayed on a PPI-type screen. The display is similar to a radar PPI presentation, and it gives much the same data. At the center of the screen a bright area indicates the position of own ship. Various underwater objects are represented by the bright spots (pips) that appear on the screen.

The first scanning sonar to be used extensively by the Navy was the model QHB. Several modifications later the QHB became the AN/SQS-10. Today, the AN/SQS-10 is an obsolete equipment, but many of its components and features are incorporated in the newer sonar sets. For this reason, it is described in the next topic.

Sonar Set AN/SQS-10

The AN/SQS-10 sonar set is used for detecting, tracking, and displaying underwater targets. Target detection (and subsequent tracking) is accomplished by echo ranging in all directions and passive listening from any desired single direction. Target presentation is provided visually on indicator scopes and audibly on loudspeakers or headphones.

The set operates on a frequency of 20 kc. It offers a choice of three pulse lengths: 6, 30, and 80 milliseconds. The pulse length controls the amount of energy leaving the transducer. Power output for the short pulse is approximately 50 kw; for medium pulse, 10 kw; and for long pulse, 2 kw. Available modes of operation are (1) listening for echoes without transmitting (passive listening), (2) echo ranging at any one of three range scales (1000, 3000, and 6000 yards), and (3) echo ranging with a range gated sweep.

1. When the equipment is set for passive listening, the scope picture is a continuously oscillating spiral sweep. This sweep occupies approximately the outer third of the screen, and a twin-dotted cursor, indicating the bearing of audio scanning, appears on the scope. Signals from an underwater noise source appear on the screen as a narrow radial line or a wedge of light. Bisecting the wedge with the cursor gives the bearing of the noise source. Range cannot be determined because the noise source is not returning an echo.

2. In the echo ranging mode of operation, the cycle commences with the cursor appearing on the scope at the instant a transmitted pulse is leaving the transducer. After the pulse is transmitted, the cursor disappears from the scope, and an electron beam spirals out from the center of the screen to produce an ever-enlarging circle. Sweep of the electron beam is synchronized with the rotation of the video scanning switch in such a way that a returning echo brightens the scope at a spot corresponding to the range and bearing of the object that produced the echo. Because the system is alert in all directions and echo indications remain for a time on the screen, the scope becomes a map of all echo-producing objects in the vicinity of the ship. After each scan period, the circular sweep fades out (or blanks), the transmitter is energized with a new pulse

of energy, the cursor reappears, and a new cycle begins.

3. With the equipment adjusted for range gated sweep operation, the bearing cursor remains on the scope for an extended period of time. The cursor remains visible until the expanding sweep, which is invisible at this time, reaches a point 300 yards short of the expected appearance of the echo pip. At that point, the cursor disappears and the spiral sweep appears. For instance, if the cursor is adjusted for a target range of 1000 yards, it disappears and the spiral sweep starts at 700 yards—300 yards short of the target. This mode of operation facilitates the accurate tracking of targets detected by the other modes of operation or by other means.

The major components of the AN/SQS-10 are seen in figure 8-3. With the exception of the capacitor assembly and signal data converter units, the function of each of the illustrated components was discussed in the preceding chapter.

The capacitor assembly consists of a bank of high-voltage storage capacitors. Its function is to supply a high voltage (approximately 8000 volts) to the power amplifiers in the transmitter during the time a pulse of energy is being transmitted. By this action, a high-powered pulse is transmitted and the power output is maintained at a relatively constant level for the duration of the pulse. Because the capacitors lose most of their charge during transmission of the pulse, they are recharged to their original voltage level of 8000 volts at the end of each pulse.

The signal data converter was introduced into the sonar system when underwater fire control systems became too complex to operate with target bearings that were relative to the ship's bow. By means of synchromechanisms, relays, amplifiers, and associated circuitry, this unit converts the video presentation on the scope to true bearings, stabilized in the horizontal plane. With stabilization, the position on the scope of the echo pip is unaffected by ship's roll and pitch.

Because the data converter orients the scope presentation to true north, some means is required for locating the ship's bow with reference to the sonar picture. The converter provides this means by generating a signal that places a stern line indicator into the sonar display.

The signal data converter also is used in an operation called aided tracking. By accepting tracking orders from the attack director and feeding these orders to the control indicator so that the cursor tracks the target automatically, the converter aids the sonar operator in keeping the cursor on target during underwater attacks. The operator adjusts the cursor in bearing when it tends to drift off the pip.

Sonar Set AN/SQS-4( )

The AN/SQS-4( ) search sonar, which replaced installations of the AN/SQS-10 on ships of the active fleet, operates on the azimuth scanning principle. Like other scanning sonars, it is an echo ranging and passive listening equipment. It provides a continuous video display of acoustic reception in all directions, and an audio response from any desired single direction.

This set has practically the same major units as the AN/SQS-10. Although the units are essentially the same, those in the AN/SQS-4( ) are of an improved design and perform much better than those in the older set. This improved performance gives the AN/SQS-4( ) a maximum range that is considerably more than the range of the AN/SQS-10.

An additional feature of the AN/SQS-4( ) is that it has a built-in test set and control unit. The test set and its control unit provide facilities for testing and calibrating the sonar system, and for training sonar operators in the use of the system.

Sonar Sets AN/SQS-29( ) to -32( )

The AN/SQS-29( ) to -32( ) sonar sets are the result of modifications to the AN/SQS-4 series of sonars. Foremost among the improvements incorporated in these modified sets is a mode of operation called rotating directional transmission (RDT).

In the past, scanning sonar used only the omnidirectional type of searching. In other words, it scanned equally in all directions. With the RDT mode of operation, the total power

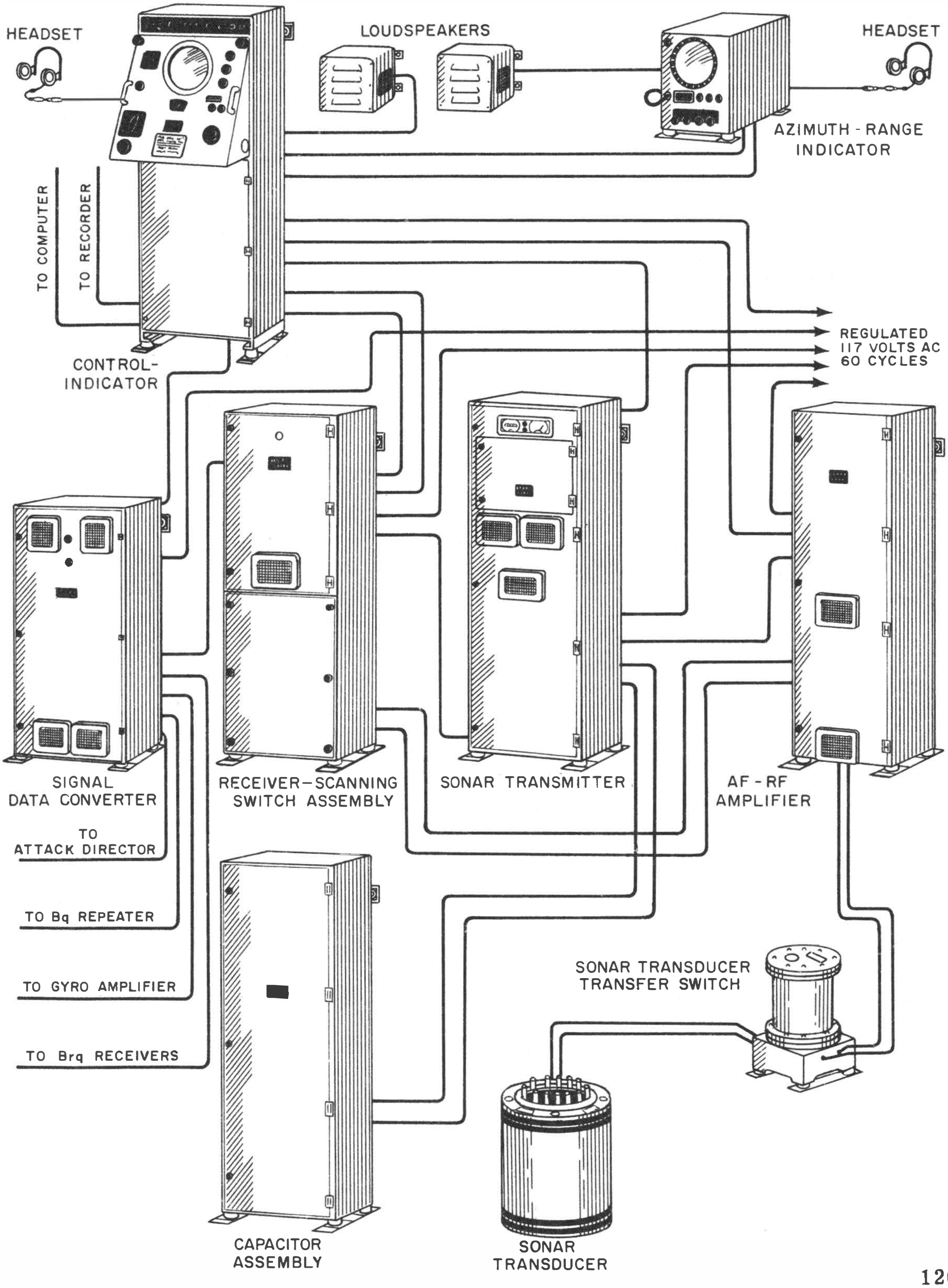

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Figure 8-3.—Major components of the AN/SQS-10 sonar set.

output is concentrated into a directional transmission beam that covers a narrow sector. This beam then is caused to rotate 360° in azimuth around the ship. Rotation of the beam is similar to the rotation of a radar antenna, but it is accomplished electronically and at a much faster rate. The benefits attained from RDT are greater power of transmission and improved ranges.

Except that some of the sets in the AN/SQS-29 to -32 series are further modified to permit use of the AN/SQA -10 variable depth sonar (discussed later in this chapter), the sets comprising this series differ from one another only in their operating frequencies.

Sonar Set AN/SQS-23( )

The AN/SQS-23( ) sonar detecting-ranging set, a scanning type of search and attack sonar equipment, is similar in its audio and video presentation to older scanning sonars. Essentially, it is a refinement of the AN/SQS-29 to -32 series of sonars.

This equipment operates on a very low frequency. A directional sonic beam rotates around the transducer to form the echo ranging transmissions. The transducer is designed so that it can be driven without damage to extremely high-power levels. The transmission frequency of the equipment, combined with rotating directional transmission and the ability of the transducer to operate at high-power levels, makes this set effective for long-range target detection.

Features incorporated into the AN/SQS-23( ) include (1) a means of lowering or raising the normal operating frequency a slight amount to minimize interference during multiship operations; (2) a beam depression control that permits a downward tilt of the transmitting and receiving beams for use in maintaining contact with close targets; (3) a built-in test set for use in evaluating the overall performance of the system; and (4) a unit for inserting synthetic and maneuverable target signals into the receiving circuits to provide for operator training.

Sonar Set AN/SQS-26( )

The AN/SQS-26( ) sonar is a recently developed, advanced search sonar that represents a radically improved approach in concept and in application to the present-day problems of submarine detection. Detection features and operational flexibility of this equipment permit long-range coverage independent of water conditions and the depth and speed of the target. Because of security reasons, details of this equipment are not discussed in this text.

MINE-DETECTING SONAR

Until relatively recent years, minesweeping was the only available means for eliminating the danger of mines in naval warfare. It still is one of the prime methods of removing or neutralizing these hazards to safe navigation, but supplementing this plan is the procedure of detecting the actual location of the mines so that sweeping operations may be employed in only the exact required locations.

In many instances, the known location of mines is sufficient to neutralize their effectiveness. Marking the location of a minefield with buoys permits ship traffic to remain clear of the danger area. Thus no further action is required when this obstruction can be bypassed safely and expeditiously.

The equipment presently used by the Navy to search for mines and other small underwater objects is the AN/UQS-1( ) mine-detection set, described next.

MINE-DETECTION SET AN/UQS-1( )

The AN/UQS-1( ) sonar employs two transducers (transmitting and receiving) enclosed within a single housing. The transmitting (projecting) transducer uses a piezoelectrical system to transmit into the water a sonic beam that covers an arc 60° wide in azimuth and 10° in the vertical. Echoes reflected from underwater objects are received by the receiving transducer, converted into an electrical signal, and applied to the PPI scope, showing an indication of range and bearing of the object.

Either manual or automatic searching is available. In manual operation, the transducers are caused to rotate as a bearing handwheel is rotated, searching through 360° in azimuth at selectable ranges of 200, 500, and 1000 yards. When operating automatically, the transducers may be caused to rotate through 360° in azimuth, to search all around the ship, or to rotate back and forth through an arc 90° in azimuth, to search from 315 relative to 045 relative ahead of the ship. (A field change to the equipment provides for an automatic sweep of 180° ahead of the ship.) For automatic search, the equipment can be set to search in ranges of 200, 500, or 1000 yards.

Whether searching manually or automatically, the depression angle of the transducers is controlled manually by a handwheel. The transducers may be tilted to cover from plus 5° to minus 50° in depression. The angle of tilt can be observed on a depression indicator dial, which shows the angle of depression of the sound beam.

The scan pattern appears on the face of the scope as a 20° triangular sector with the vertex of the sector at the center. Targets are indicated on the scope as a bright spot at the correct range and bearing of each target.

DEPTH-SOUNDING SONARS

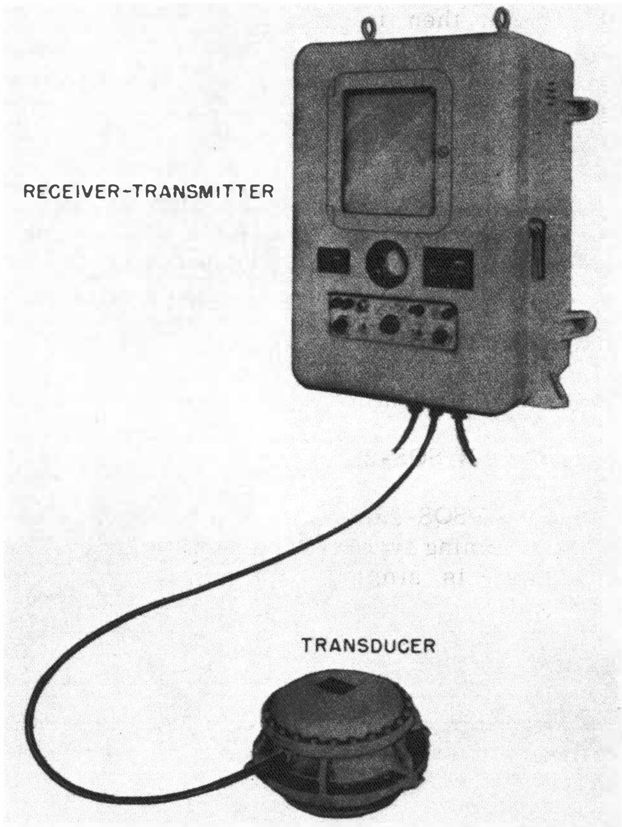
The depth of the sea can be measured by several methods. One is by dropping a weighted, distance-marked line (lead line) to the bottom of the water, and observing the depth directly from the line. The chief disadvantage of this method of determining depth is that its use is limited to very shallow water.

Sound is another method of measuring depth. A sound pulse is transmitted, aimed at the bottom of the sea, and its echo is heard. The time between transmission and echo reception is considered in relation to the speed of sound through water, then the depth is determined thereby. Depth-sounding sonars, or fathometers, apply this principle of sound physics to find the bottom of the sea.

Among the depth-sounding sonars installed aboard ships in the active fleet are the models AN/UQN-1( ), AN/UQN-2( ), AN/SQN-8, and NMC series. A comparison of installation records shows that the AN/UQN-1( ) is by far the most common fathometer in use today. For this reason, it is the only one described herein.

DEPTH-SOUNDING SONAR AN/UQN-1( )

The AN/UQN-1( ) fathometer and its transducer are shown in figure 8-4. This fathometer is a compact unit, capable of giving accurate readings at a wide range of depth—from about 5 feet to 6000 fathoms. It employs the hot stylus and sensitized paper method of recording depths. For shallow depths, it has a visual scope presentation.

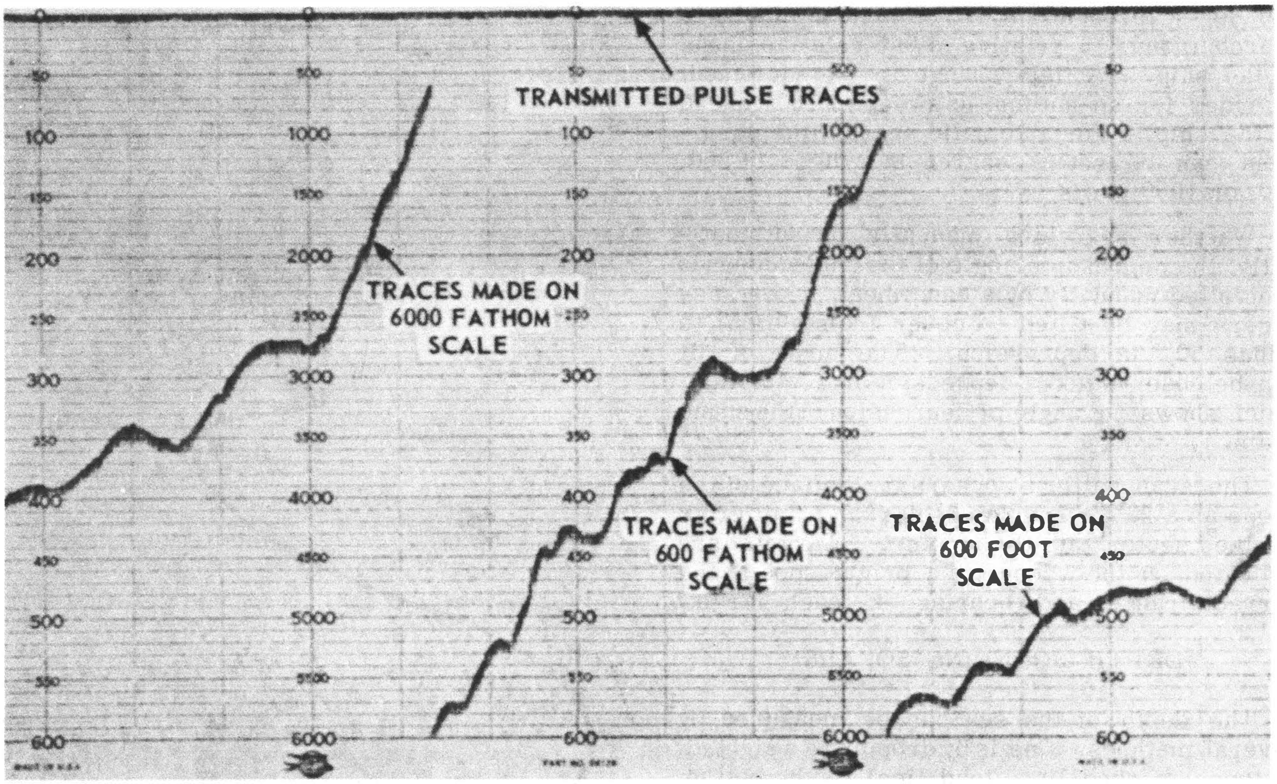


62.9

Figure 8-4.—Depth-sounding sonar AN/UQN-1( ).

