RESTRICTED

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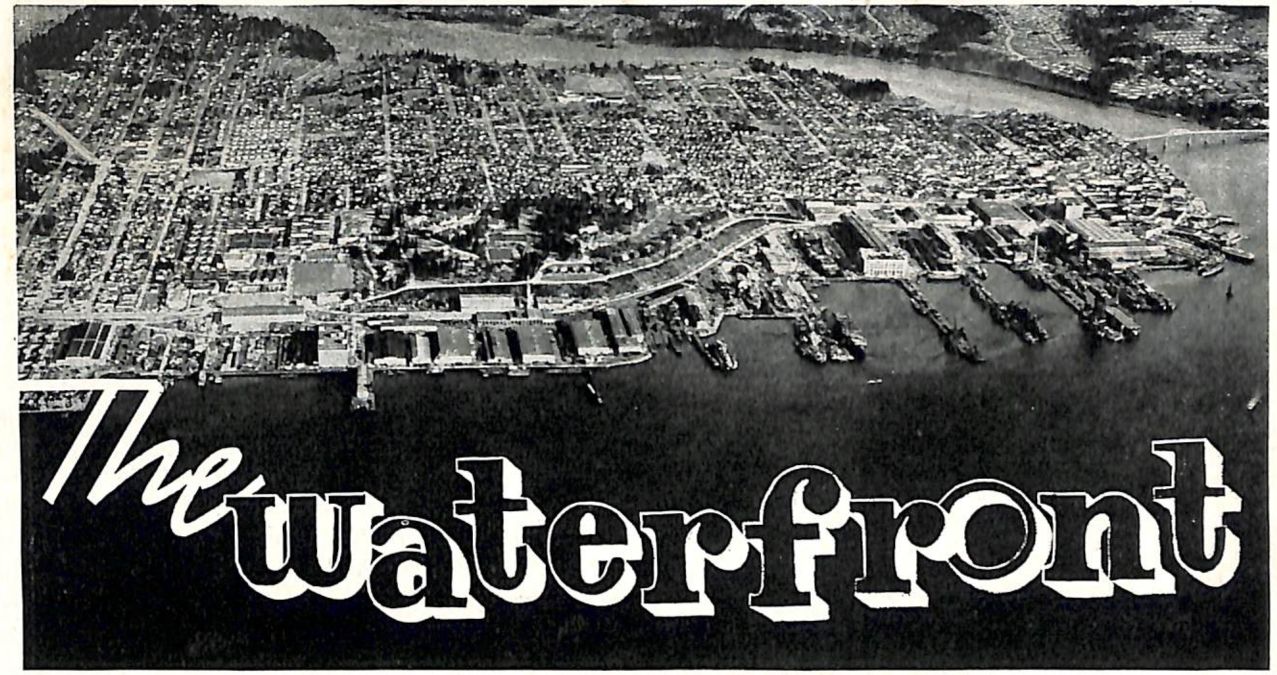


Puget Sound Naval Shipyard

By F. N. Gruwell
Supervisor, Electronics Ship Section

The Electronics Ship Section has completed another year with a most gratifying record. During the calendar year 1948, 109 ships of the classes normally overhauled by this shipyard (including district craft) were assigned for repairs, alterations and conversions. The electronics work on these ships, which was exceptionally heavy, was completed to the satisfaction of the Commanding Officers and the shipyard without delaying any scheduled sailings.

While there is little romance in quotations of statistics, a summary of the electronics systems and major equipment classes which were inspected, tested and calibrated by the Electronics Office, and a large portion of which were repaired or installed by the Electronics Shop and the associated trades, does disclose the magnitude of the electronics waterfront workload.

Search Radar

There were 81 ships with search radar equipment and associated equipments. These ships' installations included 64 air search radar systems, 85 surface search radar systems, 249 radar repeaters, 149 radar countermeasures units and 219 IFF units.

Fire-Control Radar

Thirty-two ships were equipped with 9 types of fire-control radar which represented approximately 120 systems comprised of 1000 units. This shipyard installed a large number of Mark 25 gun fire-control systems and is now in the process of installing 6 Mark 56 gun fire-control systems in the *U.S.S. Toledo*.

Radio

All ships were equipped with radio. The listing of radio equipment items is rather astounding because this listing totals 6179 units! There were 1472 receivers, 400 transmitters, 75 loran, 1665 antenna systems, 333 transceivers, 95 frequency meters, 206 teletypewriter equipments, and 1933 miscellaneous items such as speakers, remotes, etc.

Sonar

Eighty ships were equipped with sonar. There were 35 sonar models which included a total of 918 units. Twelve Model QHB equipments were installed, and the operational reports on these installations are very gratifying.

The accomplishments of the Electronics Ship Section for the calendar year 1948 were not limited to the above work, as numerous service calls were made on ships in the Puget Sound area to effect minor repairs to electronic equipment and to calibrate equipment. The engineers from this Section also solved a number of equipment design problems which resulted in improved performance. These solutions were transmitted to the Bureau of Ships for publication.

NAVY RADIO TRANSMITTING STATION

Battle Point, Bainbridge Island, Washington

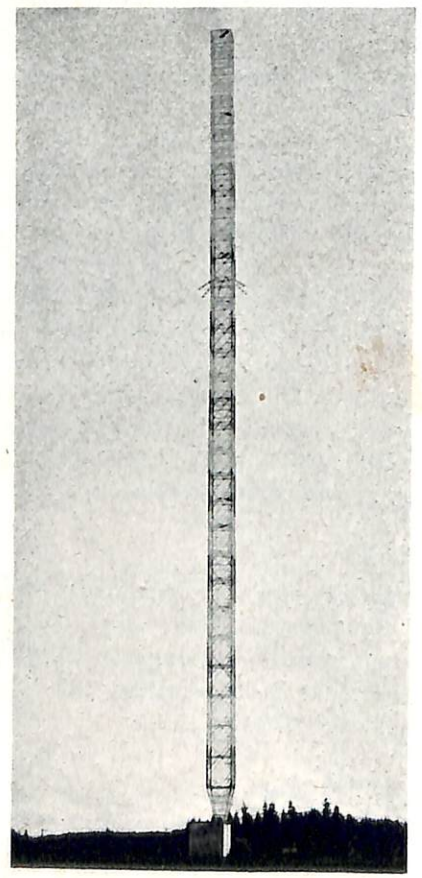
By A. H. Brudwig, *Electronics Engineer, Supervising Engineer, Electronics Shore Station*

The Navy Radio Transmitting Station, Battle Point, a component of the Navy Communication Station, Bainbridge Island, Washington and the transmitting facility for "Radio Seattle," was constructed in 1942. Battle Point is situated near the northwesterly end of Bainbridge Island, seven miles from the Puget Sound Naval Shipyard, ten miles from the Thirteenth Naval District Headquarters in Seattle and six miles from the Navy Communication Station (receiving) at the southern end of the island. The station reservation contains approximately ninety acres of level ground, lying at an average elevation of 145 feet above mean sea level and within 750 feet of salt water. The surface soil consists of deep moist clay, having good electrical conductivity. Factors which influenced the selection of this site were: (1) the absence of mountains or high terrain in the immediate vicinity; (2) transmission paths to San Francisco, Alaska and the North Pacific area have "take offs" almost entirely over salt water; (3) sufficient elevation is available to permit the use of v-h-f radio links with control points; (4) availability of space for future expansion; and (5) security against encroachment or sabotage. The site possesses many of the qualities desirable for a radio transmitting station.

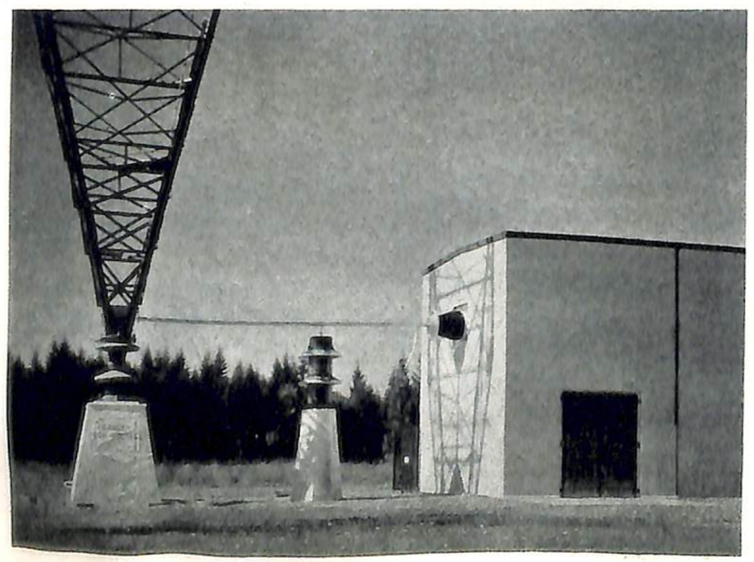
The transmitter building is of reinforced concrete construction and provides a transmitter room measuring 32 x 95 feet. Office space is contained in a wing measuring 22 x 23 feet. A full basement provides space for the 375 KVA Diesel engine-generator standby power unit, transmitter water cooling system, storage rooms, heating plant and related utilities. A portion of the wall at each end of the building is made of translucent glass blocks which admit light to the transmitter room. Wiring ducts in the floor of the transmitter room provide a convenient means for the installation of inter-connecting wiring between transmitter units, control panels and power panels. Antenna lead-ins and transmission lines enter the building through ports in the building walls.

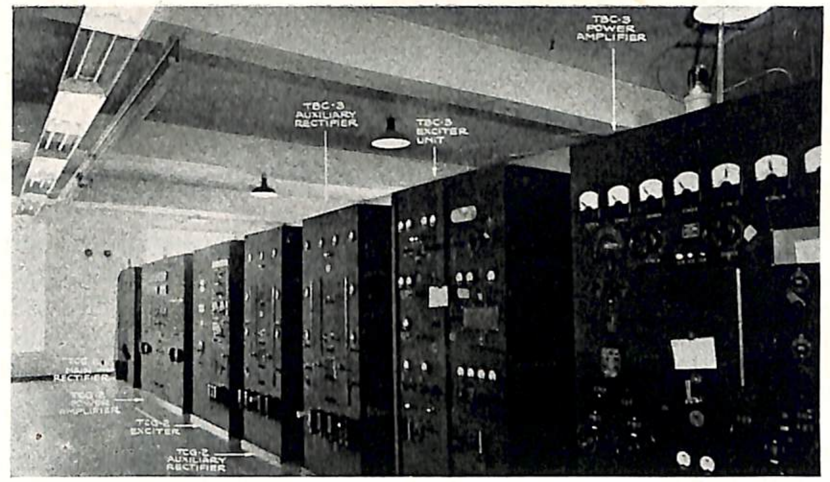
Seventeen transmitters, including the Models TCG–2, TBC–3 and TEB in the higher-powered group, are installed in the building. The transmitters' power outputs range from 500 to 50,000 watts over the frequency range of 50 kc to 27 Mc. All high-frequency transmitters and the Model TCG–2 low-frequency transmitter have been modified for frequency-shift-keying. This method of keying is used on all point-to-point circuits and to some extent on ship-to-shore circuits. Transmitters are controlled either from the Navy Communication Station (receiving), located at the south end of the island, or from the Thirteenth Naval District Headquarters in Seattle. Leased lines as well as v-h-f communication control links extend to both control activities from the transmitting station. Adequate CCL channels are available for both telegraph and voice circuits to meet all present requirements.