Three recorder ranges are provided on the AN/UQN-1( ). They are 0 to 600 feet, 0 to 600 fathoms, and 0 to 6000 fathoms. In addition to recorder chart indications, two visual indicator ranges are available: 0 to 100 feet and 0 to 100 fathoms. The equipment may be keyed manually or automatically.

When the fathometer records, a stylus starts down the recorder chart simultaneously with the transmission pulse. The stylus moves at a constant velocity and marks the paper twice—once



62.10

Figure 8-5.—Fathometer depth recording.

at the top of the chart when the pulse is transmitted, and again on the depth indication when the echo returns. A depth recording made by a fathometer of this type is seen in figure 8-5. The recording illustrated was made from a ship sailing over a sea whose depth was decreasing steadily. The first part of the trace was recorded on the 6000-fathom scale. Inasmuch as the paper moves from right to left, you can see, in the section of the paper shown, that the depth decreased from 4000 to 600 fathoms. (Later depth information is to the right of the paper.) When depth was about 600 fathoms, the scale was shifted to the 600-fathom setting. Because the depth decreased still further, the scale was shifted to the 600-foot setting when a depth of about 100 fathoms was recorded.

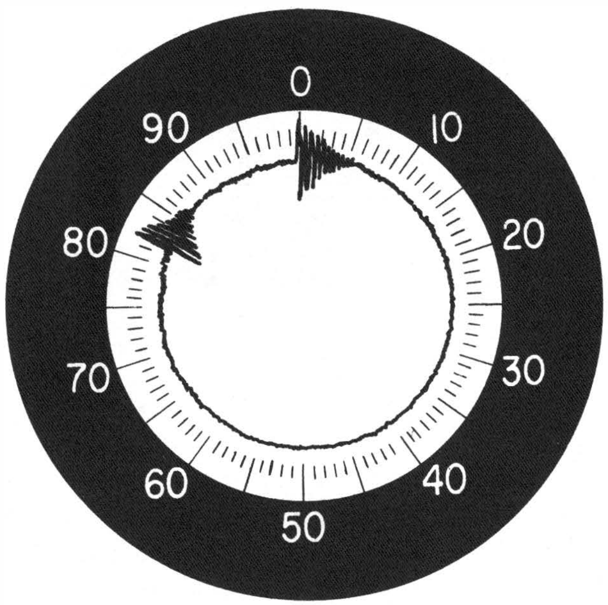
Visual indication is supplied by a circular sweep on the face of a scope. Transmitted pulse and returning echo mark the sweep trace radially. The visual indicator, pointing to a depth of 82 (feet or fathoms, depending upon the scale setting), is shown in figure 8-6.

SONAR ACCESSORIES

Supplementing the basic sonar system are a number of equipments that either extend the capability of the system or facilitate its use. Some of this supplementary or accessory equipment forms an integral part of the overall sonar system, whereas other equipment in this category is completely isolated from the system. The accessories discussed in the remainder of this chapter are of both types.

VARIABLE DEPTH SONAR

One of the problems affecting the ability of sonar to detect and maintain contact with a submarine is the thermal layers in the ocean. These layers reflect or bend sonar signals so that a submarine lying or cruising below a



71.57
Figure 8-6.—Visual depth indicator.

particular layer may go undetected. To overcome this obstacle, the variable depth sonar (VDS) was developed.

Essentially, the VDS is a conventional sonar that is modified to transmit and receive signals through a transducer contained in a towed vehicle (fig. 8-7). By means of a crane-type hoist and a tow cable, the vehicle is lowered below the interfering thermal layers and then towed behind the ship. Thus, the effect of the thermal layers on the signals is minimized.

The transducer inside the towed vehicle is connected electrically to the shipboard sonar equipment by means of an electrical cable that extends through the center of the armor of the tow cable. In general, this arrangement may be thought of as a transducer removed from the hull of a ship and towed through the water, separated from its sonar set by a long tow cable. The existing shipboard sonar equipment performs its normal transmission, receiving, and interpretive display functions unchanged by the addition of the towed transducer.

Currently, two variable depth transducer systems are installed on ships: the AN/SQA-10 and the AN/SQA-11. Except for different sized transducers, these two systems are identical in physical appearance and operation. The AN/SQA-10 is used in conjunction with AN/SQS-29 and -30 sonar sets, whereas the AN/SQA-11 is designed principally for use with the AN/SQS-23 sonar set.

AZIMUTH-RANGE INDICATORS

A complete azimuth search sonar installation includes two remote units called azimuth-range indicators. These units are remote video repeaters of the scope presentation at the sonar control indicator. They provide an indication of target bearing and range, and they have provisions for monitoring the audio response from targets.

One common type of azimuth-range indicator, the IP-286/SQ, is illustrated in figure 8-8. This particular unit is used with installations of the AN/SQS-29 to -32 series of sonars and in some of the older sonar systems. A similar unit, designated IP-481/SQ, is used with the AN/SQS-23 sonar equipment.

Controls on the front panel of the azimuth-range indicator affect the audio and video response of the remote unit, but do not affect operation of the sonar console. Three of the four controls are for adjusting the video display. The fourth, labeled speaker volume control, adjusts the audio output level.

Target bearing is read from an azimuth ring surrounding the video presentation. Target range is indicated on two dials that are visible through a window opening. Audio response is heard from either an external speaker unit or headphones, as desired.

RECORDER-REPRODUCER

A tape recorder-reproducer is employed with most sonar installations to record audible sonar information of actual ASW operations. Information thus obtained is utilized for postanalysis of ASW actions and for training sonar operators.

The AN/UNQ-7( ) recorder-reproducer set (fig. 8-9) is a two-track recorder and reproducer that uses magnetic tape to record its information. It stores for playback (immediately or indefinitely) the sounds it "hears" within the limits

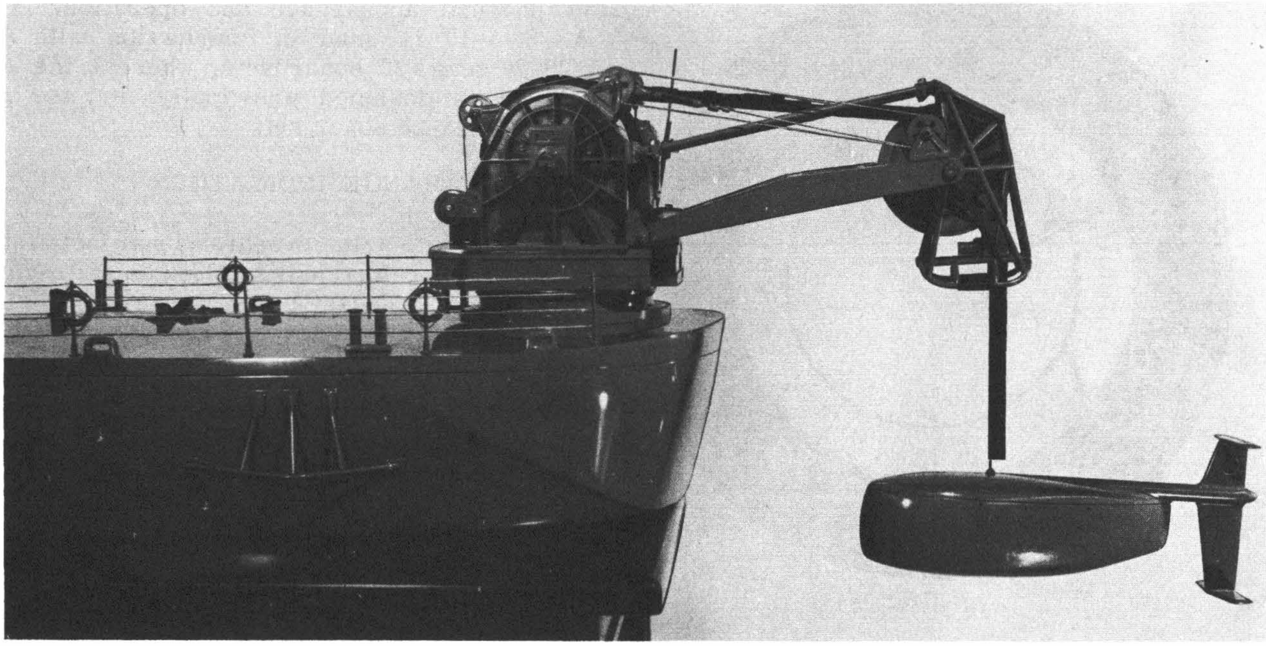


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Figure 8-7. —Towed vehicle for VDS.

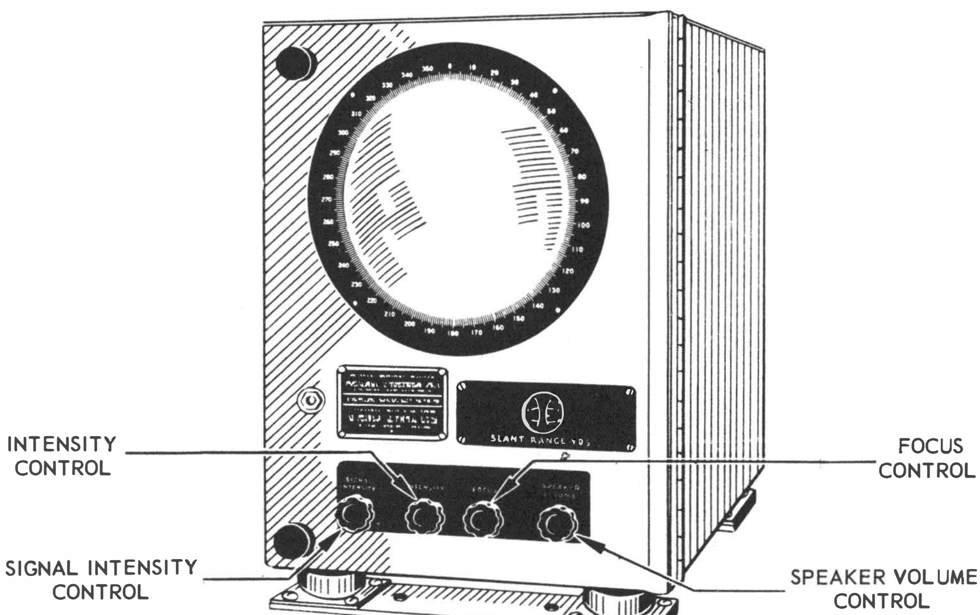

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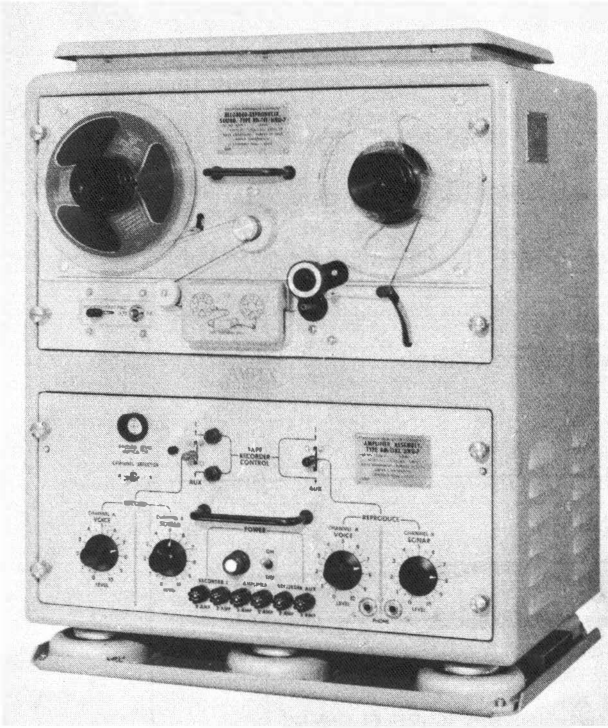
Figure 8-8. —Azimuth and range indicator.



7.54
Figure 8-9.—Tape recorder AN/UNQ-7( ).

of the audible spectrum. Channel B track normally is fed underwater sound information directly from the sonar equipment. Voice information from the vicinity of the sonar operator's station is fed to channel A. Both tracks can be (and usually are) recorded simultaneously, although either one may be recorded separately. In addition, the tape recorder allows simultaneous recording and reproducing of sounds. This feature permits monitoring what is being recorded as it is recorded.

When a recording produced by the equipment is played back, both tracks can be heard at the same time, and both tracks can be controlled in volume or can be cut out entirely. In short, the AN/UNQ-7( ) tape recorder-reproducer acts as a combination of two tape recorders, coupled together, to allow superimposing upon each other, two audio information sources.

The top half of the tape recorder-reproducer, as seen in figure 8-9, is the actual recorder and reproducer. The lower portion is the amplifier section. It includes controls and indicators that directly affect the recording and playback of tapes. The recording controls are to the left of the amplifier section. Playback controls are at the right of the amplifier section. Both channels have separate controls for recording and reproducing.

BATHYTHERMOGRAPH

Pressure, salinity, and temperature, as mentioned in chapter 7, are the conditions that have an effect upon sound travel through the water. Increases in pressure speed up the velocity of sound, making the speed of sound higher at extreme depths where pressure is greater than on the surface. An increase in salinity also has a tendency to increase the velocity of sound in water. The effects of pressure and salinity are not as great, however, as those caused by changes in temperature.

Temperature, then, is the most important consideration to contend with in calculating variations in the speed of sound in water. Information obtained about the ocean temperature, at a given depth and time, can be used to predict what will happen to the transmitted sound beam as it travels through the water.

The bathythermograph, commonly called the BT, is an instrument for obtaining a permanent, graphical record of water temperature (in degrees Fahrenheit) against depth (feet) as it is lowered in the ocean.

Figure 8-10 shows how the BT looks as it usually is seen. Figure 8-11 illustrates the temperature and pressure elements that make up the BT.

The temperature element consists of about 45 to 50 feet of fine copper tubing filled with xylene. The tubing is wound around inside the tail fins of the BT, and comes into direct contact with the sea water. As the xylene expands or contracts with the changing water temperature, the pressure inside the tubing increases or decreases. This temperature change is transmitted to a Bourdon tube, a hollow brass coil spring, which carries a stylus at its free end. The movements of the Bourdon, as it expands or contracts with changes of temperature, are recorded by the stylus on a metallic-coated glass slide. The temperature range is from 28° to 90° F.

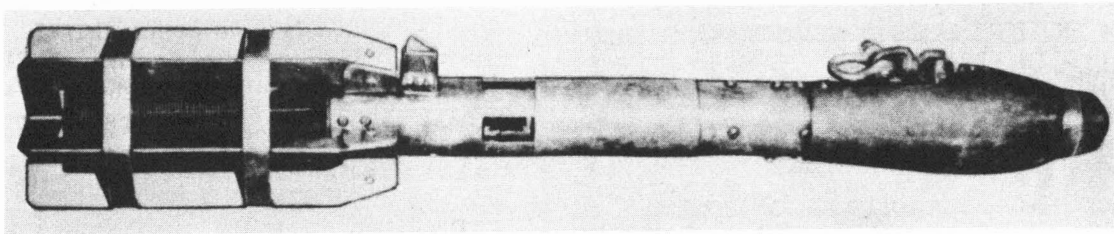


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Figure 8-10. —The bathythermograph.

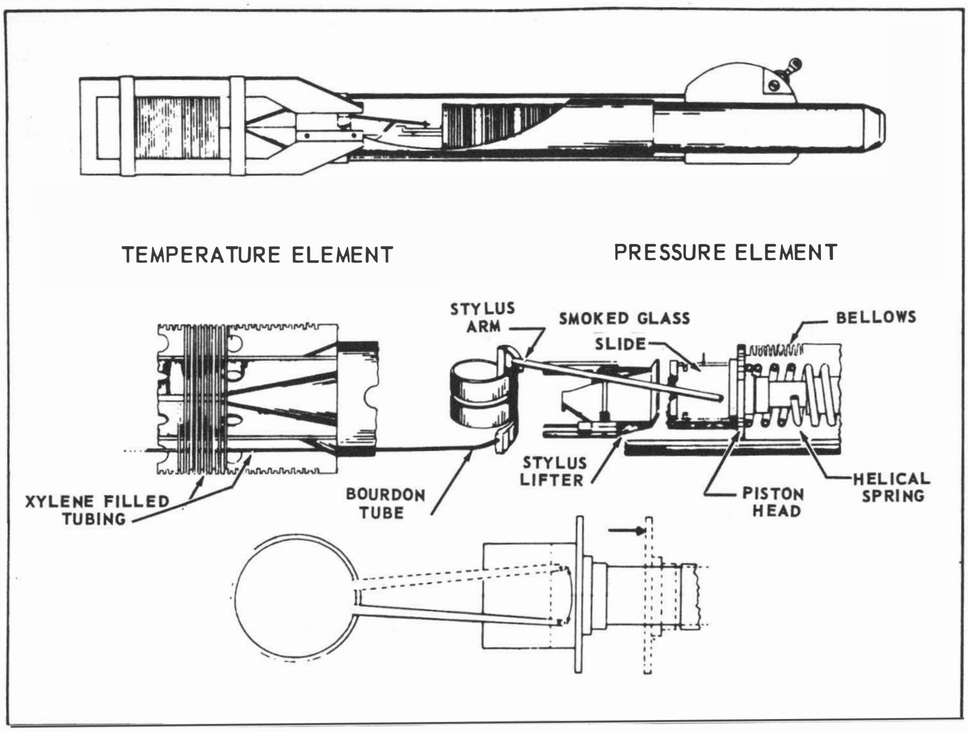

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Figure 8-11. —Bathythermograph temperature and pressure elements.