A variety of antennas are available for either directional or non-directional transmission. Four 300-foot self-supporting steel towers arranged in a diamond pattern around the transmitter building support seven medium-frequency and eight high-frequency non-directional antennas. Seven rhombic and four inclined terminated V-antennas are employed on point-to-point circuits or where directional transmissions are desired. Each rhombic antenna is of the inclined three-wire curtain type, having a slope angle of seven degrees. On six of the antennas, 100-foot poles are used at the tangent end, 70-foot poles at the sides and 20-foot poles at the transmission line end. Leg lengths on these antennas vary from 280 feet to 335 feet and tilt angles vary from 72°–24′ to 74°–50′. The seventh rhombic antenna was designed and constructed for operation in the frequency range of 6 to 10 Mc. It is supported by a 150-foot pole at the target end, 115-foot poles at the sides and a 20-foot pole at the transmission line end. The length of each leg is 460 feet and the tilt angle is 76°–10′. The terminating resistance for each antenna consists of a two-wire dissipation line of No. 8 stainless steel wire, with six-inch spacing and a length of approximately 1000 feet. The ends of the lines are short-circuited and grounded, thus providing a means for draining off static charges collected by the antenna. The transmission lines, extending from the transmitter building to the antennas, are of the open two-wire type and are constructed of No. 4 solid copper wire, spaced 12 inches and supported on 12-inch pedestal

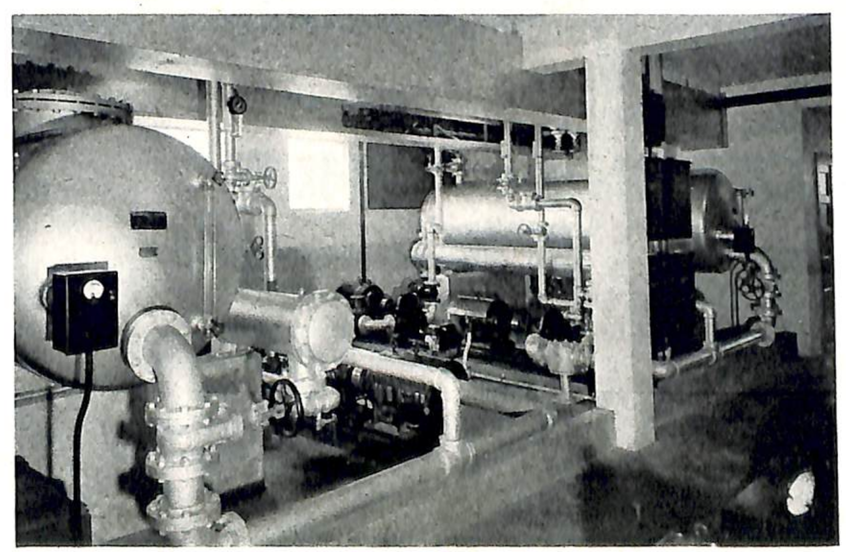


800 FOOT TOWER for Model TCG transmitter (at right). Helix house and base for the tower (below).

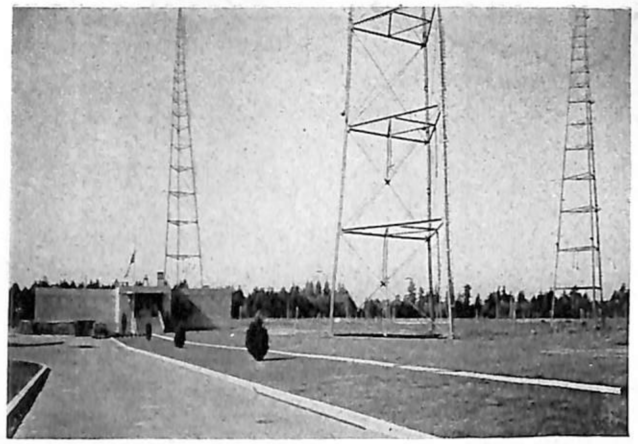




Interior of the TRANSMITTER BUILDING.



DUPLICATE WATER COOLING UNITS for TCG and TBC transmitters.



TRANSMITTER BUILDING.

insulators. The standing wave ratios on these lines range from a maximum of 1.25 to a minimum of 1.03 over the usable frequency range of the antenna.

Of particular interest is the low-frequency radiator used with the Model TCG–2 transmitter. This is an 800-foot guyed steel tower of uniform cross section, 20 feet square, resting on a single base insulator. Eight guys attached at the 515-foot level maintain the tower in a vertical position. The guys, consisting of 1⅞-inch wire rope, are each broken with four insulators, three placed near the attachment point and one near the ground end. The base insulator carries a load of 706,000 pounds at 60 degrees Fahrenheit; this loading is calculated to increase to 728,000 pounds at 0 degrees. The base insulator rests on a reinforced concrete pedestal which is covered with sheet copper to prevent heating of the reinforcing steel by the intense r-f field existing at the base of the tower. The tower is painted and illuminated in accordance with CAA specifications for tower markings. 1000-watt flashing beacons are located at the top and at the 400- and 600-foot levels. Positions midway between these levels are marked by 100-watt fixed lights placed at the four corners of the tower. Power for the lighting circuits is brought to the tower through a special high-voltage oil-filled transformer which isolates the radio frequency from the power supply system. A separate ground system is provided for the low-frequency radiator which consists of 240 radials of Number 6 bare copper wire, 600 feet long, buried to a depth of 12 inches and uniformly spaced at 1.5 degrees around the base of the tower.

The antenna loading inductor, antenna tuning variometer and coupling transformer are contained in a helix house located near the base of the tower. The helix house is a reinforced concrete structure 26 feet by 38 feet and 26 feet high. The ceiling is covered with sheet copper and grounded to prevent heating of the reinforcing steel and to reduce losses in the field of the antenna loading inductance. An open two-wire transmission line carries the radio-frequency energy from the transmitter building to the helix house, a distance of approximately 1000 feet.

At the operating frequency of 58 kilocycles the antenna has a resistance of 1.5 ohms, a capacitive reactance of 520 ohms and an effective height of 308 feet. Quarter-wave resonance occurs at 232 kc. Excellent coverage of the North Pacific area is obtained from the above described radiator. This is particularly important when high-frequency circuits to Alaska fail because of radio "blackouts" which are quite common in the northern latitudes. These black-outs occur at irregular intervals and may persist for a few hours to several days. During these periods the Model TCG–2 transmitter, frequency-shift-keyed on 58 kc, is used exclusively for radio teletype transmissions to Alaska, and handles not only the Navy's traffic, but that of the Army as well.

An inverted pyramid, broad-band antenna is under construction at the station for use in the 2- to 3-Mc band for ship-to-shore communications. The design is based on the published information collected during experiments with various types of broad-band antennas by the Naval Electronics Laboratory, San Diego, California. Since the antenna will be used only with low power from a Model TDO transmitter, Type RG–85/U coaxial cable will be used to connect the antenna to the transmitter.

THE ELECTRONICS OFFICE

The Electronics Office of the Puget Sound Naval Shipyard is organized in conformity with Chapter VI of the Shipyard Regulations. The organization is functioning very smoothly as the only new feature in the standardized organization which was not already included in the previous organization is the Electronics Services Section. This section has already proved its worth by relieving the Electronics Ship and Shore Sections of record-keeping and clerical problems, thereby permitting those sections to concentrate on affairs of a technical nature. By the same token, the Electronics Services Section is concentrating on those matters which were often deferred due to higher priority work, so that the shipyard's customers are, therefore, receiving improved service.

It may be of interest to readers to note that in this shipyard, the custody and maintenance of all electronic test apparatus is vested in the Services Section. This arrangement is proving very satisfactory.

PROGRAM Z is for ZEBRA

By L. P. Campbell
Quarterman Radio Mechanic

Program ZEBRA, the latest addition to the rapidly expanding electronics family at the Puget Sound Naval Shipyard, was established in March 1948. This program, which is quite unique, consists of the restoration of electronic equipment which has been returned from the forward Pacific areas and which has been removed from ships and shore stations. The ultimate aim is to provide all activities with good serviceable equipment, particularly the Naval Reserve.

Much of the equipment which is received for restoration to "equivalent to new equipment" was in open storage for long periods in the extremely severe climates encountered in the tropical and semi-tropical areas; the results of high humidity and boiling suns have so greatly accelerated the fungus growth, rust and corrosion that the equipment might appear to the uninitiated to be beyond hope of restoration and doomed for the scrap pile! This, however, is not the case as the equipment can be reworked to issuable condition provided the units have not been too badly damaged by breakage. Over 90% of the units received have been restored to issuable condition!

It became apparent at the outset that, if the restoration work was to be performed on an economical basis, the shipyard must adopt "mass production methods" as distinguished from the customary shipyard practice of making repairs on a "custom" or "job-shop" basis. Accordingly, all plans were made to lay out the restoration work-lines for repetitive operations and to reduce the transportation handling to a minimum.

A separate supply department building, with adequate space and handling facilities, was selected for the receipt, segregation and shipment to Shop 67 of incoming equipment and the receipt, packing and shipment of restored equipment received from Shop 67. Equipment which was screened by the Program ERUPT lines at the Mare Island Naval Shipyard and by this shipyard is pallet packed and strapped for storage and shipment. These pallets are received in the supply department ZEBRA building where the units comprising the complete electronic equipment are segregated into lots of similar items, inventoried and made ready for issue to Shop 67 for restoration as required by the shop production rates.

Shop 67 is the lead shop for all Program ZEBRA restoration work, except for miscellaneous motor-generators, magnetic controllers, patch panels, etc., which are not associated with a specific type of electronic equipment; these latter items are issued direct to Shop 51.

To permit establishing "production line" processing of ZEBRA equipment in Shop 67, the former electronics laboratory was selected as the best suited location to house this program. It was essential that the building so selected be of sufficient size to house all phases of the electronics work and at the same time be physically separated from the main shop to avoid interferences with waterfront work. The former electronics laboratory not only fulfilled these conditions, but also is located away from the industrial area of the shipyard where noise levels are low and industrial dusts are practically eliminated.

The Program ZEBRA building of Shop 67 is "L" shaped and measures 102 feet across the front with a depth of 50 feet, and is 98 feet long on the side wing with a depth of 41 feet. The building, which was designed for electronic work, is of steel-frame reinforced-concrete slab construction with a brick exterior; all structural and reinforcing steel rods are thoroughly bonded and connected to a ground grid by heavy copper conductors. This special type of construction has provided a shop building which is well suited for electronic work because of the low noise level and the ease of cleaning.

Incoming shipments of electronic equipment from the supply department are off-loaded on the loading platform onto the freight elevator and transported to the basement, where all major disassembly and clean-up is performed. The objective is to confine all "dirty" work to one section of the basement. In addition to the disassembly and clean-up work, the basement houses a special d-c power plant, the paint refinishing booth, an assembly section for transmitters and the shipping and receiving sections.

The main floor, with the exception of the spaces on the front of the building which are assigned to the Electronics Office as a small laboratory, houses the radar assembly, repair, alignment, and final test sections; also included on the first floor is the office of the Quarterman Radio Mechanic in charge of ZEBRA restoration work.

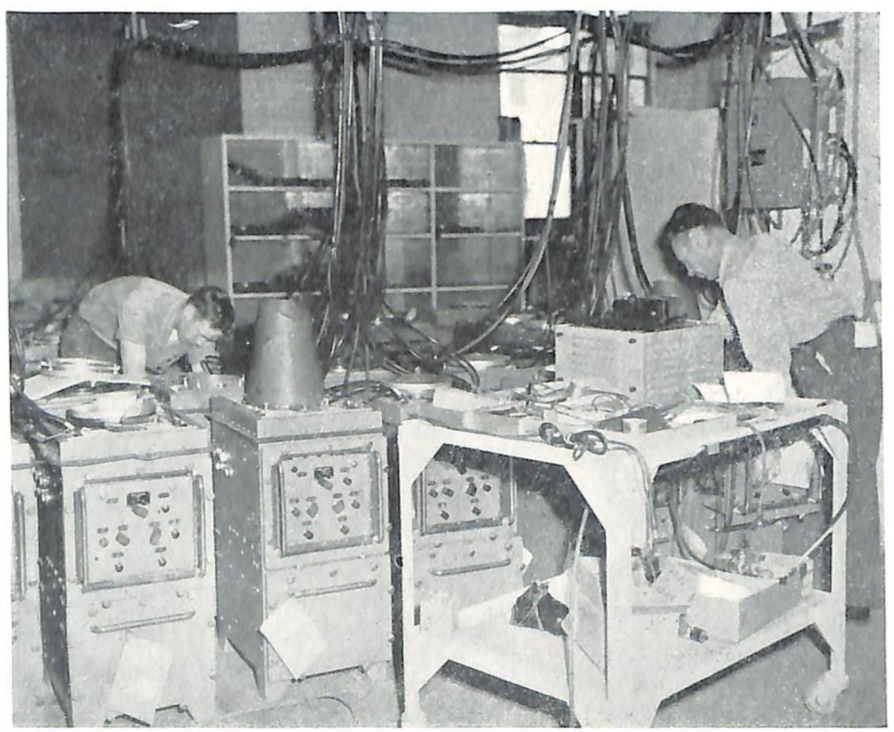
The second floor contains the assembly, repair and alignment sections for sonar; an assembly and repair section for radio transmitters, and the alignment section for radio transmitters; the test section for radio transmitters; the alignment section (screened room) for aligning receivers, measuring instruments and small transmitters. Also included on the second floor are the shop stores section and the CRF. (Due to the fact that no spaces or special security provisions are available in the main building assigned as Shop 67 for housing CRF, it is necessary to retain this activity in the Program ZEBRA building.)

Since the design of the building provided freight elevator service only to the basement, the first and second floors, and elevator service to the third floor is limited to the lighter loads which may be handled by an automatic passenger elevator, restoration work on the third floor has been restricted to the assembly, repair and preliminary alignment of receivers and small radar units. The top floor also contains a shop lunch room and locker room.

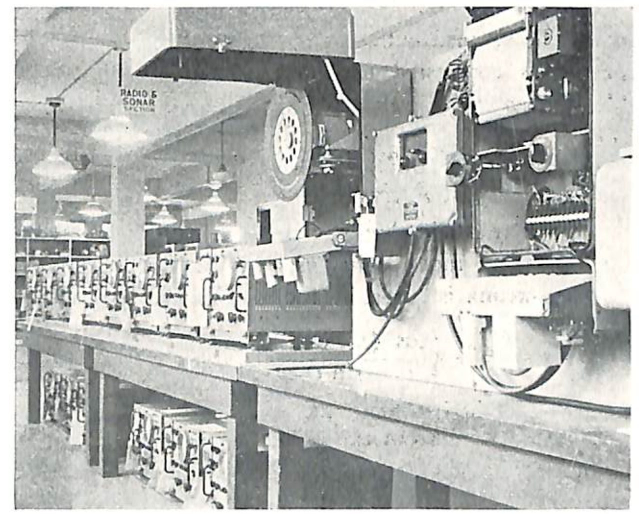
Radio and radar antennas are installed on the roof. Additionally, the roof has an outdoor lunch area where employees may have their lunches during clement weather.

The flow of work through the restoration lines in the Program ZEBRA building has been laid out in such a manner that incoming equipment is received in the basement for disassembly, cleaning and preliminary testing of the disassembled units. Bins are provided in the disassembly area for collecting all like parts, components and subassemblies. Items which require replating are shipped to the plating shop in large quantities; and cases which require complete repainting are shipped to the paint shop. Touchup painting and the refinishing of small items such as dials, nameplates, etc., are accomplished in the basement paint booth. The disassembled components and sub-assemblies are cleaned and given preliminary tests; those items which are satisfactory for further use are then moved from the basement to bins in the vicinity of the assembly lines, where the assembly crews reassemble the units. Reassembled units are then passed to the testing and alignment crews where the units are first "cold" checked to eliminate all possible dangers of casualties when power is applied to the newly assembled units. The units are then given a "hot" check which brings to light any additional repair work which may be required. Following the "hot" check, the units are aligned, if required, and assembled into complete equipments for final tests. When the shop is satisfied that the equipment is operating satisfactorily, engineers from the Electronics Office are notified. The engineers conduct the final shop test to determine that the equipment meets the original Bureau of Ships specifications. Upon completion of final tests, equipments are returned to the basement where the assembled units of each complete equipment are assigned new serial numbers and returned to the special supply department building for domestic packing in preparation for shipment to ultimate destinations.

The restoration lines, as previously stated, were established to permit the maximum use of "production line" methods. Due to the repetitive processes, it is possible to utilize quite a large percentage of electricians and semi- and unskilled workers and to train these workers as radio mechanics; personnel are rerated as radio mechanics as soon as they are qualified. The percentage of ratings employed on the strictly electronic portion of the Program ZEBRA work has varied from 26% radio mechanics, 34% electricians, 3% apprentices and 37% helpers at the peak of employment, to 37% radio mechanics, 28% electricians, 3% apprentices and 32% helpers at the present writing. The increase in the percentage of radio mechanics and the decrease in the percentage of electricians can be attributed in part to the qualifying of electricians as radio mechanics. The working force, under one quarterman and three leadingmen, has varied from fifty to one hundred and twenty men, depending upon available manpower as dictated mainly by the waterfront workload. While space is available to permit working a maximum of approximately three hundred men, an effort is being made to maintain a relatively permanent group of one hundred and fifty men.



HOOKING UP the Model VD Radar Repeaters for the final test. Harness provides means for hooking-up twelve VD's simultaneously.



COMPLETED LORAN RECEIVERS awaiting removal to Supply. Fiddle board (at right) for final test and calibration of Model NJ–8 fathometers.

At the time when this article was prepared (15 December 1948) over four thousand units of radio, radar, loran and sonar have been restored by Program ZEBRA. The types of equipment which have been or are being restored by Program ZEBRA in the Puget Sound Naval Shipyard include the Models TBA, TBL, TCS and TDE radio transmitters; Models DAS–1, DAS–3 and DAS–4 loran; Model NJ–8 fathometers including recording units; speech amplifier equipment for Model TBL transmitters; Model VD PPI's; Model PQ and PQ–1 recorders; and Model SA, SA–2 and SA–3 radar equipments.

The experience gained thus far from Program ZEBRA has proved that mass restoration work is the most economical procedure for overhauling and returning electronic equipment to store. While it is not possible in an article of this length to discuss in detail the cost breakdowns, it has been determined that complete restoration of an electronic unit through Program ZEBRA lines costs approximately 55% of the ordinary "job-shop" repairs for a similar unit repaired on a job order by Shop 67. The intrinsic value of restored equipment can hardly be measured in dollars and cents, as its importance to the Naval Reserve Program and to ships and shore stations far outweighs other considerations. The average restoration cost for used electronic equipment, however, does not exceed 10% of the original cost of the equipment.

Needless to say, many problems were encountered and had to be solved while establishing mass restoration processes. One of the major problems has been that of cleaning. Since the equipment generally arrives in a very dirty condition, heavily corroded and with fungus covering all wiring harnesses, it was essential that rapid and inexpensive cleaning methods be developed. All of the various standard solvents for general cleaning and removal of lacquer were tested, as hand cleaning was too slow and too costly. Shop 67 was assisted in this problem by the shipyard chemists who finally developed a methyl-ethyl-ketone solution which has been found to be very effective for removing dirt and lacquer without affecting the electrical properties of the components. Another problem which required considerable experimentation before arriving at the final solution was the degree to which equipment should be disassembled for cleaning and testing of components during the restoration process. Experience has dictated that, in the case of simpler types of radio transmitters, such as the Models TBA and TBL, the most economical procedure is to completely strip the incoming units. The more complicated units are stripped down to sub-assemblies.