The slide is held rigidly on the end of a coil spring enclosed in a copper bellows. Water pressure, which increases in proportion to water depth, compresses the bellows as the BT sinks.

The dotted line drawings in the lower portion of figure 8-11 illustrate the action of the stylus moving left on the slide with a decrease in temperature and the bellows being compressed to the right (arrow) as depth increases. Increase in depth pulls the slide toward the nose of the BT, at right angles to the direction in which the stylus moves to record temperature. When the BT is raised toward the surface, the spring expands the bellows to its original shape. Thus, the trace scratched on the plated surface of the slide is a combined record of temperature and pressure, the pressure being proportionate to depth.

Bathythermographs are designed for use in measuring three different depth ranges. In general, a No. 1 designation means it is a shallow type, No. 2 means it is a medium type, and No. 3 indicates that it is a deep type BT. Table 8-1 lists the various BTs in use and gives their design depth.

TRAINING DEVICE

The AN/SQS-T3( ) sonar trainer, shown in figure 8-12, is a synthetic training device used aboard ships equipped with scanning sonar. This trainer supplies simulated sonar echoes from a maneuverable artificial target to the audio and video indicating channels of the tactical scanning sonar equipment. It provides realistic training for sonar operators in the techniques of sonar search-attack procedures.

Output signals for positioning a dead reckoning tracer (DRT) are also supplied for simulating own ship's motion. Training is accomplished without interrupting the normal operation of the ship's sonar transmitter and receiver. Along with the artificial target, actual targets appear while the trainer is in operation. These actual targets are presented by the ship's sonar equipment audio and video indicators.

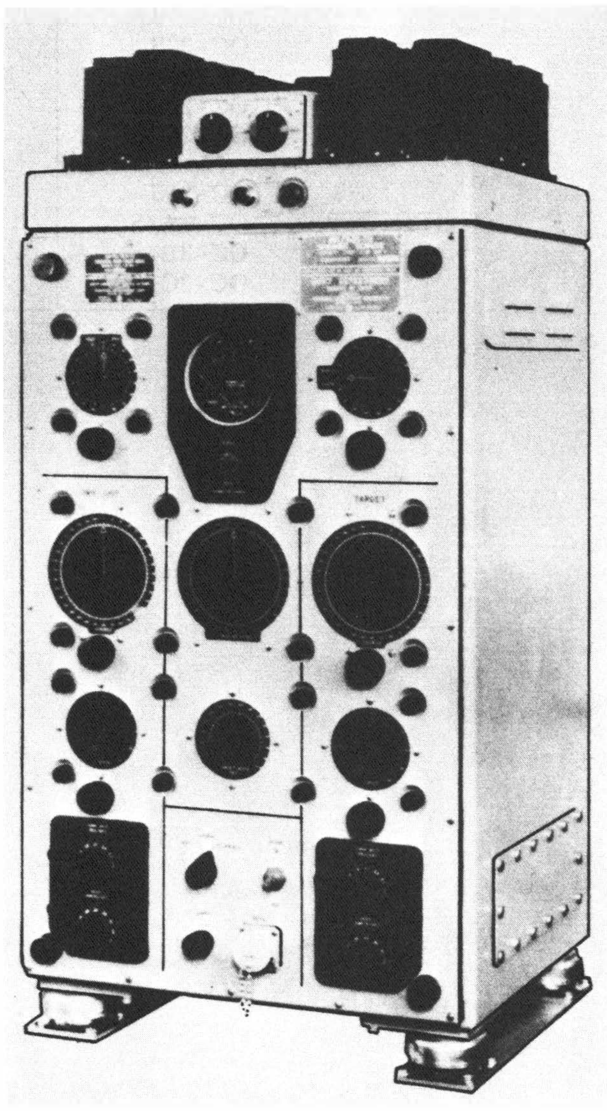

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Figure 8-12.—Sonar trainer AN/SQS-T3( ).

Table 8-1. —BT Series Designations

Series No.	Name	Design depth (feet)
OC-1/S OC-1A/S OC-1B/S OC-1C/S	Shallow	0 to 200
OC-2/S OC-2A/S OC-2B/S OC-2C/S	Medium	0 to 450
OC-3/S OC-3A/S OC-3B/S OC-3C/S	Deep	0 to 900

CHAPTER 9

MISCELLANEOUS FACILITIES

Although many of the equipments discussed in this chapter operate on the radio, radar, or sonar principle, their application is so specialized that they are dealt with more appropriately as miscellaneous facilities, instead of as radio, radar, or sonar equipments. For this reason, they were not included in preceding equipment chapters.

ELECTRONIC AIDS TO NAVIGATION

Electronic equipment, invaluable though it may be as an aid to the navigator, depends upon the performance of manmade apparatus, which is always subject fo failure and casualty. Consequently, electronics supplements but does not supplant such tried and true methods of navigation as celestial navigation.

Basically, electronic navigation is a form of piloting. Piloting is that branch of navigation in which a ship's position is obtained by referring to visible objects on the earth whose locations are known. This reference usually consists of bearing and distance of a single object, cross bearings on two or more objects, or two bearings on the same objects with an interval between them.

Position in electronic navigation is determined in practically the same way that it is in piloting. There is one important difference, however. The objects by which the ship's position is determined need not be visible from the ship. Instead, their bearings (and in most instances their ranges) are obtained by electronic means—usually radio.

The advantages of piloting by radio are obvious. A ship's position may be fixed electronically in fog or thick weather that otherwise would make it impossible to obtain visual bearings. Moreover, it may be determined from stations located far beyond the range of even clear-weather visibility.

RADIO DIRECTION FINDERS

Not too long ago, the radio direction finder (RDF) was the only electronic means of obtaining a ship's position at sea. Today, the more accurate loran and tacan systems (discussed later) have relegated the RDF to the position of a seldom-used secondary navigational aid. The RDF, however, still is installed aboard most ships for use in locating personnel afloat in liferafts or lifeboats equipped with radio transmitters. It also is used to obtain bearings on intercepted radio and radar signals of both known and unknown origin.

Essentially, the radio direction finder is a sensitive receiver connected to a directional antenna. Early models utilized a loop antenna that was rotated manually to the position of strongest signal reception. Bearing of the signal was read from an indicating device consisting of a pointer and an azimuth scale. Modern RDFs have antennas that are rotated at a constant speed by a motor. Bearing information is indicated on the face of a cathode ray tube.

Range data cannot be obtained from taking a single bearing with an RDF. Usually, several bearings are taken either as rapidly as possible on several radio beacons or radio stations of known geographical location, or on a single beacon or station of known location, allowing from 10- to 30-minute intervals between bearings. Plotting these bearings gives a fix that is more or less accurate, depending on the accuracy of the bearings.

Currently, three different models of radio direction finders are installed on ships in the active fleet. They are models AN/URD-2( ), AN/URD-4( ), and AN/SRD-7( ). Of the three models, the most common is the AN/URD-4( ), which is described in the next topic. The AN/URD-2( ) is a VHF equipment of limited distribution. A combination m-f/h-f radio direction finder, the AN/SRD-7( ), is installed mostly on submarines.

Radio Direction Finder AN/URD-4( )

Shipboard installations of the AN/URD-4( ) direction finder set (fig. 9-1) consist of an antenna, a receiver/power supply unit, an azimuth indicator, and a signal data converter (not shown). The set provides visual (and sometimes aural) direction-finding information from radio signals in the frequency range of 225.0 to 399.9 mc. For surface to surface operation, the range of the equipment is approximately 20 miles; for surface-to-air, approximately 90 to 125 miles. Bearing accuracy is plus or minus 5°.

Tuning controls for the receiver are located on the front panel of the azimuth indicator. By setting the digit selector switches to the desired frequency, the receiver can be tuned to any one of 1750 frequencies, spaced 0.1 mc apart. To facilitate rapid tuning, any 20 of the 1750 available frequencies may be preset on the digit selector switches. Then, the preset frequencies are selected by means of a single channel selector switch. For convenience in servicing the equipment, or for emergency operation, digit selector switches also are provided on the front panel of the receivers.

Visual information appears on the face of a cathode ray tube in the azimuth indicator. Around the perimeter of the scope is a compass scale from which is read the signal bearing. When no signal is present, the pattern on the scope is a circle. When a signal is present, this circle is resolved into a propeller-shaped pattern whose axis lies along a line indicating the signal source direction and a point 180° displaced from the direction of signal origin. To eliminate this ambiguity, it is necessary to cause a further change in the shape of the pattern. Placing the calibrate-sense switch in its sense position causes the propeller-shaped pattern to become a V-shaped pattern, the apex of which indicates the signal bearing.

The direction finder set is designed for either shipboard or shore use. When the equipment is installed on ships, the bow of the ship is used as reference or zero degree direction. Signal bearings, consequently, are relative to the ship's heading if not corrected by the action of the signal data converter. A switch, on the front panel of the azimuth indicator permits selection of either a relative bearing or a true geographical bearing of a received signal.

LORAN SYSTEM

The long-range navigation (loran) system provides a means of obtaining accurate navigational fixes from pulsed radio signals radiated by shore-based transmitters. With loran, a ship's position can be fixed at much greater distances from the transmitting stations than is possible with radio direction finders. Depending on the mode of loran operation and the time of day or night, fixes are possible at distances up to 3000 nautical miles from the transmitting stations.

The loran system comprises two subsystems, or modes of operation, called loran A and loran C. Because loran A is the basic mode of operation, it is used as the vehicle for explaining the loran principle of operation. Loran C is a refinement of loran A, differing from the basic mode mainly in operating frequency and coding of signals employed. It has a much greater distance range than loran A.

Loran involves establishing a fix at the intersection of two or more "lines of position." A loran line of position is a line of constant time difference between the arrival of two pulse-modulated radio signals transmitted from a pair of synchronized loran transmitting stations that are located several hundred miles apart. Because r-f energy travels at a constant velocity, the time difference in reception of the two signals is a measure of the differing distances from the transmitting stations to the point of observation.

The loran principle of operation is illustrated by the simplified drawings in figure 9-2. In part A of the illustration, the transmitters at stations A and B are pulsing simultaneously. As evidenced by the geometry of the drawing, the two pulses arrive at the same time at any point on the centerline. An observer, equipped with the proper receiving equipment, can tell when he is on this line. From this determination, he knows that he is centered between the two stations.

Suppose, however, that the observer is located closer to station A than to station B. Then the pulse from station A arrives at his location before the pulse from station B. Assume that the time difference is 800 μs, as shown in

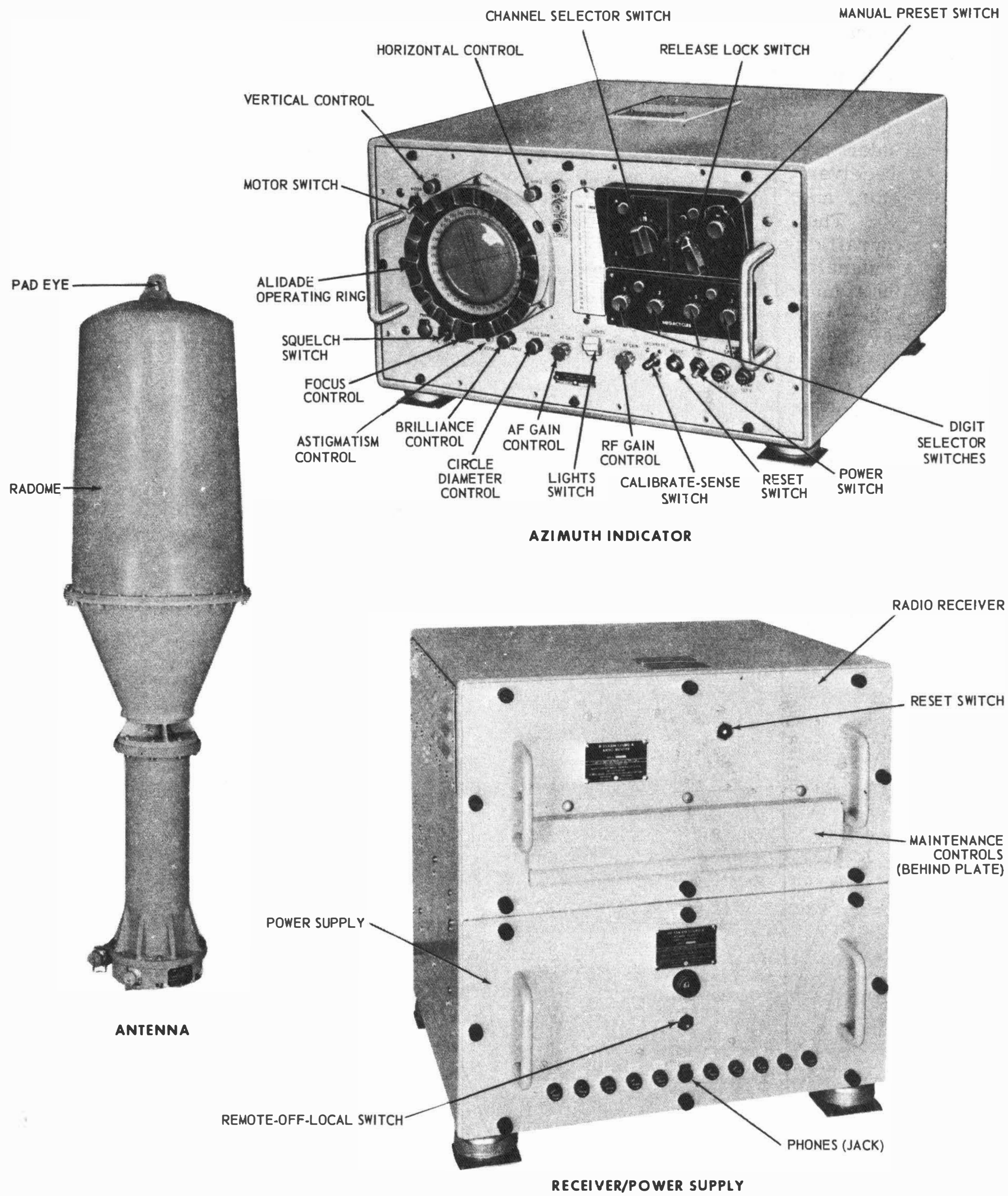

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Figure 9-1. —Radio direction finder set AN/URD-4( ), major components.

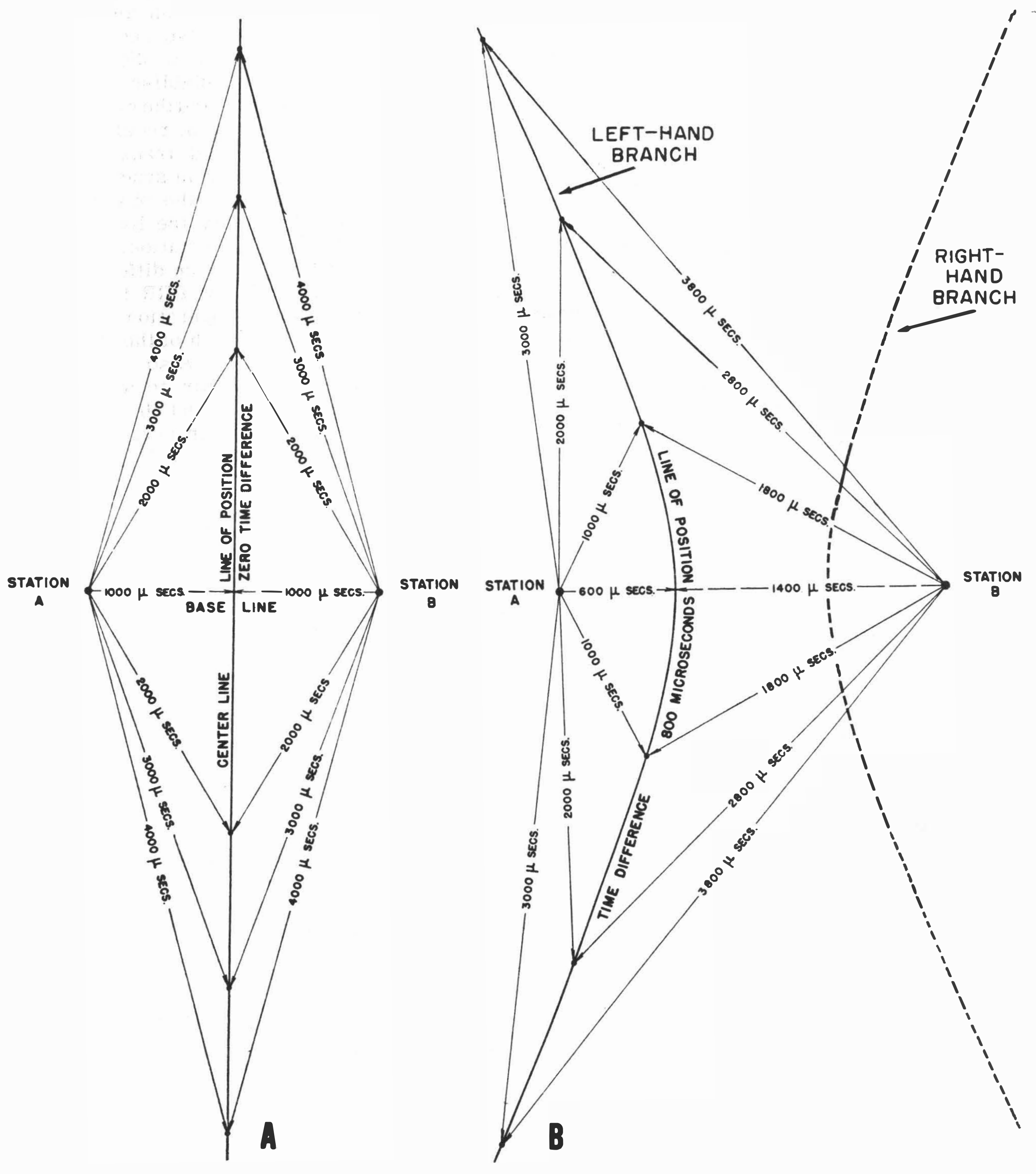

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Figure 9-2. —Principle of loran simplified.