Not only has Program ZEBRA provided the shipyard with a most excellent training vehicle, but it has also developed a by-product which should be very valuable to the Service. This by-product is the assembly of servicing manual data. Each test and alignment section maintains a special log where data on troubles encountered are recorded. These logs are maintained in tabular forms under three columns captioned "Symptoms," "Diagnosis" and "Treatment." When the test and alignment mechanics encounter troubles, they consult the log to see if similar symptoms have been encountered by other mechanics; if not, they record the symptoms and then proceed to determine the causes thereof. When the causes have been determined and the deficiencies corrected, the mechanics enter the causes under "Diagnosis" and repairs required under "Treatment." Because of the large volume of similar items which are treated in this manner (for example, the reassembly and final test of over 250 Model DAS series loran) almost every type of casualty is encountered and recorded. These data are now being assembled for transmittal to the Bureau of Ships for ultimate publication.

GRAPHICAL METHODS

FOR PREDICTING POWER RADIATED BY ANTENNA ARRAYS

By LIEUT. COMDR. CHARLES W. HARRISON, JR., USN,
Electronics Design Division
Bureau of Ships

Introduction

Perhaps the earliest method evolved for estimating the power radiated by an antenna or antenna array consisted in evaluating the integral

$$P_o = \frac{1}{R_c}\int_{\text{(spherical surface)}} /\mathcal{E}_{(\Theta,\phi)}/^2\, d\sigma \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Here P_o is the power radiated in watts.

R_c is the characteristic resistance of space, $R_c = 376.7 \backsimeq 120\Pi$ ohms.

$\mathcal{E}_{(\Theta,\phi)}$ is the electric field in volts per meter existing at the element of spherical surface $d\sigma$.

The integration is to be carried out over the entire surface of an imaginary sphere completely encompassing the radiating system. It is presumed that the radius of this sphere is at least one hundred wavelengths, or one hundred times the maximum extension of the antenna system, whichever leads to the greater radius.

The assumption is made that dissipationless media exist within the sphere. Accordingly, the power transferred from inside to outside the envelope of integration, as calculated by (1), must be interpreted as the power radiated by the antenna system.

The electric field $\mathcal{E}_{(\Theta,\phi)}$ is invariably computed by assuming that a given distribution of current exists along the radiating wires. The power radiated, as determined from (1), is the power required to maintain the assumed current distribution, and therefore includes the effect of inter-element coupling (mutual impedance). If the actual current distribution in the array being analyzed departs significantly from that assumed, the answer obtained may bear little resemblance to the true answer sought. It should be said, however, that for arrays composed of sufficiently thin conductors, the assumption of a sinusoidal distribution of current for resonant antennas, as contrasted to non-resonant radiating structures, often yields valuable engineering information.

Power Radiated by a Symmetrical Center-Driven Antenna

The electric field due to a current of sinusoidal form flowing along the two halves of a symmetrical center-driven antenna is given by the familiar expression

$$/\mathcal{E}_\Theta/ = \frac{60 I_o}{r}\left\{\frac{\cos(\beta h \cos\Theta) - \cos\beta h}{\sin\Theta \sin\beta h}\right\} \ldots\ldots (2)$$

In (2), I_o is the input current.
r is the distance from the center of the antenna to the point where $/\mathcal{E}_\Theta/$ is computed. (This distance may be regarded as the radius of the imaginary sphere circumscribed about the antenna.)

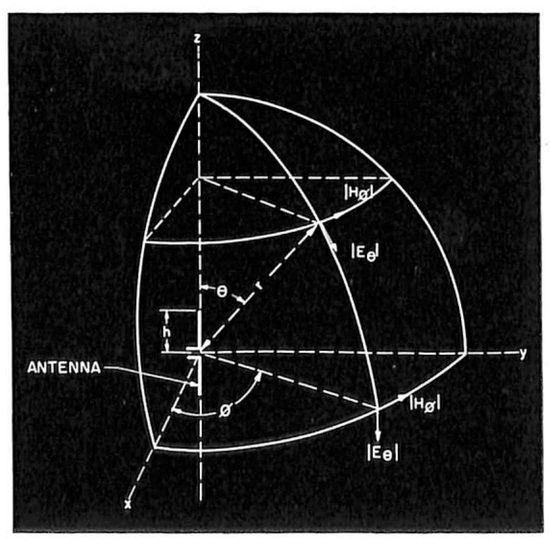


FIGURE 1—*Components* $/\mathcal{E}_\Theta/$ and $/H_\phi/$ *of the electromagnetic field due to moving charge along a center-driven radiator; polar coordinates r,* Θ *and* ϕ *are employed.*

$\beta h = 2\Pi h/\lambda$ is the radian half-length of the antenna.

Θ is the angle between the axis of the antenna and the line connecting the point of field calculation in space to the center of the antenna.

The situation involved is depicted in figure 1.

The amplitude and time phase of the magnetic field $/H_\phi/$, referred to the electric field $/\mathcal{E}_\Theta/$ is given by

$$H_\phi = \mathcal{E}_\Theta / R_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

however, the magnetic field is in space phase quadrature with respect to the electric field. The sense of the fields at a selected instant in time is shown in the drawing.

It is to be observed that $/\mathcal{E}_\Theta/$, as well as $/H_\phi/$ are independent of the angle ϕ. This is due to the fact that rotational symmetry obtains about the axis of the wire. Under these circumstances (1) is particularly well adapted to numerical integration.

If $\beta h = n\pi$ (n any positive integer) the assumption of a sine distribution of current along the antenna requires I_o vanish. In practice this difficulty is avoided by referring the field to the maximum current existing along the antenna. The relation between I_{max} and I_o is

$$I_{max} = I_o/\sin\beta h \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Suppose, for example, that it is desired to predict the power radiated by an isolated dipole of half-length $h = \lambda/4$. From (2),

$$/\mathcal{E}_\Theta/ = \frac{60 I_o}{r}\left\{\frac{\cos\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta}\right\} \ldots\ldots\ldots\ldots\ldots (5)$$

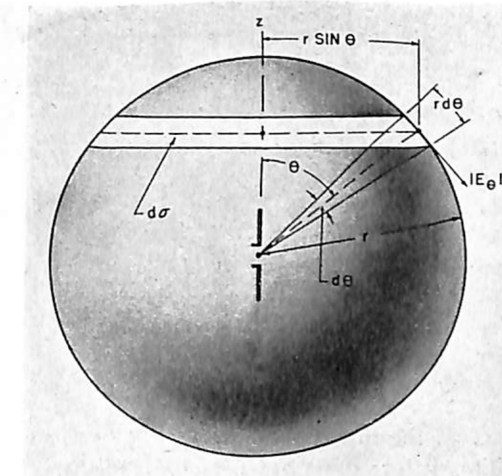


FIGURE 2—*Construction for use in determining the differential area* $d\sigma$ *when the field is rotationally symmetrical about the axis of a radiator.*

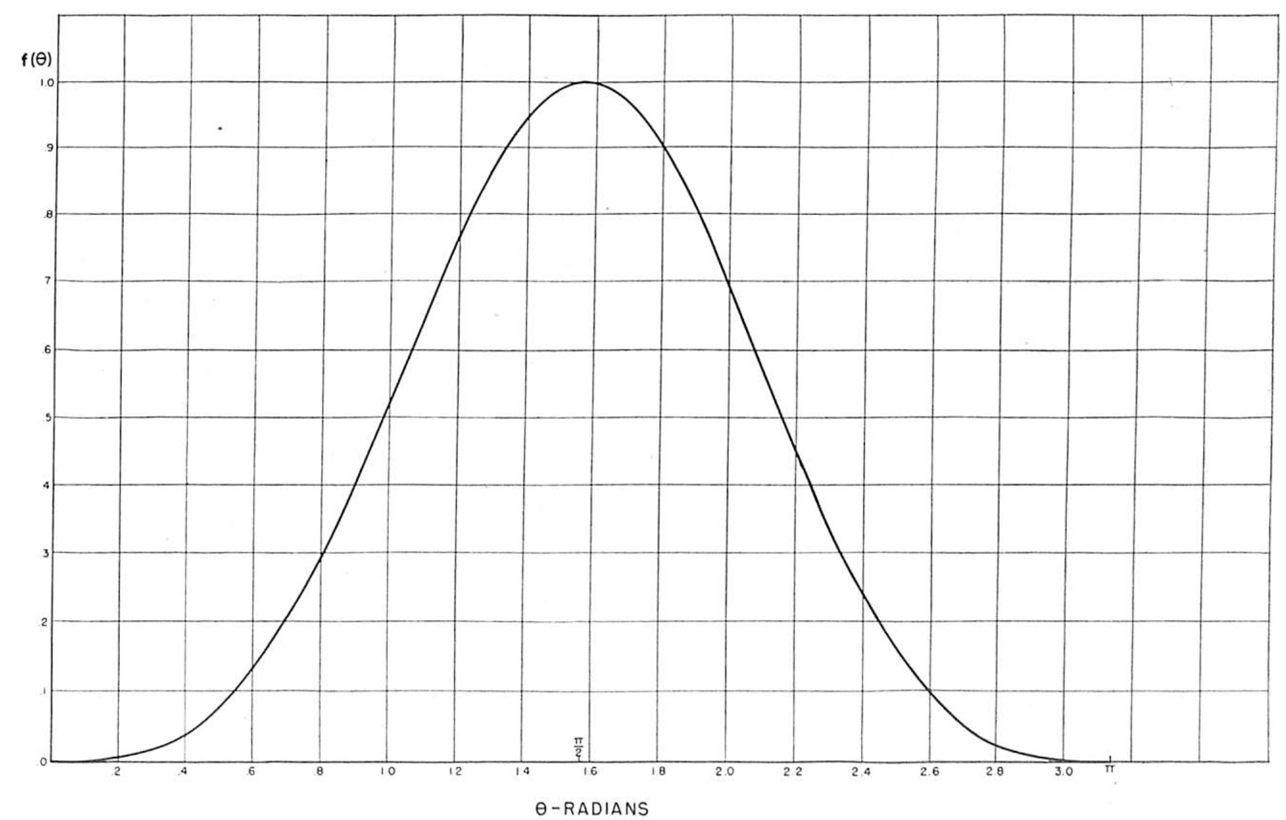


FIGURE 3—*Plot of the function* $f(\Theta)$ *for a symmetrical center-driven dipole. The antenna half-length is* $h = \lambda/4$.

Before (1) may be employed it is necessary to determine the value of $d\sigma$. This is done with the aid of figure 2. Then $d\sigma$ is given by

$$d\sigma = 2\pi r^2 \sin \Theta \, d\Theta \qquad (6)$$

(It can be shown that the most general expression for $d\sigma$ is

$$d\sigma = r^2 \sin \Theta \, d\Theta \, d\phi) \qquad (7)$$

Upon substituting (5) and (6) in (1),

$$P_o = 60 I_o^2 \int_0^\pi \frac{\cos^2\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta} d\Theta \qquad (8)$$

The limits on the integral are selected by observing that the limiting values of Θ are 0 and π radians. The integral (8) is readily evaluated by plotting a curve of

$$f(\Theta) = \frac{\cos^2\left(\frac{\pi}{2}\cos\Theta\right)}{\sin\Theta} \qquad (9)$$

for various values of Θ beginning at $\Theta = 0$ radians and ending with $\Theta = \pi$ radians. Actually, because of symmetry, it is only necessary to calculate values of (9) over the range $0 \leqq \Theta \leqq \pi/2$. (Observe that $f(\Theta) = 0$ when $\Theta = 0$ radians or $\Theta = \pi$ radians.) The value of the integral is the area under the plotted curve. There are several methods for determining this area. For example, a polar planimeter may be employed, or alternatively the squares under the curve may be counted. Another method consists of plotting the curve on a piece of paper of uniform density and thickness. One then cuts out the curve with scissors and "integrates" by weighing it on a sensitive balance!

Figure 3 is a plot of (9) for $0 \leqq \Theta \leqq \pi$. The area under this curve is approximately 1.2 units. Accordingly the power radiated by the dipole is

$$P_o = 72 I_o^2 \qquad (10)$$

The radiation resistance, referred to the input current

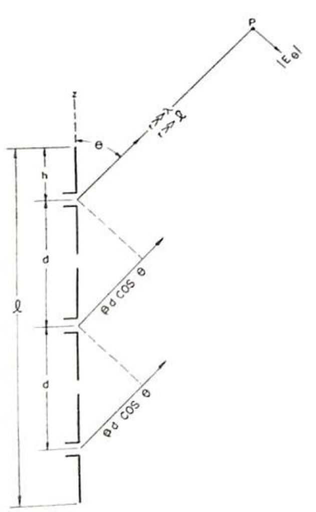


FIGURE 4—*Construction for use in calculating the field of a three-element collinear array.*

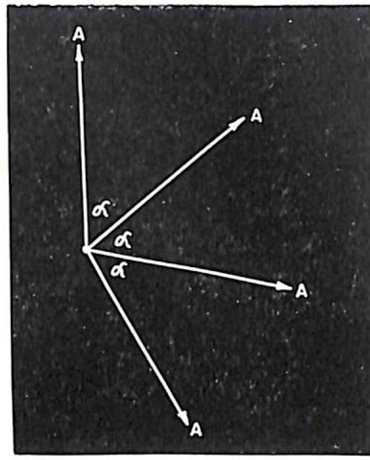


FIGURE 5A—*System of vectors of equal amplitude differing in direction by equal angles.*

(which is also the maximum current when $h = \lambda/4$), is

$$P_o/I_o^2 = R_o = 72 \text{ ohms} \qquad (11)$$

The radiation resistance as given by (11) is based upon the assumption that a sinusoidal distribution of current exists along the dipole. More exact integration shows that $R_o = 73.13$ ohms.

Power Radiated by an N-Element Collinear Array

By definition, a collinear array comprises several identical radiators, oriented axially in a straight line, with a constant separation distance between driving points. Figure 4 illustrates a collinear array for which $N = 3$. The field at point P which is located on the surface of the great sphere circumscribed about the array is the vector sum of the fields set up by the three antenna elements. Each of these fields may be computed from (2), provided the assumption of a sinusoidal distribution of current in all antennas is made. The fact that a collinear array is inherently an asymmetrical system (from the point of view of the driving points) causes no difficulties under this circumstance. Although the distance r from each antenna comprising the array to the point P is somewhat different, for the purpose of computing the amplitude of the field this fact is ignored. A person at point P looking toward the array would observe only a dot on the landscape. Accordingly, the "rays" from the antenna elements may be regarded as emanating from the array parallel to one another. If the input currents in all antennas have the same amplitude and phase, the individual fields at point P will differ by a progressive phase angle $\beta d \cos\Theta$ radians, as shown by figure 4. In general the problem of calculating the net field is one of adding N vectors of amplitude A but differing in phase by a constant angle α. The system of vectors shown in figure 5A is equivalent

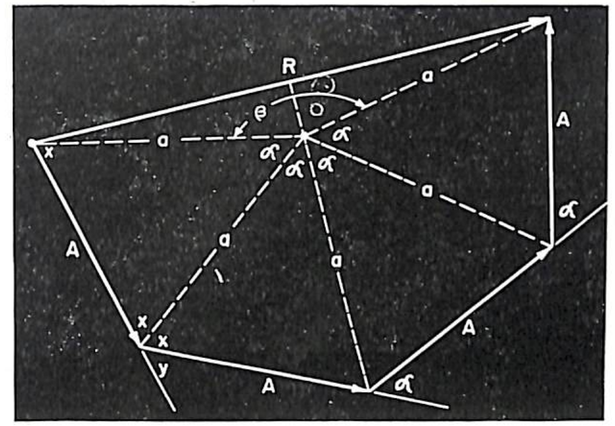


FIGURE 5B—*System of vectors equivalent to that shown in figure 5A. The resultant is R. Construction is useful in proving the diffraction formula.*

to the system of vectors shown in figure 5B. The resultant is R.

Now by inspection of figure 5B:

$$R = 2a \sin \frac{\beta}{2}$$

$$B + N\alpha = 2\pi$$

Hence

$$\frac{\beta}{2} = \frac{2\pi - N\alpha}{2}$$

Therefore

$$R = 2a \sin \frac{N\alpha}{2}$$

But

$$\sin \frac{\alpha}{2} = \frac{A}{2}/a$$

or

$$a = \frac{A}{2}/\sin\frac{\alpha}{2}$$

Accordingly,

$$R = A \frac{\sin N\frac{\alpha}{2}}{\sin\frac{\alpha}{2}} \qquad (12)$$

Since $2x + y = 180$ degrees

and $x + \frac{\alpha}{2} = 90$ degrees

$\alpha = y.$

When the angle α is small $\sin N\frac{\alpha}{2} \rightarrow N\frac{\alpha}{2}$, and $\sin \frac{\alpha}{2} \rightarrow \frac{\alpha}{2}$. Under this condition, $R = N A$.

The value of A in (12) is given by (2). The angle α in (12) is $\beta d \cos\Theta$. Accordingly, when $N = 3$,

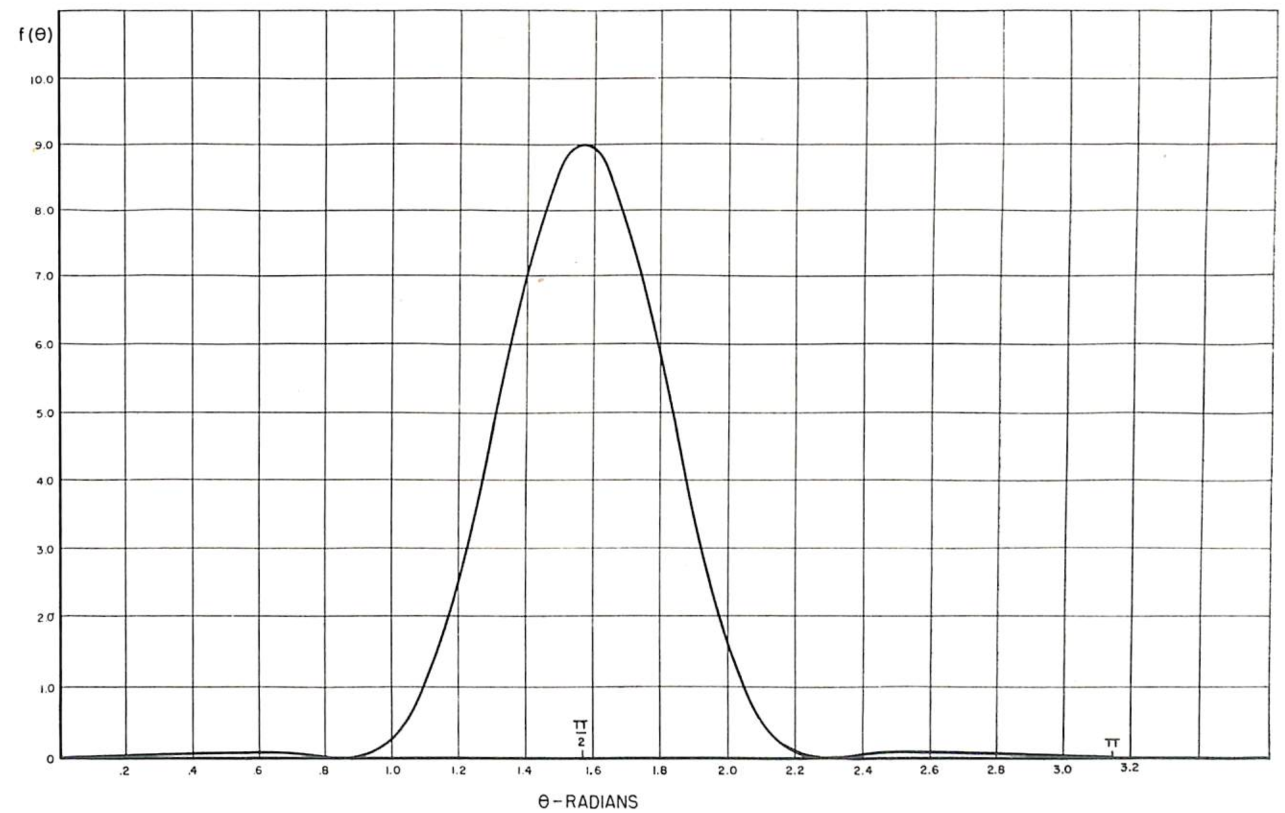


FIGURE 6—*Plot of the function $f(\Theta)$ for a three-element collinear array for which $h = \lambda/4$ and $d = \lambda/2$.*

$h = \lambda/4$ and $d = \lambda/2$ (assuming that the adjacent ends of the antenna elements are not touching), one has

$$/\varepsilon_\Theta/ \text{ (3-element collinear array)} = \frac{60I_o}{r} \frac{\cos(\frac{\pi}{2}\cos\Theta)}{\sin\Theta} \frac{\sin(\frac{3\pi}{2}\cos\Theta)}{\sin(\frac{\pi}{2}\cos\Theta)} \quad \ldots\ldots (13)$$

The power radiated is

$$P_o = 60I_o^2 \int_0^\pi \frac{\cos^2(\frac{\pi}{2}\cos\Theta)}{\sin\Theta} \frac{\sin^2(\frac{3\pi}{2}\cos\Theta)}{\sin^2(\frac{\pi}{2}\cos\Theta)} \, d\Theta \quad \ldots\ldots (14)$$

A plot of the function

$$f(\Theta) = \frac{\cos^2(\frac{\pi}{2}\cos\Theta)}{\sin\Theta} \frac{\sin^2(\frac{3\pi}{2}\cos\Theta)}{\sin^2(\frac{\pi}{2}\cos\Theta)} \quad \ldots . (15)$$

is shown in figure 6 for $0 \leqq \Theta \leqq \pi$ radians. The area under the curve is approximately 5.25 units.