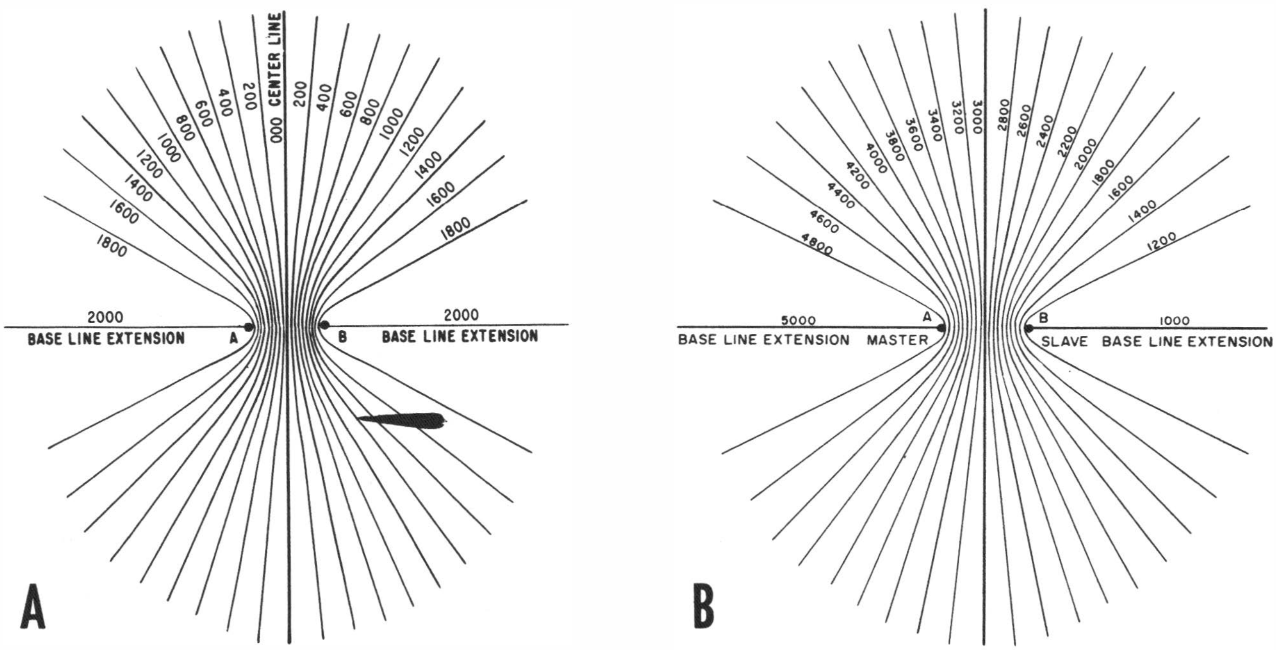
part B of figure 9-2. There are many points at which the receiving equipment indicates this same time difference. Connecting these points forms a line of constant time difference, or hyperbolic line of position. This line (shown as a solid curved line) is concave toward station A, and is the left branch of the hyperbola.

Now assume that the observer is nearer station B than station A and that the time difference between the arrival of the two pulses is 800 μ s. The line of constant time difference (represented as a dotted curved line) is concave toward station B, and forms the right-hand branch of the hyperbola. The observer now has two hyperbolic lines of position that give him the same time difference reading. He is unable to determine on which branch of the hyperbola he is located because the pulses from the transmitters are identical.

Many lines of position can be established for each pair of loran stations. Selecting several time differences for a given pair of stations results in a family of hyperbolas such as those shown in part A of figure 9-3. The pulses from both transmitters are identical, resulting in many ambiguous time difference readings.

In practice, the ambiguity in the lines of position is eliminated by delaying the pulse of one of the transmitters by an amount that is more than one half the pulse recurrence rate (PRR) of the other station. (See part B of fig 9-3). The station establishing the pulse recurrence rate is designated the master station. The second, or slave station, receives the pulse of the master station and transmits its own pulse, delayed in time but in synchronism with the master pulse. Thus, the observer knows that the pulse followed by the longer interval is always from the master station.

The PRR is different from different pairs of stations. Using a different PRR for each pair of stations permits the operation of more than one pair of stations on each of the four loran A frequencies (channels). Also, it serves to identify the particular pair to which the receiver is tuned. Channels and channel frequencies are as follows: channel 1, 1950 ks; channel 2, 1850 ks; channel 3, 1900 kc; and channel 4, 1750 kc. The basic PRR for loran A is either 25 cps (the low, or L, rate) or 33 1/3 cps (high, or H, rate). A third basic repetition rate of 20 cps (the special, or S,



70.17

Figure 9-3.—Loran lines of position.

rate) is not in operational use, but is provided in new equipment to allow for expansion of the loran system.

The basic pulse repetition rates are subdivided into specific PRR. The specific low PRR is from 0 through 7, corresponding to 25 through 25 7/16 pulses per second in 1/16 PPS steps. The specific high PRR is from 0 through 7, corresponding to 33 1/3 through 34 1/9 pulses per second in 1/9 PPS steps.

To establish his position, the loran operator must have the proper loran charts as well as the proper receiving equipment. A loran fix is the point of intersection of two lines of position. Two pairs of transmitting station (or one master and two slave stations) are needed to establish the lines of position necessary for the fix. One pair of stations acts as foci for one family of hyperbolas. The second pair of stations acts as foci for another family of hyperbolas. (A fix as already stated, is the intersection of two hyperbolas, one from each family.)

Figure 9-4 illustrates how a loran fix is obtained by using only one master and two slave stations. This arrangement is accomplished by having the master station transmit two distinct sets of pulses. The double-pulsed master station transmits one set of pulses at the PRR of the pulse transmitted by the first slave station and the other set of pulses at the PRR of the pulses from the second slave station.

Lines of position are identified by a letter and several numbers. The letter represents the basic PRR—low (L), high (H), or special (S). The first number represents the channel (1 through 4), or carrier frequency; the second number denotes the specific PRR; and the last numbers indicate the time difference in microseconds. For example, 2L 6-2500 indicates channel 2, which is 1850 kc; a low basic PRR of 25 cps; a specific PRR of 6, corresponding to 25 6/16 cps; and a time difference of 2500 μs.

For loran C operation, a master and two slave signals are transmitted on a carrier frequency of 100 kc. These signals are multiple-group transmissions, identified as master or slave signals by the number of pulses transmitted in each group. The master group transmission is comprised of nine phase-coded pulses. The pulses are separated from one another by either 1000 or 500 μs, except that the ninth pulse is separated from the eighth by approximately 600 μs. The slave group transmission is comprised of eight pulses, each separated from the others by either 1000 or 500 μs to conform to the master station transmission. Phase coding is a method of changing the radiofrequency of each pulse relative to the frequency of the carrier. The phase is varied within each group of pulses in accordance with a prescribed program.

Loran C operation has capabilities for single or double rate reception. Single rate reception provides maximum time difference readings of 30,000 (H), 40,000 (L), and 50,000 (S) microseconds. Double rate reception extends the time difference readings to 60,000 (SH), 80,000 (SL), and 100,000 (SS) microseconds. For single rate reception, basic repetition rates are 16 2/3, 12 1/2, and 10 groups per second; for double rate reception, 33 1/3, 25, and 20 groups per second.

The advantage of loran C over loran A is due to the characteristics of the transmission and the lower operating frequency. Greater power output results from using group pulsing instead of single pulsing. The lower operating frequency permits greater distances with the available power output. Measurement of the phase relationship between the pulses and the carrier contributes to accurate fixes at greater distances. In addition, a fix may be made in one operation without changing the selected channel, the basic repetition rate, or the specific repetition rate.

The instrument used for measuring the small periods of time that elapse between the arrival of signals from the loran transmitting stations is a combination radio receiver and video indicator. The receiver accepts the r-f pulses, converts them to video pulses, and sends the video pulses to the indicator for display on the face of a small cathode ray tube.

The master and slave pulses appear on two horizontal traces, as in figure 9-5. With the two signals aligned properly, the time difference between their reception is read from timing markers displayed on the scope or from revolution-type counters on the front panel of the receiving set. Because the measuring process is quite lengthy and varies from equipment to equipment, it is not discussed in detail in this text.

Four shipboard loran receiving sets, currently installed in the active fleet, are models DAS-4, AN/SRN-7( ), AN/UPN-12( ), and AN/UPN-15( ).

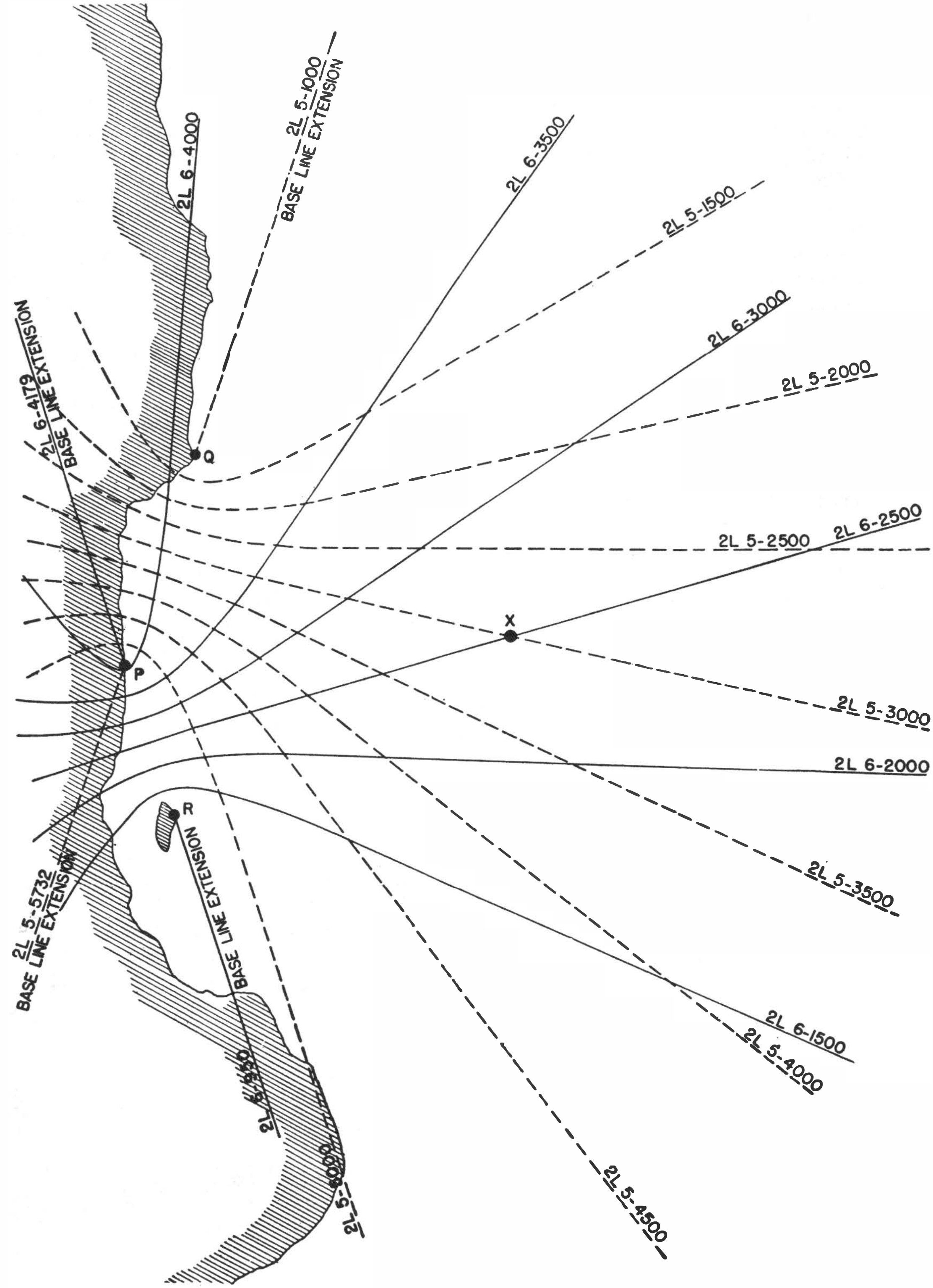


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Figure 9-4.—Obtaining a fix with one master and two slave stations.

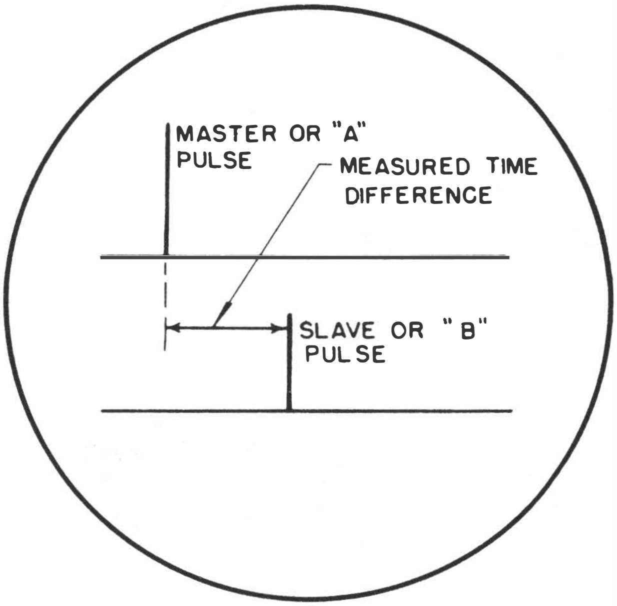

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Figure 9-5.—Traces on a loran indicator.

Loran Receiving Set Model DAS-4

Perhaps the oldest loran receiving set still installed aboard ships in the active fleet is the model DAS-4 (fig. 9-6.)

This set, consisting of a receiver unit and an indicator unit, is capable of receiving loran A signals only.

The receiver (left-hand unit in the illustration) is a conventional superheterodyne receiver that covers the frequency range 1700 to 2000 kc. It has no variable tuning. Instead, it is preset to four different frequencies, corresponding to the four loran A channels. Channels are selected by means of a switch located on the front panel of the receiver.

The indicator unit contains the circuitry necessary for measuring the difference in time of arrival of the pulses from a pair of loran transmitting stations. By manipulating the front panel controls (in the manner prescribed in the operating instructions accompanying the equipment), the received pulses and the timing markers are seen on the face of the scope. Interpretation of the timing markers results in a time difference measurement that is correct to 1 μs.

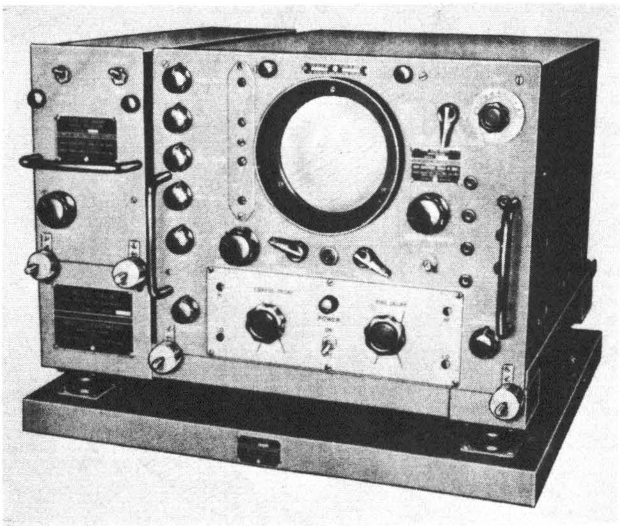
Loran Receiving Set AN/SPN-7( )

The AN/SPN-7( ), shown in figure 9-7, is another loran A receiving set. Like the DAS-4, the receiver portion of this set is a crystal-controlled superheterodyne receiver that is preset to the four loran A frequencies. The indicator portion is an accurate timing device that measures the time difference in arrival of the signals from the loran transmitters.

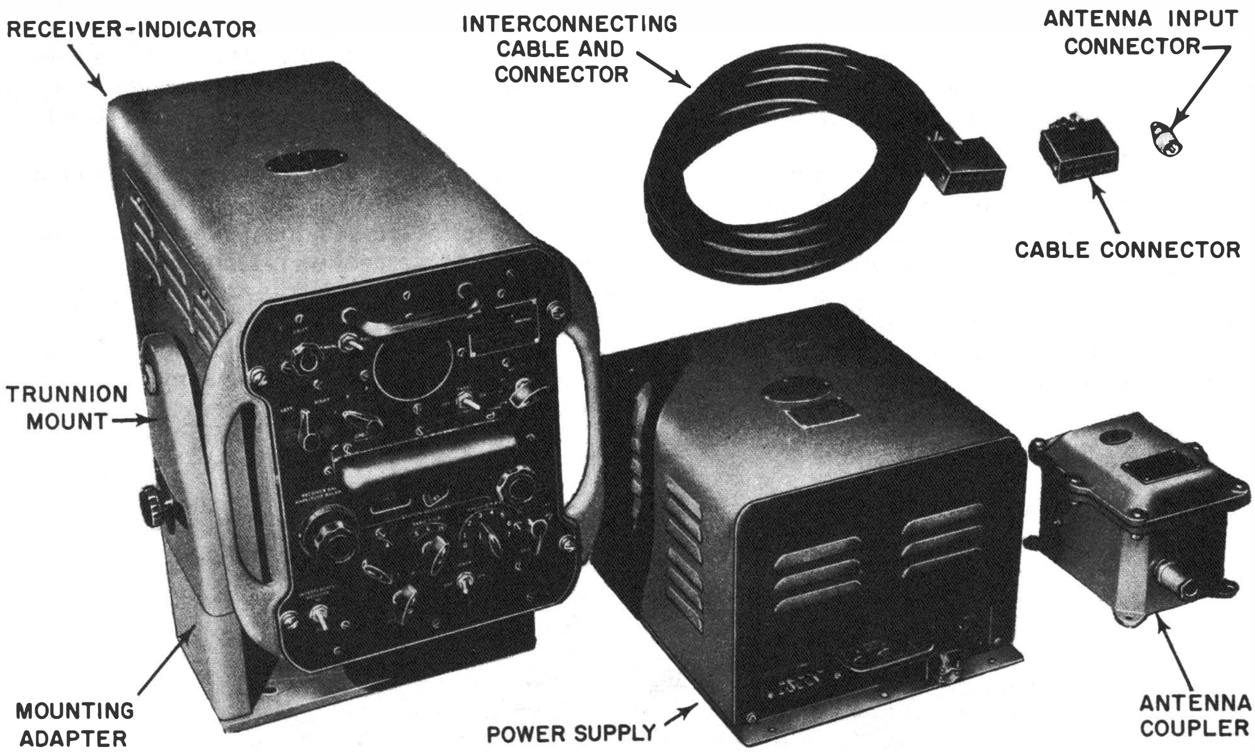
The receiver-indicator accepts the loran signals from the transmitting stations and presents the two signals on the scope. When the two signals are matched properly, the time difference in their arrival is indicated directly on a revolution-type counter and a dial. Thus, time measurements are simplified, and inaccuracies that could result from misinterpretation of timing markers are eliminated.