The radiation resistance of the array, referred to the current I_o, is therefore

$$P_o/I_o^2 = R_o = 60\ (5.25) = 315 \text{ ohms} \quad \ldots\ldots (16)$$

More exact integration shows that $R_o = 316.5$ ohms.

Power Radiated From Antenna Arrays, General Case

The determination of the power radiated by an antenna array is a rather simple procedure provided the electric field may be expressed in terms of one variable Θ. The foregoing calculations substantiate this, for in principle it is just as easy to calculate the power radiated by a fifty-element collinear array (whether it be isolated or suitably oriented over the surface of a perfectly conducting earth) as it is to calculate the power radiated by a simple dipole.

If the electric field is a function of two variables (Θ and ϕ) then the graphical method for predicting the power radiated becomes a very tedious process. In such cases perhaps the best procedure is to employ a synthesis of the graphical and analytical approach. Frequently it is possible to integrate with respect to one variable (either Θ or ϕ) without too much difficulty. This may or may not complicate the integrand, but complication is of small moment particularly if an automatic calculating machine is available for computing values required for construction of the curve $f(\Theta)$.

TESTS OF THE SP RADAR B-MODULATOR

By R. Herring, Jr.

U. S. Naval Research Laboratory

The SP and SP–1M Radar Sets are provided with two modulators, the A-modulator for one-microsecond pulses and the B for five-microsecond pulses. The A-modulator has been satisfactory, but operation with the B-modulator has been reported to result in very short 4J47 magnetron life due to internal arcing. At least part of this trouble was originally due to failure of the rotary spark-gap to fire consistently; a misfire caused the next modulator pulse to tend to be at twice the normal voltage. In spite of a field change provided by the manufacturer to help insure steady firing of the gap, and other work by the manufacturer and by the Electronics Field Service Group at the Naval Research Laboratory, the trouble is reported to have persisted, and to such an extent that the B-modulator is rarely used in the fleet or the field.

The Naval Research Laboratory has been investigating the B-modulator problem for some time. Continuous-operation tests using the B-modulator were first made with new magnetrons to obtain the life expectancy, but no failures whatsoever occurred, and these tests were discontinued after it became apparent that lives of several hundred hours, at least, were to be expected. Attention was then concentrated on producing internal arcs in the magnetrons. It was found that, with the rotary spark-gap in proper condition and with the use of approximately-normal pulse voltage, arcs can be produced only by applying pulse voltage before sufficient cathode heating time has elapsed. The heating time required to prevent arcing decreases rapidly from the value of a few minutes characteristic of a new tube to about twenty seconds with a well-aged tube. Of most importance is the fact that the tubes are able to stand many repeated instances of heavy arcing. Only a small percentage have failed.

The most significant observation has been that at *low* pulse voltages (below about the 20-ma plate-current level) the magnetron, due apparently to oscillation in an improper mode, couples very little power into the waveguide, and there is increased r-f leakage power on the cathode lead. Corona and sparking in the jelly filling of the protective glass tube around this lead results. (There will also be occasional r-f sparks from the anode block to the magnet, due again to leakage of r-f power.) This r-f corona and sparking in the cathode lead tube looks very much like the flash due to reflection of the light from a true internal arc within the magnetron, but is easily distinguished from the latter in a number of ways: 1—The flash from the r-f effect will be seen on the cathode lead only, and not on the other filament lead, whereas a true internal arc is seen by reflection in *both* filament lead tubes. 2—The r-f effect will cause no change in the appearance of the modulator pulse seen on the monitor scope, but a true arc short-circuits this pulse, so that it "misses" when an arc occurs. This miss can be seen easily when the arcing occurs occasionally. If the arcing occurs very frequently, but not on every pulse, the normal pulse shape will be seen but with the sweep base line extending across the bottom of the pulse. 3—A true arc will cause the standing wave indicator needle to jump, but the r-f sparking and corona will not.

The r-f corona and sparking will cease as the pulse voltage is raised. It is thought that much of the trouble reported from the field has been due to observation of this r-f effect. A new magnetron would normally be started with low pulse voltage (particularly now that the belief is prevalent that the tubes arc frequently with the B-modulator). This would produce the r-f corona which might be mistaken for internal arcing. The voltage would then certainly not be raised. When the "arcing" did not clear up, the tube might be discarded as having failed.

The situation is slightly complicated by the fact that at very-low pulse voltages, in addition to the r-f sparking, there will occasionally also be some actual internal arcing in the magnetron. This is due to the fact that the voltage is so low that the rotary spark-gap may misfire occasionally,' causing the following pulse to be at too high a voltage. If the magnetron is not actually defective, this arcing also will cease when the pulse voltage is raised—it does not indicate a poor magnetron.

The Naval Research Laboratory has been attempting to obtain field-used magnetrons which are reported "inoperable with the B-modulator but satisfactory with the A-modulator." Of twelve such tubes received so far, nine operate normally with the B-modulator. This lot of twelve tubes included five Type 720CY tubes, of which two were failures, and three non-factory-aged Type 4J4/720CY tubes, of which one was no good, accounting for all the bad tubes. The Naval Research Laboratory is still interested in testing such field-used tubes which are reported inoperable with the B-modulator but satisfactory with the A-modulator. A very brief history of such tubes, accompanying them, would be appreciaed. Please address tubes to: Naval Research Laboratory, Attention Code 3930, Anacostia 20, D. C.

Such are the results obtained from the N.R.L. tests made to date.

The following procedure is recommended for use with the B-modulator: Whenever it is possible, the magnetron should be allowed to warm up for two or three minutes with just the filament voltage alone applied (adjust to 12.5 v) before the high voltage is applied. This should be done, even though, as noted above, it is not strictly necessary with tubes which have been broken in. A *new* tube should be given a warm-up period of about ten minutes before high voltage is applied. In the case of magnetrons which have been used previously, the pulse voltage usually can be applied at the full operating value, without the necessity for starting at low voltages. If any internal arcing is observed, the pulse voltage should be reduced somewhat, for a time. New tubes should be started at lower voltages, preferably at about the 20-ma plate-current level. If lower voltages are used, and r-f corona and sparking (and perhaps some internal arcing) are observed, the pulse voltage should be *raised*. Increasing the voltage to the point where the plate current is about 18 to 20 ma will generally stop the corona and any internal arcing. Above this level, if any internal arcing (which can be distinguished from the r-f corona as explained previously) persists, the pulse voltage should not be raised higher until the arcing stops. It may be well to turn off the high voltage for a few minutes, and it should then be reapplied intermittently at the same level for short periods until the arcing ceases. Any new magnetron will have a tendency to arc occasionally, and intermittent operation at intermediate pulse voltages is best if the arcing is frequent.

The rotary spark-gap should be kept in good condition. The points should be clean and the gaps correctly adjusted. The V–2301 and V–2302 tubes and R–2308 and R–2309 resistors of Field Change No. 26 should be checked if persistent magnetron arcing develops. A failure of one of these components is very likely to cause arcing. The small-diameter fixed pins supplied by this field change also help to prevent arcing (provided the gaps are correctly adjusted), but most of the improvement is provided by the tube circuits.

The air-cooling channel for the magnetron should be kept cleaned. The dust filter at the air intake may become clogged, and when the circulation is reduced the magnetron will run excessively hot.

Factory-aged 4J47/720CY tubes can be operated up to 30 ma plate current, and the older type 720CY and non-factory-aged 4J47/720CY tubes up to about 28 ma, without arcing. In addition, after the non-factory-aged 4J47/720CY magnetrons have been operated for a while, their plate current can be raised to 30 ma.

SCREW THREAD STANDARDS

Thirty years of careful, co-operative study and discussion recently culminated in success when an agreement on a common, unified set of standard specifications for screw threads was formally signed by representatives of three great nations. This event was held at the U. S. National Bureau of Standards on November 18, 1948, and its significance is indicated by the fact that it was attended by such notables as Sir Oliver Franks, the British Ambassador; Mr. Hume Wrong, the Canadian Ambassador; Charles Sawyer, Secretary of Commerce; James Forrestal, U. S. Secretary of Defense; Kenneth C. Royall, Secretary of the Army; W. Stuart Symington, Secretary of the Air Force, and John Lawrence Sullivan, Secretary of the Navy.

Although the fact has never been widely publicized, for a long time the existence of different standards for the dimensions of screw threads (as in nuts, bolts, etc.) has constituted an impediment to electronic equipment exchange between these countries—if not an outright barrier.

In order, for example, to get vitally-needed threaded replacement parts for an electronic equipment manufactured in America, England might be forced to order them from America, perhaps losing all benefit from the equipment until the parts arrived. Such experiences tend to discourage equipment exchanges between the countries.

When one considers the military repercussions of the lack of a unified set of standards, the need for such a set becomes even more urgent. During the first World War, the difficulty in interchanging parts between American and British electronic equipment was first felt. During the second World War, the emphasis placed on electronics by all the armed forces made the problem even more serious. American industry supplied many thousands of pieces of equipment to the British, threading all screw parts to British specifications. This led to considerable delay, and wasn't "good business." Furthermore, American military forces, based in England and supplied with equipment using American style screw threads, experienced trouble in making replacements.

The newly-achieved agreement will end such difficulties. The British have been using a screw thread with a thread angle of 55° and with rounded thread crests and roots (See figure 1). The Americans have employed a screw thread with a thread angle of 60°, and with flat crests and roots. The new standard thread has a thread angle of 60°, rounded roots, and either rounded or flat crests (optional).

Not only has the standard thread form been chosen,

but the number of threads per inch has also been standardized. Furthermore, standard tolerances have been formulated and are included in the agreement. This accord on tolerances is as important in facilitating mechanical fabrication as the agreement on a standard thread form itself.

Standardization of screw-thread forms serves as a precedent for standardization in other fields of engineering practice and we may expect to see similar formal agreements reached. As the Bureau of Standards technical report on the screw-thread standardization (No. 1315, P. 2) says, "Economic production in the automotive, aircraft, agricultural implement, and other industries using assembly-line methods requires not only a steady supply of components but also that the components, including a large number of fasteners, be interchangeable so that they can be fitted together without selection, subsequent marking, or hand-fitting of any kind."