Loran Receiving Sets AN/UPN-12( )
and AN/UPN-15( )

Originally designed for loran A operation only, the AN/UPN-12( ) receiving set is being modified to accommodate both loran A and loran C signals. Modification is accomplished by adding a small receiver-control unit and associated components to the existing AN/UPN-12( ) set. When so modified, the



120.46
Figure 9-6.—Model DAS-4 loran receiving set.



120.47

Figure 9-7.—The AN/SPN-7( ) loran receiving set.

nomenclature of the receiving set is changed from AN/UPN-12( ) to AN/UPN-15( ). The AN/UPN-15( ) is shown in figure 9-8.

When functioning as a loran C receiver-indicator, the set utilizes the signals received by the receiver-control unit mounted atop the main chassis. This unit contains a 100-kc radio receiver of the tuned radiofrequency type. The controls that affect its operation as a loran C receiver are on the front panel of the unit.

With the equipment set for loran A operation, the 100-kc receiver is isolated from the set and the four-channel superheterodyne receiver in the main chassis is used to receive the loran signals.

The indicator unit of the set displays either loran A or loran C signals. When the received pulses are aligned as prescribed for the particular mode of operation, time difference readings are taken from a counter. By taking a second reading from a different set of loran stations and referring to loran charts and tables, the geographic position of the ship is determined.

TACAN SYSTEM

Tacan, (formed from the underlined letters of the term tactical air navigation), is an electronic polar coordinate system that enables an aircraft pilot to read—instantaneously and continuously—the distance and bearing of a radio beacon transmitter installed on a ship or at a ground station. In aircraft equipped with tacan receiving equipment, an azimuth indicator shows the position of the transmitting source in degrees of magnetic bearing from the aircraft. Also, the distance in nautical miles to the same reference point is registered as a numerical indication, similar to that of an automobile odometer. (See fig. 9-9.) In the illustration, the aircraft is 106 miles from the carrier, and the ship is on a magnetic bearing of approximately 230 from the aircraft.

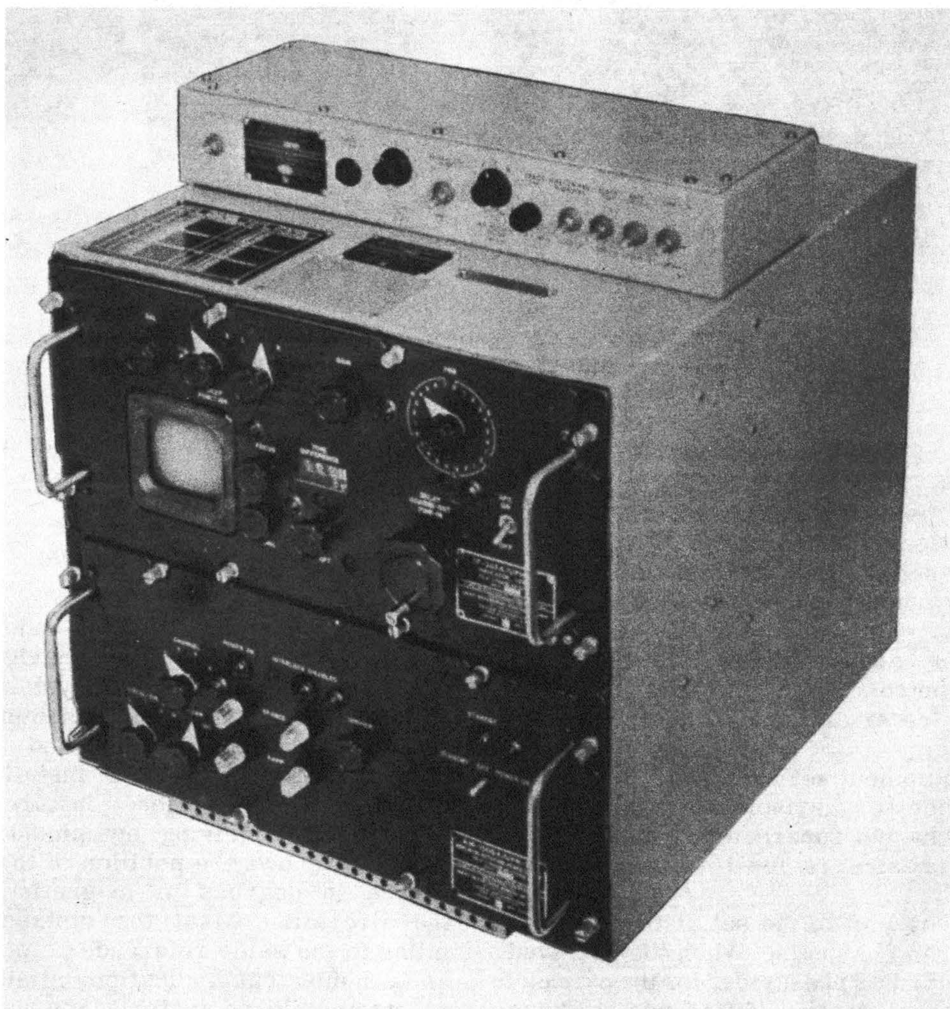
To provide for a large number of transmitting stations, the system operates on 126 selectable channels. No two stations within interference distance of each other are assigned the same channel. The pilot can switch channels to select any tacan transmitter within range.

To aid the pilot in identifying a particular transmitter, the transmitter automatically transmits a three-letter tone signal in international Morse code every 37.5 seconds. The aircraft receiver converts the signal to an audible tone that is heard in the pilot's headset.

Two radiofrequencies are employed, as indicated in figure 9-10. One frequency (Y) is used for transmissions to the aircraft; another frequency (X) is used for transmissions from the aircraft. The surface-to-air frequency carries bearing and range intelligence as well as station identification information. The transmission from the aircraft-to-surface unit is required to trigger the distance-measuring system.

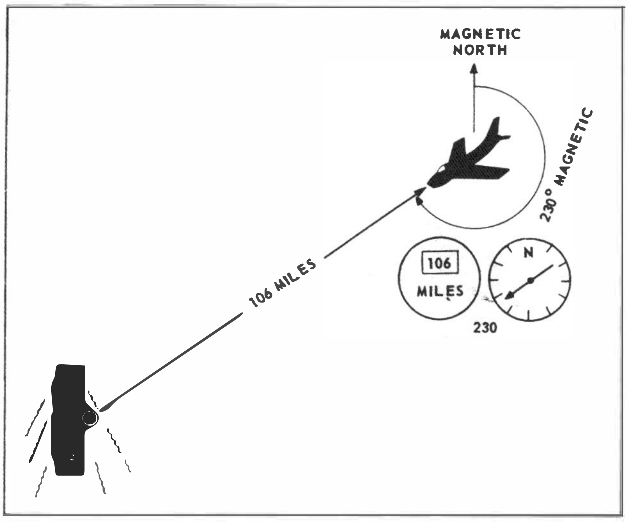
When the pilot closes the proper switch on his set control, his receiver-transmitter radiates a series of range interrogation pulses (frequency X).

The interrogation pulses are detected by any ship or station operating on the same channel.



120.48

Figure 9-8.—The AN/UPN-15( ) loran receiving set.



32.73
Figure 9-9.—Polar coordinate presentation of tacan data.

The pulses cause the transmitter to radiate a response, which is a series of pulses on frequency Y.

When the reply signal is received in the aircraft, it is fed to range circuits that determine the time that elapsed during the round trip of the two signals. Other circuits convert the time difference to equivalent dial indication in miles. Bearing information is radiated continuously on frequency Y.

The shipboard end of the system is the AN/SRN-6( ) (discussed in the next topic) or its older counterpart, the AN/URN-3( ). The airborne installation is a combination transmitter-receiver-indicator, such as the AN/ARN-21( ).

Tacan Radio Set AN/SRN-6( )

Radio set AN/SRN-6( ) is replacing the AN/URN-3 as tacan radio sets on board ship. The AN/SRN-6( ) system (fig. 9-11) comprises three major groups: receiver-transmitter, antenna, and power supply assembly.

As many as 100 aircraft may simultaneously obtain navigational information in conjunction with a single installation of the AN/SRN-6( ). The set is capable of receiving on any one of 126 frequencies (channels) in the range of 1025 to 1150 mc. Transmission of information also takes place on 126 channel frequencies in the ranges of 962 to 1024 mc and 1151 to 1213 mc.

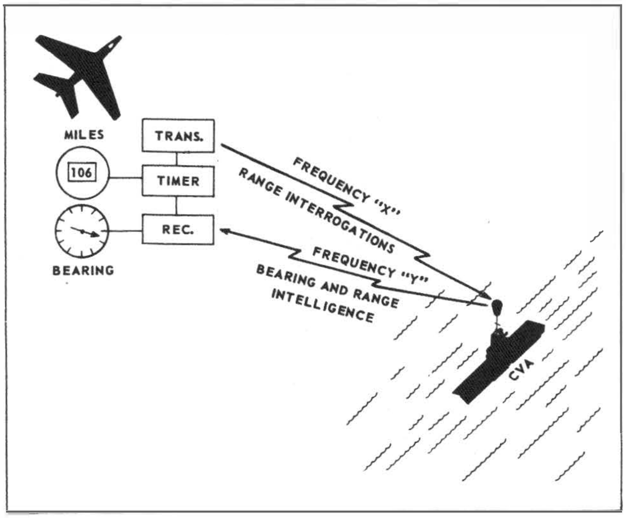
Two types of antennas are available for use. Each antenna operates on 63 channels, corresponding to low band frequencies and high band frequencies, respectively. Low-band installations transmit at frequencies between 962 and 1024 mc inclusive, and receive at frequencies between 1025 and 1087 mc. High band installations transmit in the range of 1151 to 1213 mc, and receive in the range of 1088 to 1150 mc.

Two frequencies are used in each channel: one for receiving, and one for transmitting. The frequency used for receiving in low band installations is 63 mc above the frequency used for transmitting in the same channel.

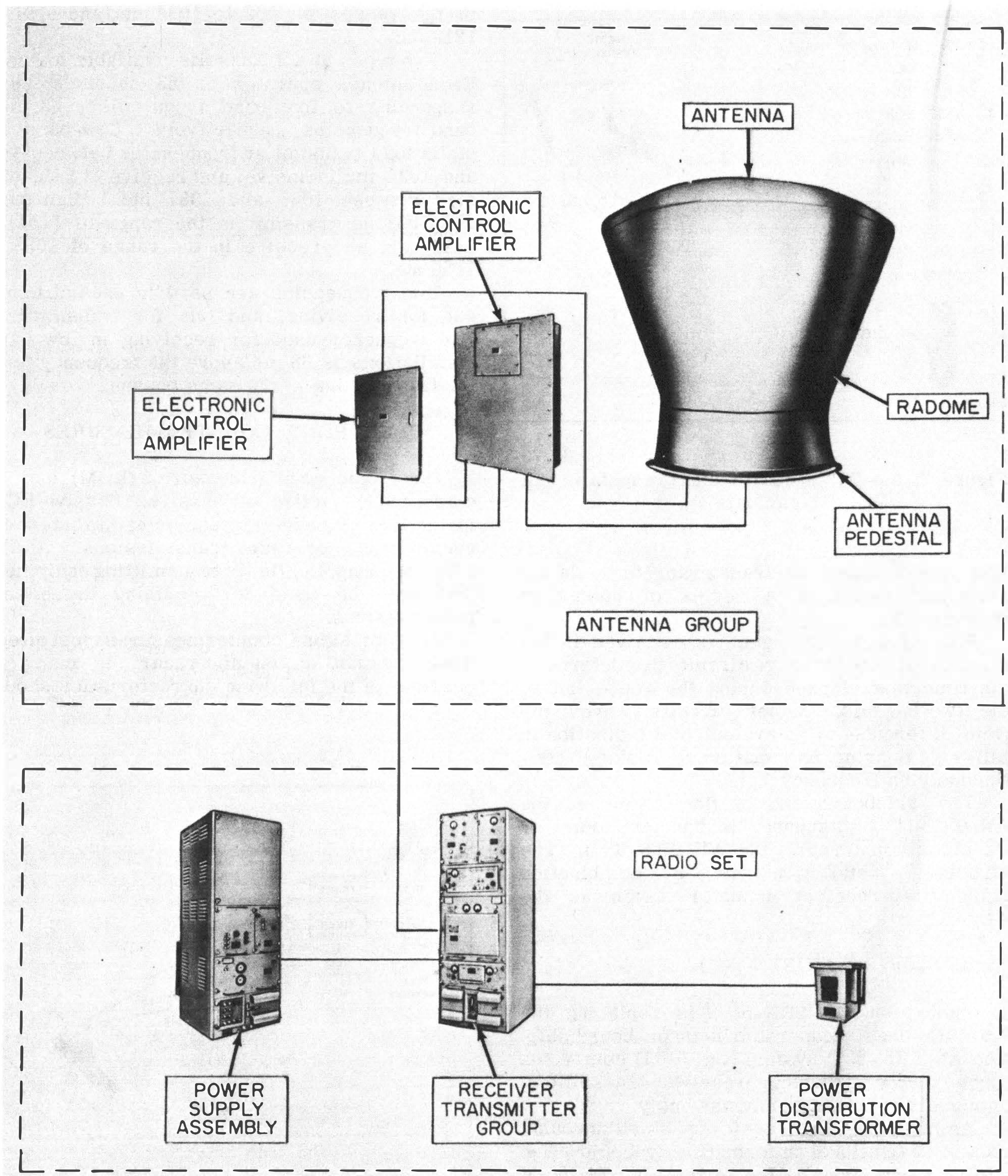
ELECTRONIC COUNTERMEASURES

Electronic countermeasures (ECM) may be classified as active or passive. Passive ECM is the use of receiving equipment to intercept enemy radar or radio transmissions. Active ECM is the application of transmitting equipment that may be used for jamming the enemy transmissions.

In order to use countermeasures most effectively against an enemy radar, as many as possible of the following characteristics should



70.16
Figure 9-10.—Dual-frequency transmission.



32.72

Figure 9-11.—Major components of radio set AN/SRN-6( ).

be known about the enemy radar facility: (1) the frequency, pulse width, pulse repetition frequency, and peak power of the transmissions; (2) the receiver bandwidth and the time constants of the receiver coupling circuits; (3) antijamming features; (4) amount of shielding; (5) type of indicator; (6) antenna beamwidth; (7) types of scan; and (8) use of the radar.

To use countermeasures most effectively against enemy communications systems, the following information is needed: (1) frequency of transmissions, (2) type of modulation, and (3) receiver bandwidth.

Some of the foregoing information is obtained by analyzing the enemy transmission. Other data may be obtained by examining captured equipment.

Special equipment has been developed for use in analyzing r-f transmissions. This equipment includes search receivers, which search the various frequency bands for the various types of emissions; panoramic adapters, which measure the frequency, strength, and type of modulation of a transmission in a selected band of frequencies; and pulse analyzers, which measure the pulse rate and width. The pulse analyzer and the panoramic adapter are used with the search receiver.

Antijamming measures or counter-countermeasures (CCM) are used to reduce the effect of enemy jamming on our own equipment. Some of the most important CCM devices in receivers are special filters that pass only the most important parts of signals, thus rejecting as much of the jamming signal as possible. In the transmitters, a great many radar equipments have tunable magnetrons whose frequency may be varied at intervals to prevent an enemy jamming transmitters from locking on the radar signal.

Several ECM equipments (or systems) are in use today. Among these equipments are the models AN/SLA-1 and -2 series, AN/SLR-2, AN/SLR-10, AN/WLR-1, AN/WLR-3, AN.ULQ-5, and AN/ULQ-6. Because of the security classification assigned these equipments, a detailed description cannot be given in this text. Further information concerning ECM and ECCM equipments may be obtained from the training manuals for the Radarman rating, or from the appropriate equipment technical manuals.

CCA EQUIPMENT

Carrier controlled approach (CCA) equipment provides the means for guiding aircraft to safe landings under conditions approaching zero visibility. By means of radar, aircraft are detected and watched during the final approach and landing sequence. Guidance information is supplied to the pilot in the form of verbal radio instructions, or to the automatic pilot (autopilot) in the form of pulsed control signals.

Five CCA systems (or equipments) currently are installed aboard carriers in the active fleet. They are models AN/SPN-6( ), AN/SPN-8( ), AN/SPN-10, AN/SPN-12, and AN/SPN-35. Models AN/SPN-8( ), -10, and -12 are described in the next three topics. The AN/SPN-6( ) is similar to the AN/SPN-8( ). The AN/SPN-35 is similar to the AN/SPN-10; both are recently developed systems of limited distribution.

CCA SYSTEM AN/SPN-8( )

The AN/SPN-8( ) CCA system is designed to guide aircraft from a distance of approximately 6 nautical miles to within a minimum of 200 feet from the touchdown point on an aircraft carrier. This action is accomplished by displaying an aircraft's position relative to an ideal approach path on offset sector PPIs. These presentations are viewed by an aircraft final controller, who transmits verbal landing instructions to the pilot over any of 11 available radio channels. A communication control panel at each operation position has panel lights that indicate to the controller the radio channels in use, so that the controller can select any of the available channels. In addition, he can communicate with various stations on the carrier over any of the 10 intercommunication channels.