At present it appears that the major effect on the field of Navy electronics of this far-reaching agreement will be to encourage exchange of equipment between the countries, and to facilitate the manufacture of apparatus as described above.

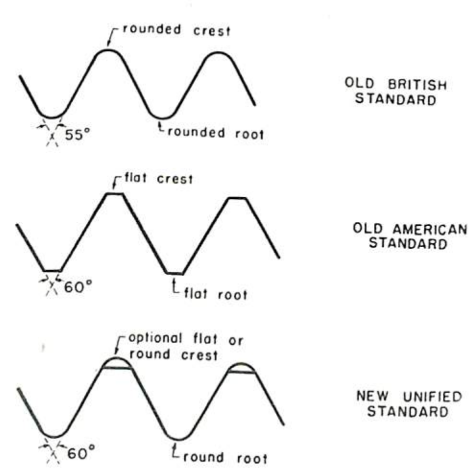


FIGURE 1.

TYPE-49545

SPEAKER-AMPLIFIER LOUDSPEAKER CONES

Several reports have been received by the Bureau of Ships stating that the loudspeaker cones for the Type –49545 Speaker-Amplifier Units contained in spare parts boxes have been found damaged and unfit for use. The dehydrating bag has been found resting on the cone, and because of the vibration incident to the handling of the spare parts boxes and the cone container itself, the bag has caused the cone to wrinkle and become unuseable.

All vessels and activities using the Type –49545 speaker-amplifier are requested to check the loudspeaker cones in their spare parts boxes for possible damage. Two cones are included in each set of equipment spares and tender spares, and three in each set of stock spares.

Cones that are found to be undamaged should be retained in the original container but the container should be stored in an inverted position, i.e. with the dehydrating bag on the bottom of the container. The gasket will retain the cone at the top, away from the bag, resulting in less chance of damage. The outside of each container should be marked accordingly. Damaged cones should be turned over to the nearest Electronics Officer for disposal, and a failure report card NavShips-383 submitted to the Bureau of Ships.

LM FREQUENCY METER CALIBRATION HANDBOOK

Constant and frequent use of calibration handbooks for the LM series meters soon irreparably damages them. Replacement of them entails expensive recalibration of the instruments in a special laboratory, which keeps them out of service for months.

This time and expense is materially reduced and the life of the handbooks prolonged by encasing the calibration books in protective aluminum covers. These can be fabricated readily and economically from aluminum sheet stock of 0.032-inch thickness, preferably anodized ST, using the LM book cover as a template. The cardboard covers should not be thrown away, but saved, since essential information is printed on them.

When enclosed in the two aluminum covers, not exceeding the specified thickness, a calibration book may be readily stowed in the compartment provided under the instrument.

MODIFICATION

OF KEYER KY–43/URT

The Model KY–43/URT Frequency-Shift-Keyer is used for frequency-shift-keying of the Model TAB–5 Radio Transmitting Equipment, and works well in most installations. In some installations, however, the desired 170-cps shift at 100 kc is not obtained. This is due to insufficient grid excitation of the 6SA7 tube V–801. Individual differences in keyers and transmitter oscillators is enough to cause this to happen in those equipments affected.

This difficulty was corrected at the Naval Communication Station, Annapolis, Md., by changing resistor R–811 from 1000 to 2400 ohms. It is to be noted, however, that this alteration also changes the frequency-dial settings of the keyer. It is necessary to recalibrate these dials for all frequencies.

Personnel at the Annapolis station also report that the fine-control potentiometer "R" open-circuited when set in the extreme clockwise position. This was remedied by connecting a wire between the terminals of the moving-contact arm and the low-potential end of the potentiometer.

All KY–43/URT Frequency-Shift-Keyers should be checked for these troubles, and corrected if necessary.

MODELS QHB/–1 MCC WIRING

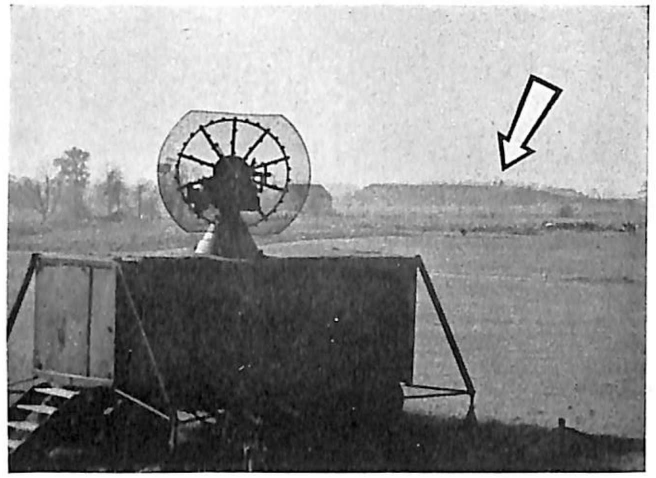
Due to an original wiring error in the Models QHB/-1 Scanning Sonar Equipments, the MCC leads from the Type CAN-241242 Scanning Switch Assembly to the Type CAN-51114 Transducer were reversed. Accordingly, all vessels and activities are requested to examine terminals No. 49 and 50 of terminal strip 4B of the scanning switch assembly.

Terminal No. 49 of the strip should have the black lead from transducer terminal No. 50 connected to it; terminal No. 50 of the strip should have the purple lead from transducer terminal No. 49 connected to it. If these leads are reversed, they should be connected correctly. In this connection, reference should be made to figure 3-14 on page 3-23-24 of NavShips 900,976(A), the instruction book for Models QHB/-1 Scanning Sonar Equipment, or to figure 3-4 on page 3-29-30 of NavShips 900,976, the preliminary instruction book for Models QHB/-1 Scanning Sonar Equipment.

REMOTING THE AN/TPS-1B

Marine Ground Control Intercept Squadron 17, located at U. S. Naval Air Station, Willow Grove, Pa., is equipped with a Search Radar Set AN/TPS-1B, which because of terrain considerations is located 3300 feet from the Ground Control Intercept Radar SP-IM, and the Combat Information Center at the station. The AN/TPS-1B was designed and equipped for remoting radar information for a maximum distance of only 750 feet. However, this AN/TPS-1B has been remoted at this station over the distance of 3300 feet by direct underground cabling without appreciable loss in radar presentation at the repeater scopes.

Three separate cables were used for remoting the information. Each cable had to be spliced several times, splicing connectors being used where appropriate. Two of the cables used were coaxial, Navy Type RG-11/U, and the third was a multiple conductor cable, Type MHFA-10. No line amplifiers were used.



AN/TPS-1B UNIT (indicated by arrow) located 3300 feet from the SP-1M antenna van shown in the foreground.

One coaxial cable was used to carry the radar video information; the other coaxial cable was used to carry the radar trigger pulses. The ten-conductor multiple cable was used to carry the syncrho information between the AN/TPS-1B radar and the repeators at the SP-1M radar. One each single conductor in the cable was used to carry the three stator voltages. Since the rotor of the AN/TPS-1B synchro generator must be excited from a 60-cycle source, and only 400-cycle power is available at the AN/TPS-1B, the excitation voltage was furnished by the SP-1M radar and carried the 3300 feet to the search radar. To minimize line drops 3 conductors in the multiple cable were connected in parallel for each line of the 110-volt, 60-cycle excitation, requiring six conductors in all.

Although remoting was accomplished over a distance of 3300 feet without appreciable loss, serious thought is being given at this station to installing one line amplifier at the midway position in the event that the video, trigger or positioning information weaken with aging of the cable and/or connectors.

MODEL SR-6 ANTENNA MAINTENANCE

During tests of a Model SR-6 Radar Equipment installation, the antenna stopped rotating. Upon investigation it was found that the Garlock Packing Ring, Symbol Designation U-1307, located in the groove of Top Cover Plate O-1342, had worked its way out of the groove. Inspection revealed that the packing ring was chewed up due to improper installation. After the antenna was removed from the ship and a new packing ring was installed, no further antenna trouble of this nature was experienced.

There are two possible ways in which the Garlock Packing Ring can be inserted into the groove. One side of the packing has a slightly larger dimension than the opposite side. The proper way to install the packing is to insert the side with the larger dimension first, as shown in figure 1. It will have to be forced into the groove before it is seated. Also make certain that the two ends of the packing ring are cut clean at a 45° angle. Any frayed edges should be trimmed.

Installation of the Garlock packing cannot be checked without removing the antenna and pedestal. If the antenna stops rotating or becomes unusually sluggish, however, the Garlock Packing Ring should be inspected.

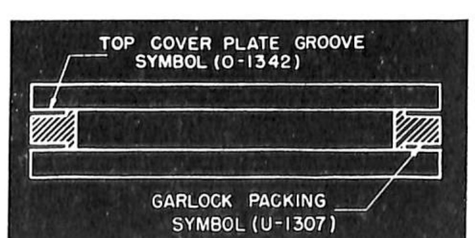


FIGURE 1—*Cross-sectional view showing Garlock Packing Ring properly installed with wide dimension against bottom of groove in top cover plate.*

RACK MOUNTING FOR TYPES AM-215/U AND AM-215A/U AUDIO-FREQUENCY AMPLIFIER

The Long Beach Naval Shipyard has designed a rack mounting for the Type AM-215/U a-f amplifier. Figures 1 and 2 illustrate the Type AM-215/U amplifier in the rack mounting. Construction data and fabrication information are included in figure 3.

This type of mounting with slight modification can also be used for the Type AM-215A/U amplifier. The front panel of the AM-215A/U amplifier will have to extend about 3/4 inch in front of the mounting rack in order to allow the front panel to be lowered and the hinge pin to be removed.

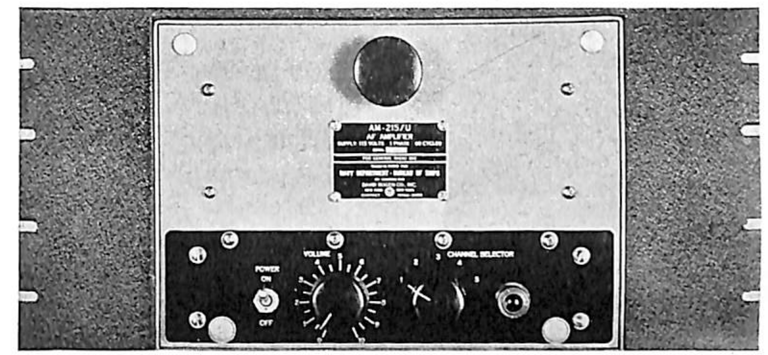


FIGURE 1.