The aircraft is directed along an ideal approach path to a point where it is visible to the landing signal officer (LSO). When the aircraft is visible, the LSO operates a "contact" light that informs the controller that contact has been made and that the aircraft is being brought aboard by visual means. If the aircraft approaches to the minimum range of 200 feet from touchdown without the LSO indicating that he made contact, it is given an instrument waveoff by the final controller at the radar set.

CCA SYSTEM AN/SPN-10

The AN/SPN-10 is a computerized CCA system that provides precise control of aircraft during their final approach and landing. The equipment automatically acquires, controls, and lands a suitably equipped aircraft on any type of aircraft carrier, regardless of the size of the flight deck, ship's motion, or weather conditions.

Aircraft returning to the carrier are assigned to the AN/SPN-10 system by means of an air traffic control computer. On receipt of an assignment, the system programs an optimum flight path for the aircraft. It also establishes a radar acquisition window (search area). When the assigned aircraft enters the window, it automatically is detected, locked onto, and tracked by the precision radar subsystem. The radar-derived vectors of the aircraft's position are compared with the optimum flight path. As a result of this comparison, correction signals are generated to control the aircraft along the optimum flight path to touchdown.

If an unsafe flight or landing condition is probable, the AN/SPN-10 signals a waveoff and returns control of the aircraft to the air traffic control computer. In addition, the LSO or equipment operator may initiate a waveoff sequence when, in their judgment, a safe landing cannot be accomplished. The pilot can terminate the automatic landing at his discretion.

The AN/SPN-10 has two identical control channels. These channels, operating independently of each other, provide an overall system landing rate capability of two aircraft per minute. Each channel has three modes of operation: automatic, semiautomatic, and manual (voice talkdown). In all instances, the mode of operation is selected by the pilot of the landing aircraft.

RANGE-RATE RADAR AN/SPN-12

The AN/SPN-12 is a range-rate radar set that computes, indicates, and records the speed of aircraft making a landing approach to the carrier. Both true air speed and relative speed are indicated. Thus, the LSO is supplied with accurate information on the speed of the approaching aircraft, and he can wave off those attempting to land at an unsafe speed.

TARGET CONTROL SYSTEM

The AN/SRW-4( ) target control system is installed principally aboard destroyers equipped with the drone antisubmarine helicopter (DASH). The system provides positive control of the drone during all phases of flight, including takeoff and landing, by transmitting to the helicopter commands in the form of coded f-m radio signals.

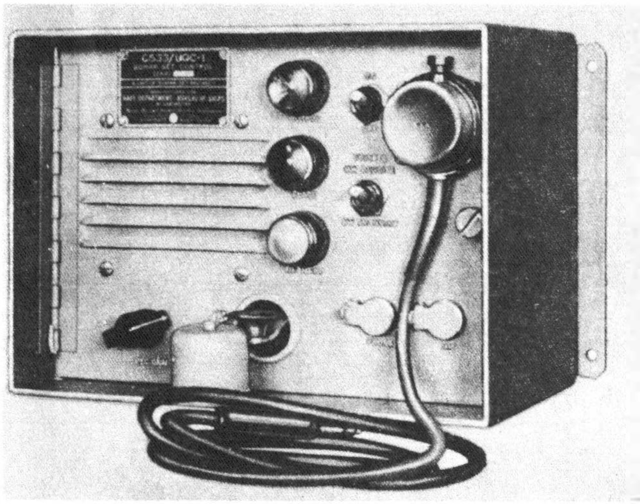
The system consists of duplicate transmitters, coders, antennas, and operating control positions. Selection and operation of the transmitting arrangement are accomplished by the flight controllers at the operating positions. Normally, one operating position is installed in the CIC; the other position is located in the vicinity of the flight deck. By manipulating the controls at the operating control positions, the controllers send altitude, bearing, speed, and various special command signals to the drone. In the drone, the signals are accepted by a receiver, processed, and applied to an automatic flight control set (AFCS). The AFCS causes the drone to execute the command signals.

The drone is started and preflighted from the deck controller's position. On signal from the CIC controller, the deck controller launches the drone and vectors it toward the target or to a holding position. He then relays to the CIC controller the altitude, speed, and heading of the drone as indicated at his control position. The controller in CIC sets these data into his operating position, and takes control of the drone when it appears on the CIC radar display. He pilots the drone throughout its mission and return to the ship. When the drone comes into view, control is transferred back to the deck controller, who executes the approach and landing.

UNDERWATER TELEPHONE

The AN/UQC-1( ) sonar set, popularly known as the underwater telephone, provides CW and voice communications between surface vessels and submarines. Although its application differs, the set operates on the same principle as other sonar equipments.

The set consists of a transmitter, receiver, power supply, transducer, and remote control unit. All controls needed to operate the set are contained in the remote control unit (fig. 9-12).



71.71
Figure 9-12.—Remote control unit for AN/UQC-1( ).

To transmit by voice, a toggle switch on the front panel of the remote control unit is set to VOICE & CW RECEIVE, the microphone button is depressed and the message is spoken into the microphone. For CW transmission, the toggle switch is set to CW TRANSMIT, and the handkey is used to send the message. During either type of transmission, an output indicator on the control unit flashes each time energy is transmitted.

The range of the transmission varies with water conditions and the relative noise output of the ship. Under good conditions, communications between ships is possible at ranges up to 12,000 yards and in some instances far beyond this range. On board submarines, the range may be extended over that obtained by surface ships by the phenomenon of channeling, that is, keeping the transmission between sharp temperature gradients within the layer in which it was transmitted. If this layer extends for many miles, the range of the signal also is extended for many miles.

COMMUNICATION CONSOLE

To centralize the control of voice communication circuits at key tactical stations, some large types of ships utilize communication console equipments such as the AN/SIC-2 illustrated in figure 9-13. A system may comprise 1 or 2 master consoles, 16 subconsoles, 4 radio-control/terminal-unit assemblies, and 1 or 2 power supplies. The quantities of the various components may be varied to meet the requirements of the vessel on which the equipment is installed.

Each master console provides pushbutton selection of a combination of 1 to 16 radiotelephone circuits (channels or frequencies) for both transmitting and receiving.

Selector switches and volume controls mounted on the console provide facilities for the connection of amplifiers and overhead speakers to permit monitoring any 4 of 16 radiotelephone circuits.

A selector switch provides for the selection of any 1 of 16 radiotelephone circuits for quick relay playback as recorded by a short-memory voice recorder.

An interphone system provides two-way or network communications between master consoles and subconsoles. Sixteen interphone circuits may be selected at the master console.

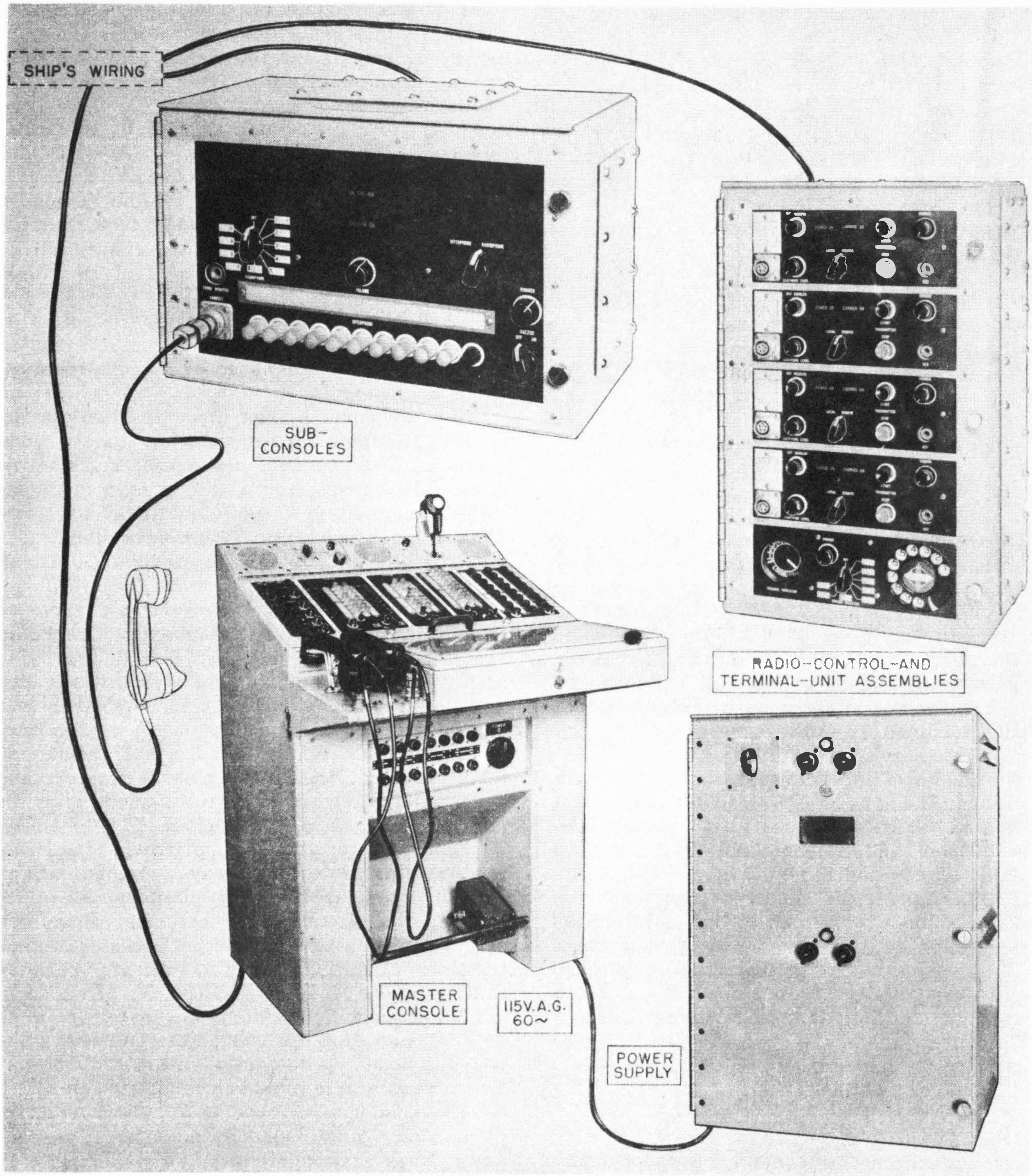
At each master console facilities are provided for communications with any combination (up to 10) of 20 ship's intercom stations.

Intercom systems differ from the interphone in this manner: Interphones systems use radiotelephone handsets or headphones. Intercoms are microphone speaker systems that provide amplified voice communications between two or more stations. The intercoms are used chiefly during routine conditions when personnel are unavailable to man all the sound-powered telephone circuits. During general quarters and condition IE, they should be used only for passing emergency information.

Each master console provides facilities for monitoring or two-way communications without crosstalk on any combination of 14 sound-powered telephone circuits. Provision also is made for crossing 7 sound-powered telephone circuits, and for monitoring or transmitting on the crossed circuits.

A microphone mounted on the master console is provided for connection to the shipboard announcing system when the communication console equipment is installed in CIC.

The subconsoles provide secondary control points for radiotelephone and interphone circuits. Each subconsole may select any 1 or 10 radio circuits for both transmitting and receiving. Two-way or network communications from the console to the master console and



7.40

Figure 9-13.—Communication console AN/SIC-2.

the other subconsoles takes place over any 1 of 10 available interphone circuits. A radiotelephone jack is provided for monitoring the selected radiotelephone circuit or interphone circuit.

Normally, the master console is the CIC watch officer's station while the ship is underway. From this station, he can control as desired radiotelephone, interphone, intercom, sound-powered telephone, and shipboard announcing circuits.

CLOSED-CIRCUIT TELEVISION

On larger ships closed-circuit television systems are becoming commonplace. They make it possible for shipboard personnel at remote locations to view or monitor various operations, and to exchange vital information rapidly. Although present applications of TV are limited to interior communications, it is envisioned that future applications will include intership conferences and briefings.

One closed-circuit TV system installed aboard ships is the AN/SXQ-2 (fig. 9-14). This system consists of a camera, a system control cabinet, an electronic equipment cabinet, and one or more viewer units. It is used principally for viewing, at remote locations, the data displayed on the CIC plotting board.

When the system is used to transfer tactical information from the CIC to remote stations, the TV camera is fastened to the overhead in the CIC so that it overlooks the plotting board. The video output of the camera is sent to a maximum of eight viewer units. From these video signals, the viewer units reproduce and display the data appearing on the plotting board. Thus, cognizant personnel are informed instantaneously and accurately of any changes in a tactical situation.

The AN/SXQ-2 system also is used aboard aircraft carriers for briefing pilots before a mission. When the system is used for this purpose, a viewer unit is installed in each readyroom. The TV camera is arranged so that it picks up the briefing officer and any pertinent charts or displays. With this arrangement, all pilots concerned are briefed in one session.

Most aircraft carriers now have a closed-circuit television system that aids the LSO in landing the aircraft. In general, the system operates in the following manner. A television camera mounted in the centerline of the flight deck spots the plane at the beginning of its landing approach, and follows it to the touchdown. A second TV camera on the carrier's superstructure then takes over. Viewer units installed at strategic locations reproduce the images picked up by the cameras. Crosshairs on the viewer screens and minute-by-minute records of time, air speed, wind velocity, and flight number on dials at the top of the screens are utilized by the LSO in talking the pilot down to a safe landing. All video and audio information, including the conversations between the pilot and the LSO, is recorded on tape. The tape thus becomes a complete record of each landing.

INFRARED EQUIPMENT

Infrared equipment is designed to create, control, or detect invisible infrared radiations. The equipment is of two types: transmitting and receiving. The transmitting (source) equipment produces and directs the radiations. The receiving equipment detects and converts the radiations into either visible light, for viewing purposes, or into voice or code signals, for audible presentations.

Infrared devices can be used for weapon guidance, detection of enemy equipment and personnel, navigation, recognition, aircraft proximity warning, and communications. Depending on its application, the equipment is either passive or active. The active method employs both transmitting and receiving equipment, whereas the passive method requires only receiving equipment.

The infrared spectrum, which extends from the upper limits of the radio microwave region to the visible light region in the electromagnetic spectrum (fig. 9-15), is divided into three bands: near infrared, intermediate or middle infrared, and far infrared. Devices operating in the near and middle bands are used for ranging, recognition, and communications. They normally have a usable distance range of 6.5 to 10 miles. Equipment that operates in the far infrared band is used for ranging, missile guidance, and the detection and location of personnel, tanks, ships, aircraft, and the like. This equipment usually is effective at distances between 100 yards and 12 miles.

Some of the infrared devices in use in the fleet today are the blinker equipments AN/SAR-( ), AN/SAT-( ), and VS-18( )/SAT; the voice/tone equipments AN/SAC-( ), AN/PAC-( ), and AN/PAR-( ), and the

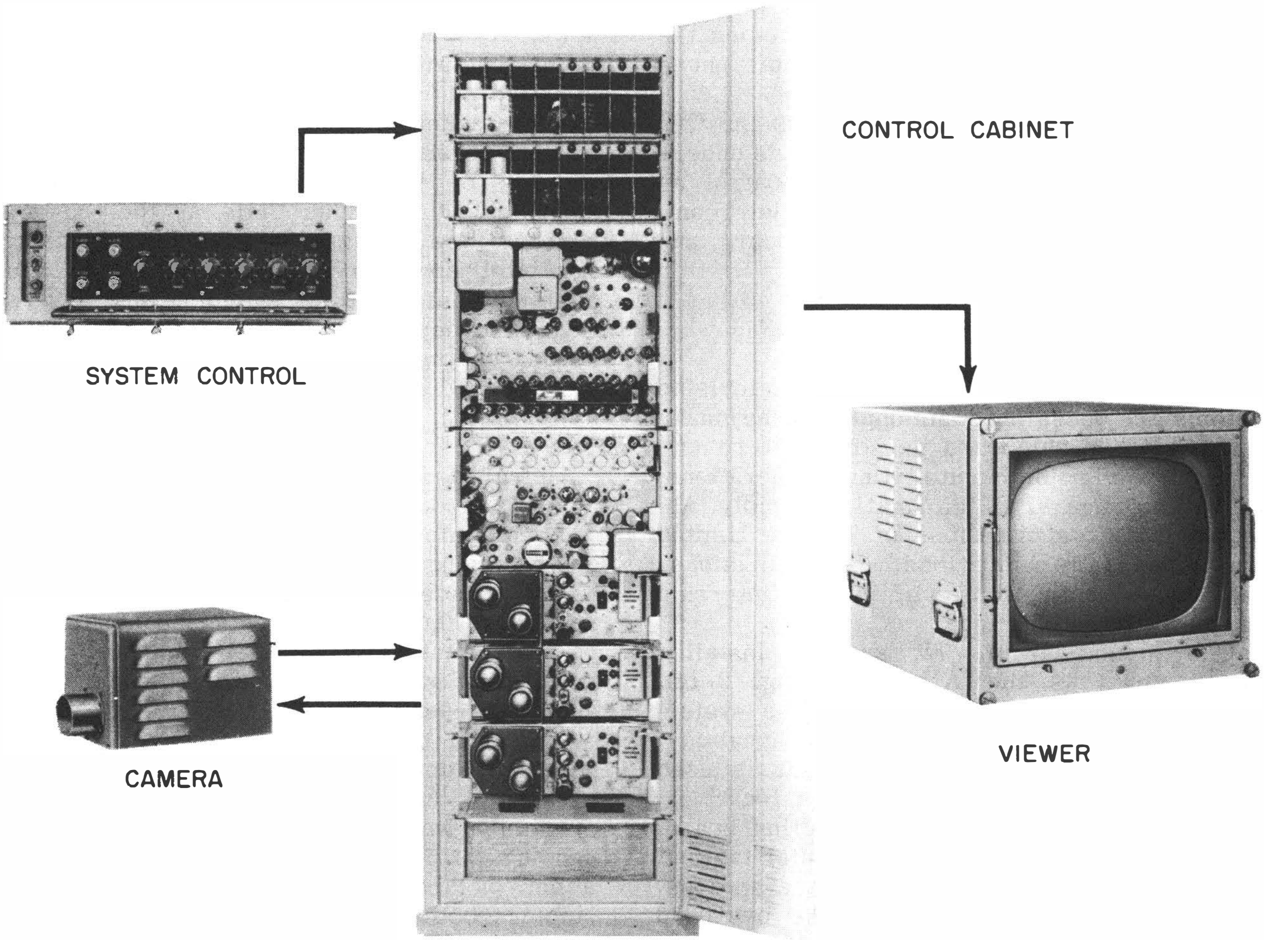


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Figure 9-14.—Television system AN/SXQ-2.

detection/tracking equipment AN/SAQ-( ). All of these equipments are classified except those in the blinker category, a brief description of which follows.

Perhaps the most widely used infrared transmitting gear is the VS-18( )/SAT hood, with filter lens. It is mounted on the standard Navy 12-inch searchlight (fig. 9-16). The light is operated in the same manner as an ordinary communication searchlight. Using the same design, there are variations to the VS-18( )/SAT hood for use on nonmagnetic minesweepers or the 8-inch signal light.

Another type of infrared transmitting equipment is a 360° light, which is installed in pairs on yardarms of the majority of naval ships. (See fig. 9-17.) These lights, designated AN/SAT-( ), are operated in the same manner as yardarm blinkers. They can be used as a steady source for "point of train" (POT) purposes, or they can be used for signaling or recognition purposes.

Two late developments, both electronic, are the receiver-viewers AN/SAR-4( ) and AN/SAR-6. Both of these equipments electronically convert the infrared rays to visible light.

The AN/SAR-4( ) viewer (fig. 9-18) consist of a main housing and a pair of interchangeable eyepiece lens assemblies. When the viewer is used on board ship or in other locations where 115-volt a-c power is unavailable, the power supply unit (provided with

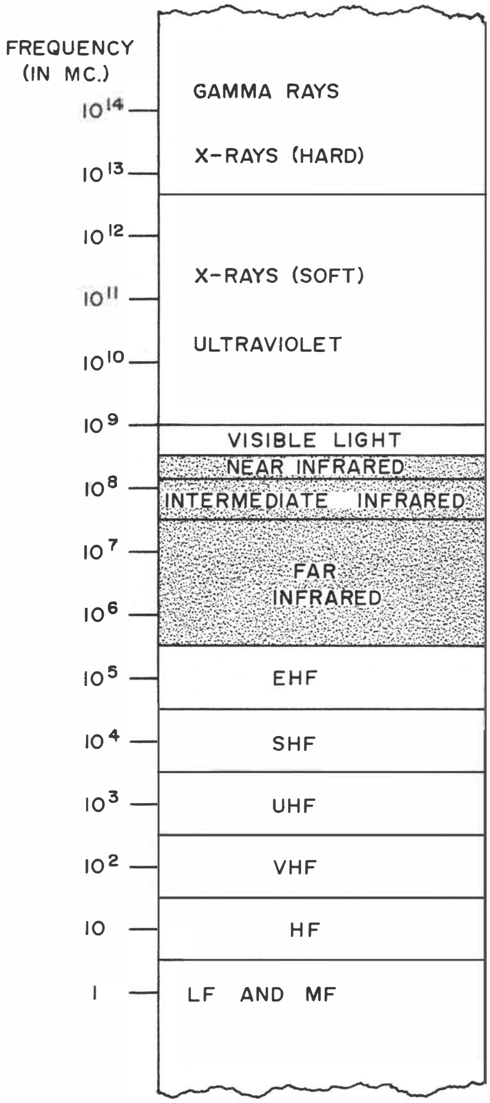

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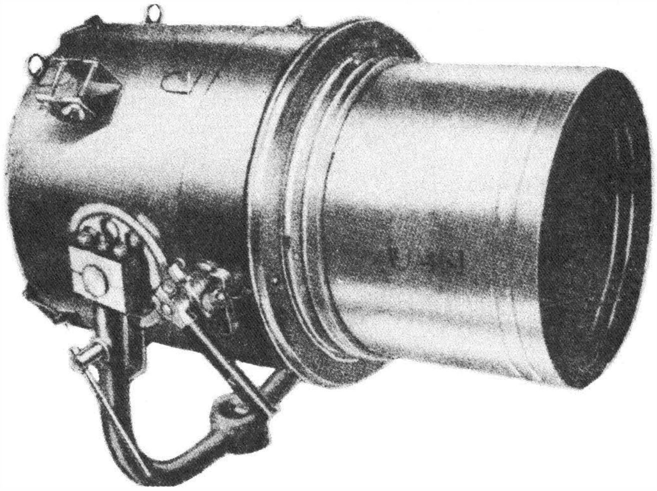
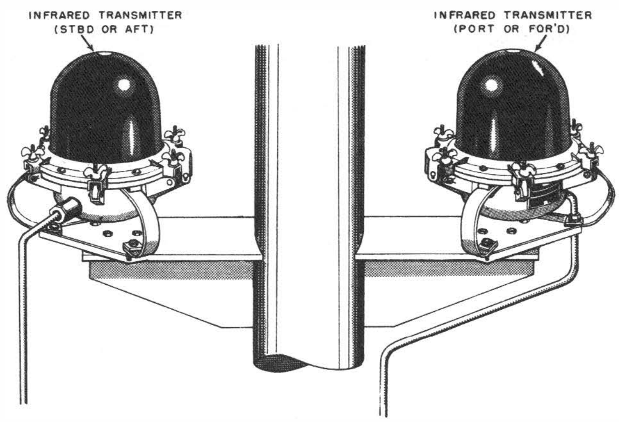
Figure 9-15.—Electromagnetic spectrum showing infrared bands.



77.58
Figure 9-16.—The VS-18( )/SAT infrared hood on 12-inch searchlight.



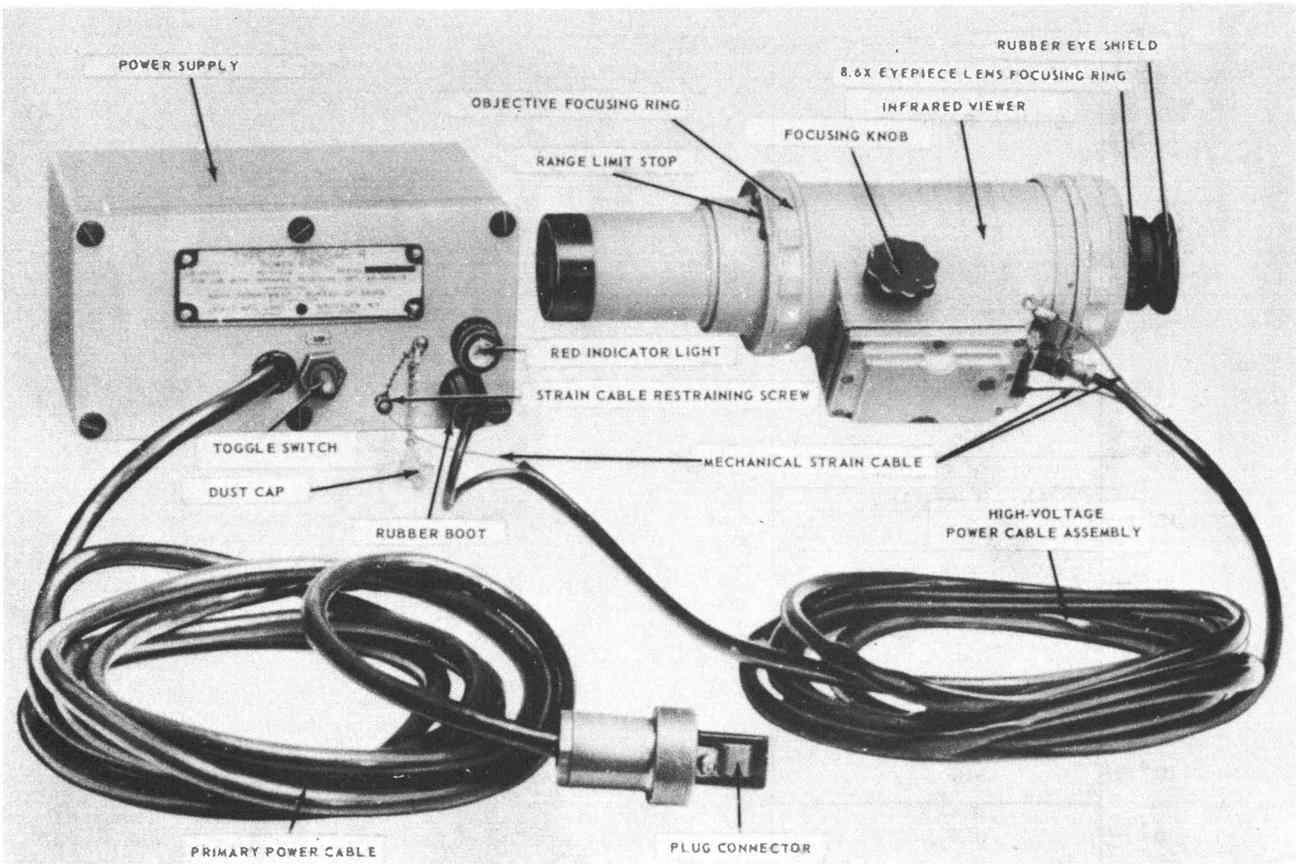
101.6
Figure 9-17.—Infrared yardarm beacons AN/SAT-( ).

the set) supplies the 20,000 volts d-c power required by the infrared viewer. If 115-volt a-c power is unavailable, or if it is desired to use the viewer as a portable unit, it can be powered by a battery powerpack.

The AN/SAR-6 viewer (fig. 9-19) is similar to the AN/SAR-4( ) except that instead of a power supply, an a-c converter is used to convert a-c power to the d-c voltage required to operate the viewer.

METEOROLOGICAL EQUIPMENT

Electronic meteorological equipments are of a number of varieties, each service various purposes. Electronic devices have been developed to measure cloud heights and visibility. Others measure winds aloft, as well as temperature, pressure, and humidity in the upper air. Still others were developed as complete weather stations that report automatically by



62.11

Figure 9-18. —Electronic infrared receiver AN/SAR-4( ).

radio. By far the most sophisticated of the recent development of electronic meteorological devices are the weather satellites.

Two meteorological devices that are representative of the types carried aboard naval vessels are the AN/AMT-11( ) radiosonde and the AN/SMQ-1( ) radiosonde receiving set. (Radiosondes are the flight equipment used in making upper air pressure, temperature, humidity, and (in some instances) wind observations. Depending on the type, they are carried aloft by balloons or are dropped from aircraft.

The AN/AMT-11( ) radiosonde (fig. 9-20) is an expendable scientific instrument designed to be carried aloft by a sounding balloon. During its flight, the radiosonde transmits pulse-modulated radio signals in the frequency range 395 to 406 mc. When properly recorded and interpreted, these signals give a continuous reading of the pressure, temperature, and humidity of the atmosphere through which the instrument passes. Wind direction and velocity are measured by tracking the radiosonde with radar or radio direction finders.

Radiosonde receptor AN/SMQ-1( ) (fig. 9-21) receives, amplifies, demodulates, and graphically records the signals transmitted by the AN/AMT-11( ). The received signals are pulses of r-f energy. The frequency of repetition of these pulses depends on meteorological conditions. Each pulse is approximately 250 to 275 μs in duration, and the pulse repetition rate varies from 10 to 200 PPS. Usually, the received signal is a series of pulses at one audio rate followed by a series of pulses at a different audio rate. Each series of pulses causes the receptor to record on a chart in a certain position, as determined by the audio rate of that particular series of pulses. The order in which these different series are

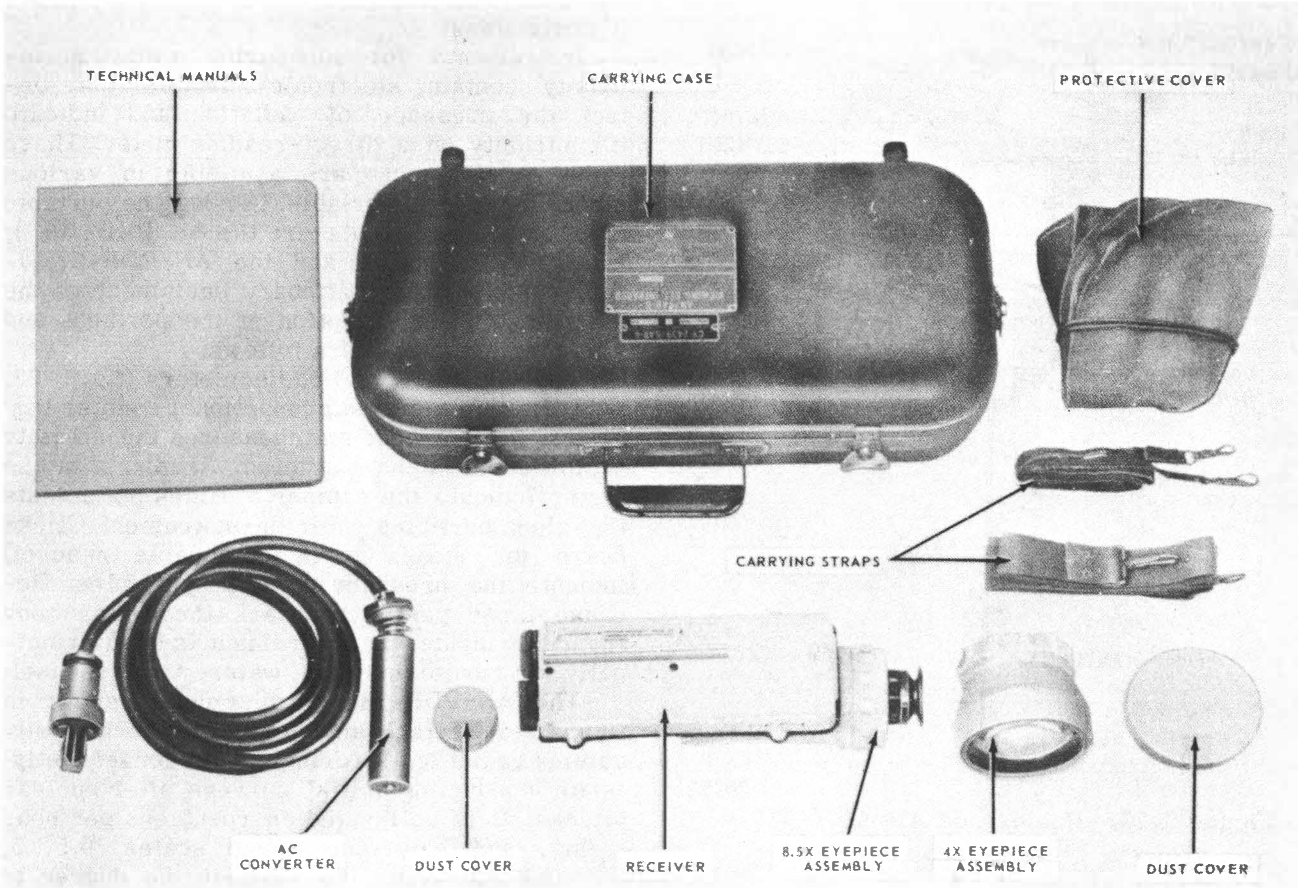


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Figure 9-19.—Electronic infrared receiver AN/SAR-6.

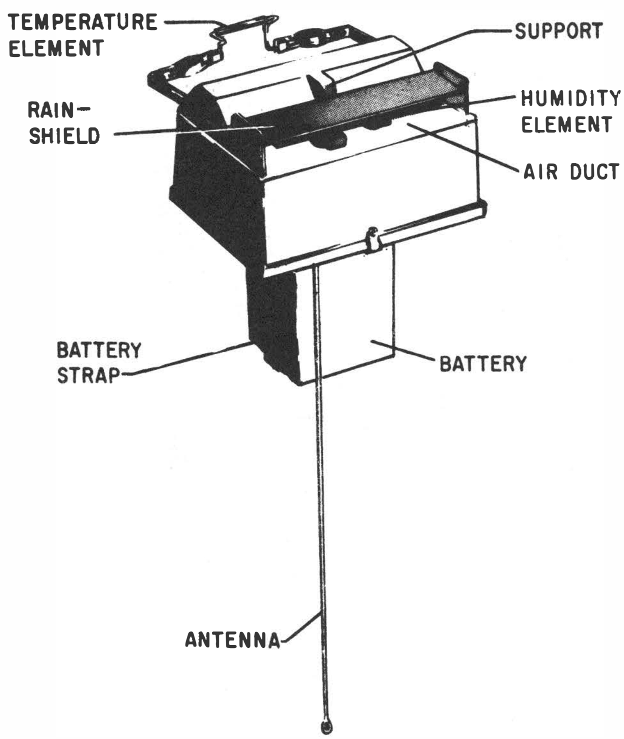
recorded is known and common to all radiosondes of a particular type. Thus, it is possible to interpret and evaluate the chart.

RADIAC EQUIPMENT

An important factor in the control of damage from nuclear radiation is the determination of how much radiation has been absorbed by personnel and how much is present on the ship. Because it is impossible to see, feel, or smell radiation, special instruments have been developed to detect and measure radiation. These radiological measuring instruments are known as radiac devices. (This acronym is derived from the underlined letters of the term radioactivity detection, indication, and computation.)

Radiac instruments are of two general types: (1) those that show how much radiation they have received over a period of time, (2) those that indicate the amount of radiation they are receiving at any particular instant. Instruments of the first type, usually called dosimeters, are used to measure the amount of radiation to which a person was exposed during a given period of time. Equipment of the second type are radiacmeters, and are used chiefly for surveying contaminated areas, structures, or objects to determine the amount and type of radiation emitted.

A typical pocket dosimeter of the self-reading type is the IM-9( )/PD. This instrument and its charging unit are shown in figure 9-22. At one end of the dosimeter is an optical eyepiece; at the other end, a charging contact. When the dosimeter is fully charged, an



120.51
Figure 9-20.—Radiosonde AN/AMT-11( ).

indicator viewed through the eyepiece is at the zero point on a scale. As radiation penetrates the instrument, its charge is dissipated or neutralized, and the indicator moves along the scale a distance proportional to the quantity of radiation received.

By holding the dosimeter to the light and peering through the eyepiece, the total radiation dose received in milliroentgens can be read directly from the scale. The instrument measures (up to 200 milliroentgens) the gamma radiation accumulated by an individual. It is used by personnel who work in contaminated areas to indicate when the accumulated maximum permissible exposure is reached.

Although a self-reading dosimeter, it requires a separate charging and adjusting device for setting the movable element on the zero of the interior scale. The charger, shown in figure 9-22, requires no external power source; it produces a static electrical charge when the knob on the front of the unit is rotated. This pocket-sized device, known as the PP-354C/PD charger, can serve many types of dosimeters.

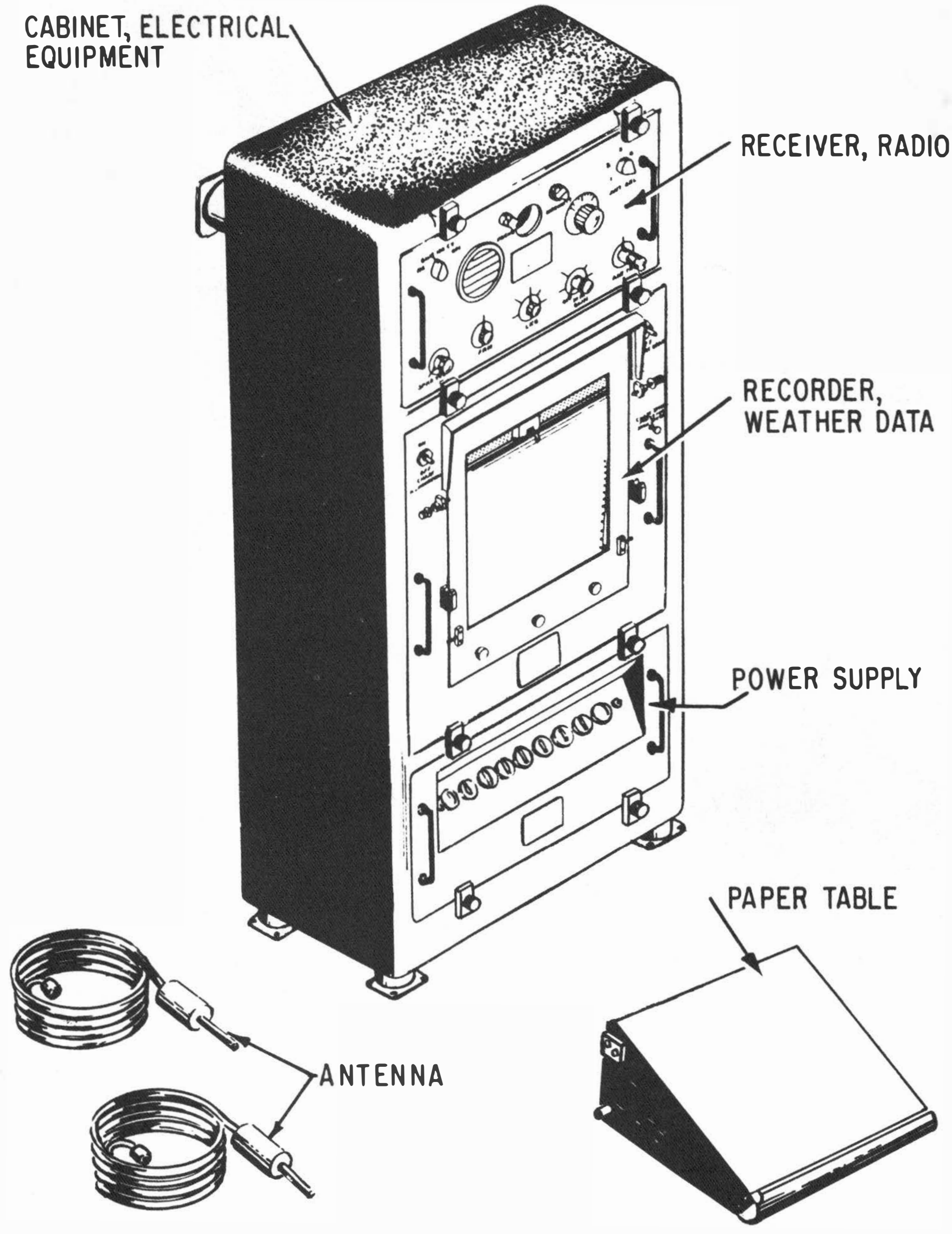
Instruments for measuring radiation intensity contain electronic circuits that detect the presence of radiation and indicate its intensity on a direct-reading meter. These radiac instruments are available in various sizes; some are portable. Among the portable monitoring equipments are the AN/PDR-10( ), the AN/PDR-18( ), and the AN/PDR-27( ). An example of a stationary equipment is the AN/SDR-1. A description of the portable and stationary radiacmeters follows.

The AN/PDR-10( ) radiacmeters (fig. 9-23) is a battery-operated proportional counter that detects the presence and measures the intensity of low-level alpha radiation. Readings on the meter indicate the number of times per minute that alpha particles enter the instrument. Clicks heard (by means of a detachable headset) indicate the presence of alpha particles. Because these particles attack the human body from the inside, the instrument is used principally for monitoring food, water, and personnel.

The AN/PDR-18( ) radiacmeter, shown in figure 9-24, detects and measures high-intensity gamma radiation. Its principal use consequently, is for conducting initial surveys after nuclear attacks. It is calibrated in roentgens per hour (r/hr), and has four range scales: 0.5, 5, 50, and 500 r/hr. To indicate the degree of personal danger, each scale has a different background color. In ascending order, the scales are colored yellow, orange, light magenta, and red.

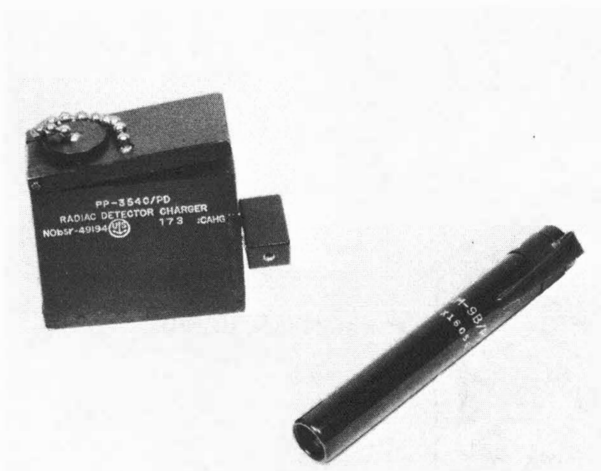
An instrument capable of detecting and measuring both beta and gamma radiations is the AN/PDR-27( ) radiacmeter (fig. 9-25). This instrument is used for detailed surveys, and can measure radiation intensities up to 500 r/hr. It can detect beta and gamma radiations together, or gamma radiation alone. When measuring gamma radiation, the detector probe can be in or out of the well. Beta radiation, however, can be detected only when the probe is removed from the well and the beta shield on the end of the probe is moved aside.

The AN/SDR-1 (fig. 9-26) is a fixed shipboard radiac system that indicates the field intensity of gamma radiation up to 10,000 r/hr. It has eight scales to cover this range, with two indicating meters to cover the scales. In addition, it has an audible alarm that rings at a rate proportional to the field intensity. The alarm may be set to operate when the

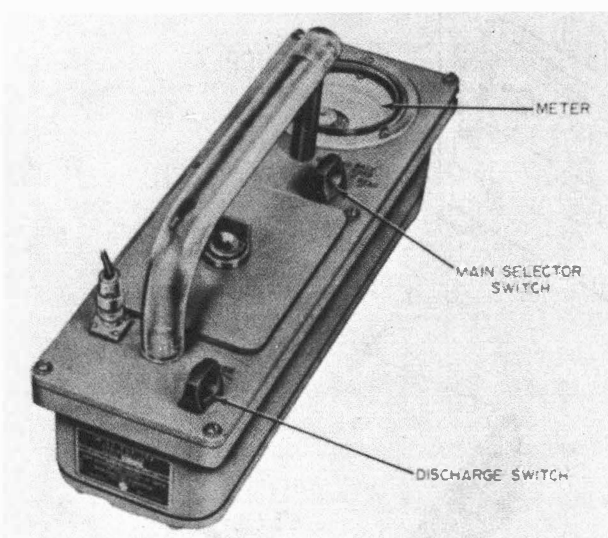


120.52

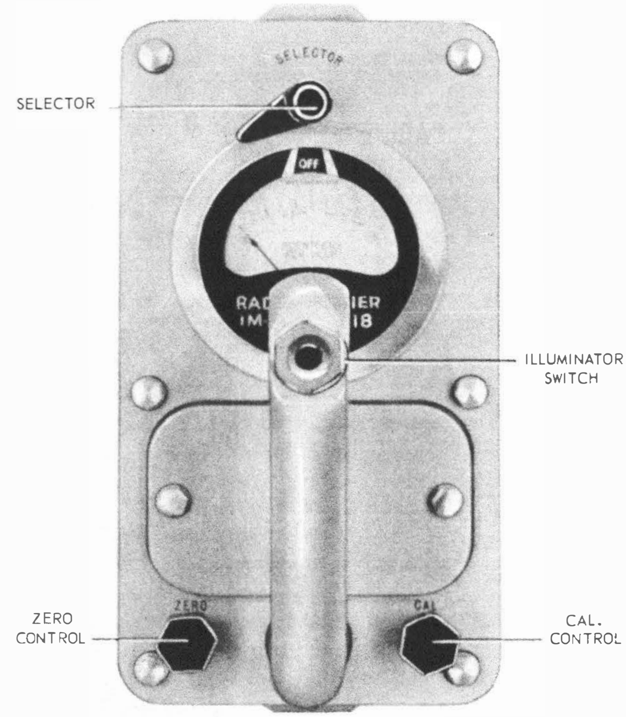
Figure 9-21. —Radiosonde receptor AN/SMQ-1( ).



11.360
Figure 9-22.—Pocket dosimeter IM-9( )/PD, with charging unit.

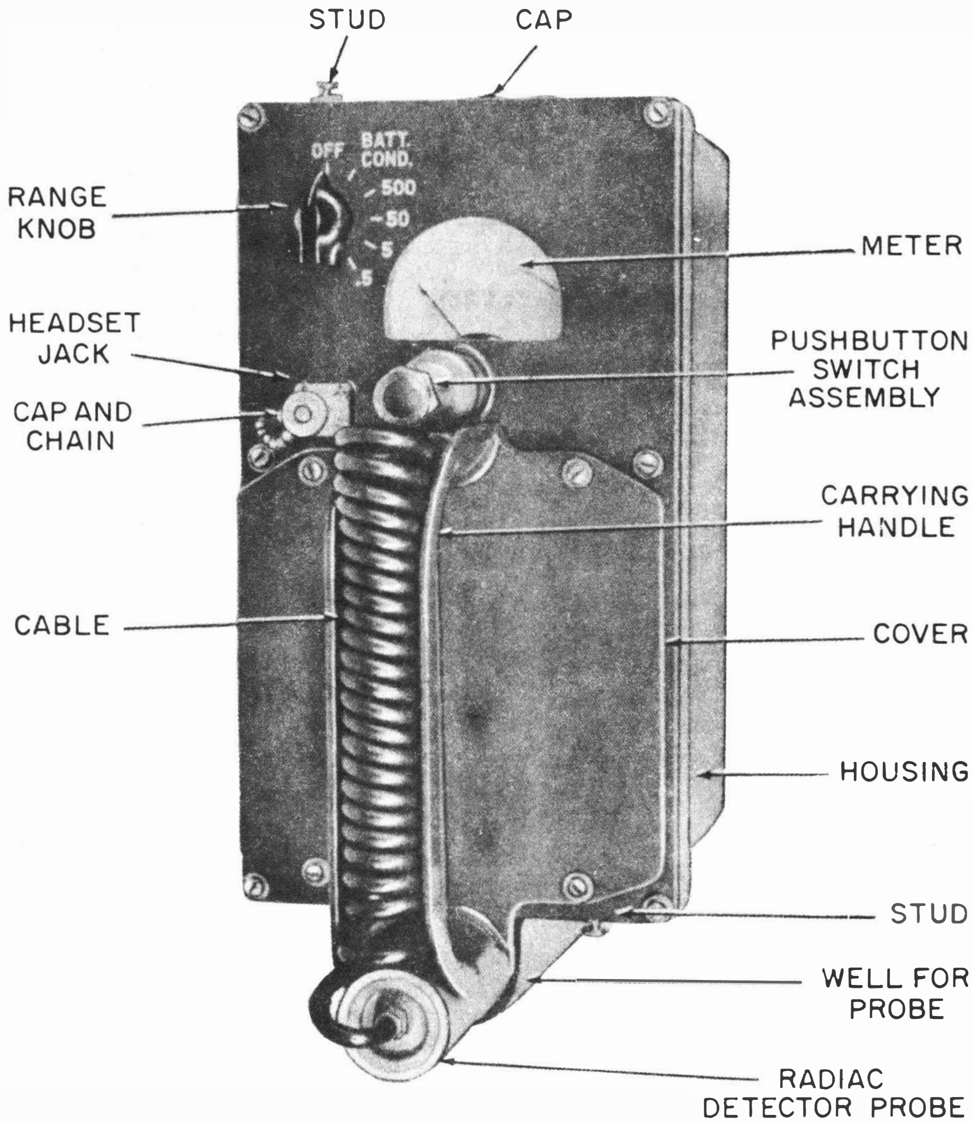


46.32
Figure 9-23.—Radiacmeter AN/PDR-10( ).



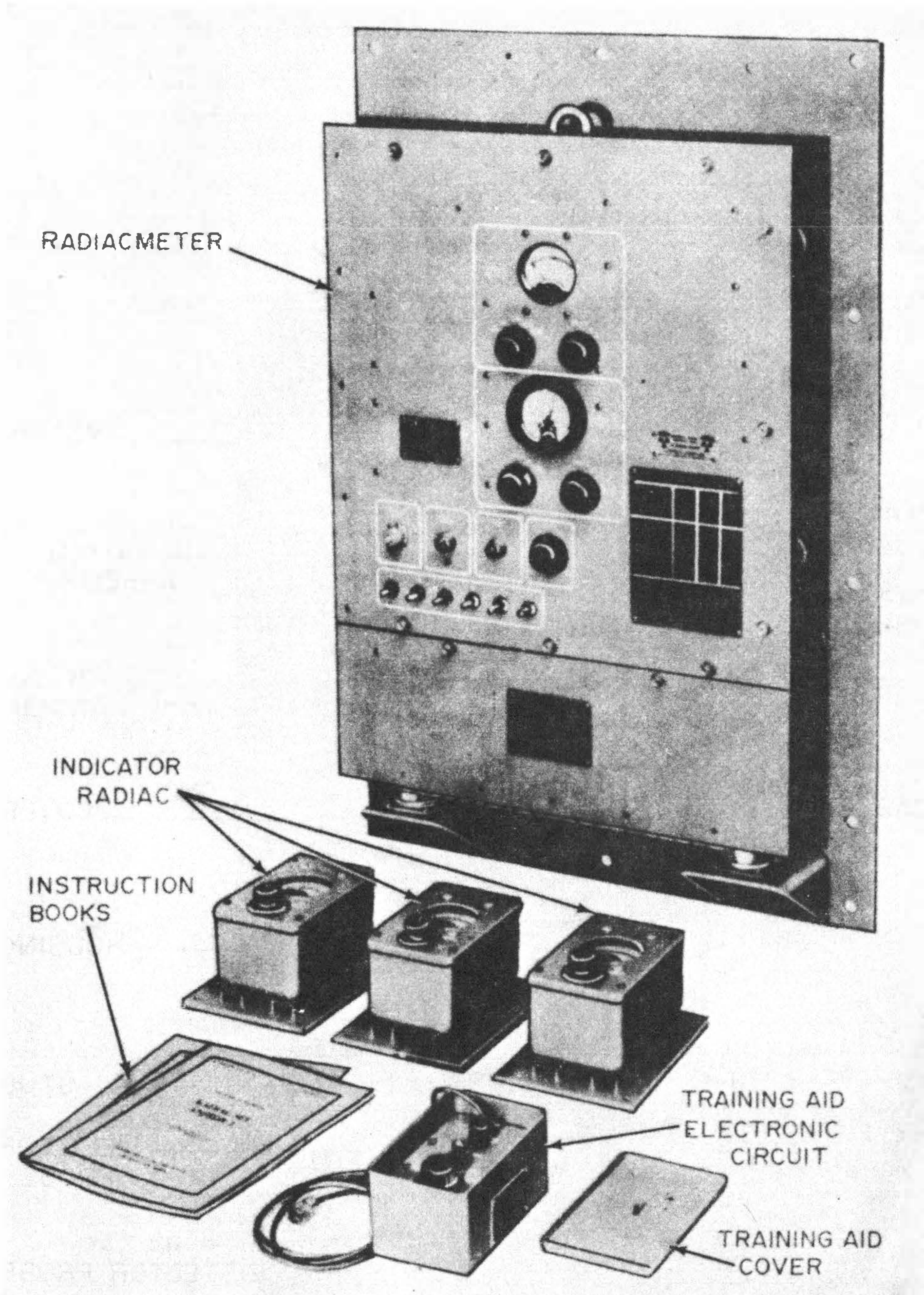
100.128
Figure 9-24.—Radiacmeter AN/PDR-18( ).

radiation field exceeds any intensity in the range 0 and 1000 milliroentgens per hour. Included in the AN/SDR-1 system are three radiac indicators and a training device. The indicators are duplicates of the high-range metering circuits in the radiacmeter. They are used to show at remote locations the radiation field defense exercises, the training device simulates high-range readings at all readout stations. The radiacmeter is designed for continuous operation from a 115-volt a-c power source. It, in turn, supplies the power to all other units. If the normal power source fails, a built-in battery operates the equipment for a maximum of 50 hours. When the a-c power is returned, the discharged battery commences recharges and assumes a full charge within 24 hours.



26.142

Figure 9-25.—Radiacmeter AN/PDR-27( ).



100.130

Figure 9-26.—Radiac set AN/SDR-1.

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