Front view of AM-215/U amplifier in rack mounting.

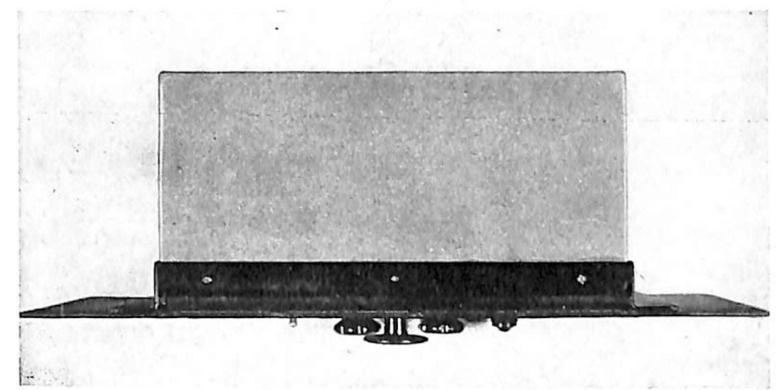


FIGURE 2.

Top view of AM-215/U amplifier in rack mounting.

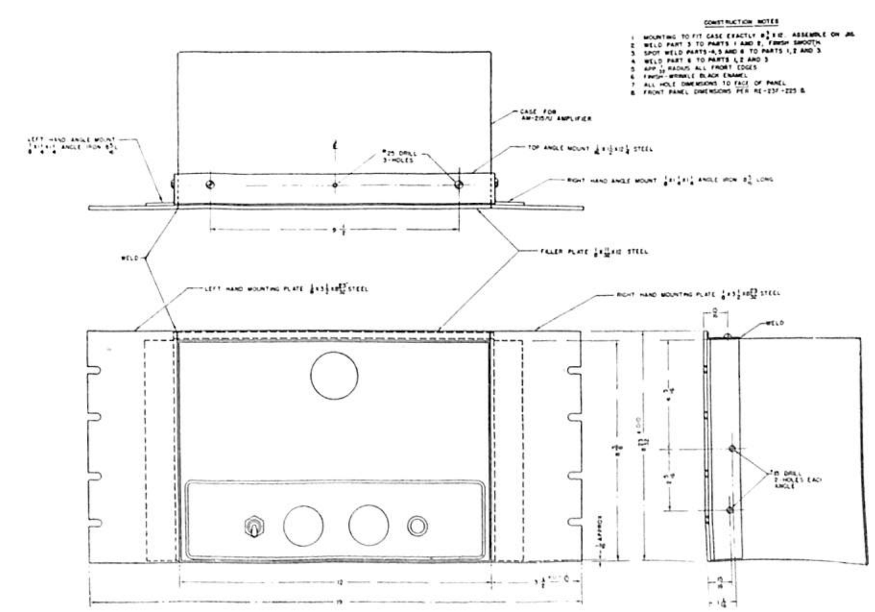


FIGURE 3—*Rack mounting designed by the Long Beach Naval Shipyard for Audio-Frequency Amplifier AM-215/U. This mounting is also readily adaptable for use with Audio-Frequency Amplifier AM-215A/U.*

THE SINGING PALM . . . YET . . .

Sirs:

The December 1948 ELECTRON described a palm tree at Guam which was performing as a fairly good receiver in emitting music from a local broadcast station.

The writer has known of a similar instance where an ordinary house stove acted as a receiver. This was believed due to a poor contact of dissimilar metals in the stove itself acting as an imperfect detector. The accomplishment of detection in the "singing palm" was probably due to the burning of the wood, providing two chemically dissimilar materials in contact such that imperfect but actual detection was taking place.

The writer will read the next issue of ELECTRON with interest to ascertain the correct solution if the above is not!

RICHARD L. WARREN

U.S.S. Eldorado (AGC-11),
Fleet Post Office,
San Francisco, California.

Sirs:

In reference to the "Singing Palm" article in the December 1948 ELECTRON, we have a theory that we believe might explain the above phenomenon.

As the wire burned into the palm, a carbon spot was formed which, we believe, would at the point of contact with the conductor, act as a non-linear impedance to provide detection of the signal, much in the same manner as different layers of rust or a cold solder joint. Assuming that the carbon was not uniformly packed, there should be enough loosely packed carbon granules to vibrate with the changes of current through it, thereby acting as a reproducer.

JACK D. BOWERS, ET1
WILLIAM H. DEWITT, ET3

U.S.S. Passumpsic (AO-107),
Fleet Post Office,
San Francisco, California.

Sirs:

Re: "The Singing Palm." It's all very simple. Demodulation took place when the carbon (burned palm-tree variety) was in contact with the antenna wire itself, producing a "coherer" effect.

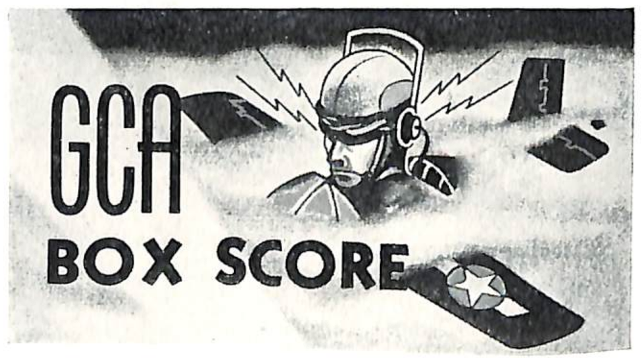
The signal modulation coming through the antenna was "picked off" the r-f carrier by this carbon-wire juxtaposition, and the antenna wire itself served as the sounding board for the resulting vibrations.

The same effect may be demonstrated by connecting a razor blade (imbedded in wood) to each end of a coil of wire, and laying a pencil lead across the two blade-edges. If there is a strong enough signal present, the rig will serve as a fairly efficient speaker.

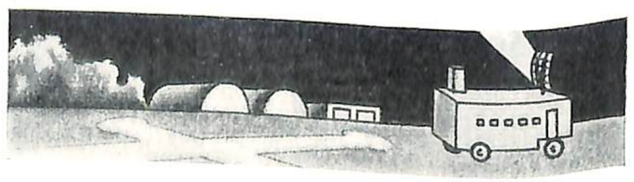
While on the subject of weird rigs, ever try hooking a PA mike amplifier into the primary of a transformer, and then wiring up the transformer secondary into the input of a ford coil (which has been souped up all possible)? Makes an A-1 plus transmitter—although just a bit broad in band!

BILL R. HARMON, YNS2, USNR

Office of Assist. Elect. Officer
for Naval Reserve, Room 268,
Administration Building,
Long Beach Naval Shipyard,
Long Beach, California.



Type of Approach	Last Month	To Date
Practice Landings	8,056	183,765
Landings Under Instrument Conditions	452	8,100



MOISTURE CONDENSATION IN CEILOMETER (AN/GMQ-2)

A method for preventing moisture condensation in AN/GMQ-2 ceilometers is given in a recent beneficial suggestion. It was submitted by Floyd L. Rinehart, Radio Mechanic (civilian), NATB, Pensacola, Fla.

During periods of high humidity, considerable moisture was found to condense within the air lines and the compressor cylinders. When the equipment was operated, the condensed moisture was forced through the nozzles, vaporized, and re-collected on the quartz mercury lamps. There was enough moisture on the lamp to set up a low resistance across the lamp transformer. Excessive current flowed, and the lamp fuse blew so that the ceilometer was rendered inoperative. As a result, the average life of the mercury lamps was shortened materially. This was found to occur repeatedly unless the apparatus was thoroughly dry.

The beneficial suggestion contains a remedy which was found to work satisfactorily at the station. A type HR101 heater unit, furnished as a spare for that used in the detector, was employed to dry out the equipment and prevent the unwanted moisture condensation. The heater was mounted on two 1¼-inch stand-off insulators, and was located on the sidewall near the top of the control-assembly box. (This location provided a slight forced draft in the region of the lower cabinet.) The 115-volt outlet in the control-assembly box was used to provide power for the heater. It was found that this heater was necessary only when excessive humidity was encountered. It materially improved the average life span of the mercury lamps, and prevented interruption of ceilometer service from the equipment protected in this manner.

The Bureau of Ships approves the suggested method, but its use is optional. It is to be restricted to those activities experiencing humidity conditions where this method would be beneficial.

R-F WATTMETER ME-11/U

One or more Model ME-11/U R-F Wattmeters are on the allowance lists of all ships which have a Model TDZ Radio Transmitting Equipment on their allowance list, and all tenders and repair ships. This wattmeter is now being distributed to various supply points and Naval shipyards, and should be requisitioned to fill authorized allowances as soon as possible. The meter is especially useful in tuning the TDZ transmitter.

It is rated at up to 60 watts at from 30 to 500 megacycles, and works into a coaxial 51.5-ohm nominal load. The application of this wattmeter is explained in detail in the instruction book (NavShips 91118), which should be referred to very carefully in order that the wattmeter can be utilized to best advantage.

NEW GCA UNITS

A Navy contract for twelve ground control approach units has been awarded to the Bendix Radio Division of the Bendix Aviation Corporation.

The twelve new GCA units will be used as normal replacement for Navy units which have been in use for a number of years in the United States and abroad. The units, to be built at the Bendix plant in Baltimore, Maryland, will cost $2,800,000.

First of the twelve new units to be built by Bendix is scheduled for delivery in August this year with delivery of two per month thereafter.

REDUCED FILAMENT VOLTAGE ON TYPE 889RA ELECTRON TUBES

The average hour life of the Type 889RA electron tube has been increased by over 95% at the Naval Communication Station, Annapolis, by decreasing the applied filament voltage from 11 volts to 10 volts.

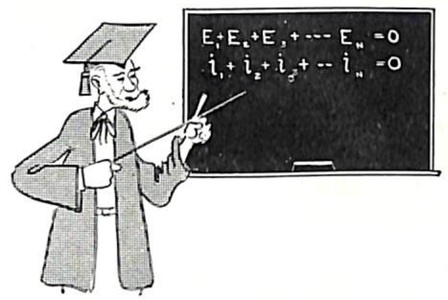
No reduction in power output or other abnormalities of operation result from this reduction in filament voltage.

In view of the economy resulting from increased tube life, it is recommended that this type tube be operated with a filament voltage of 10 volts, wherever suitable voltage regulation is maintained.

CORRECT ALIGNMENT OF MODEL QHB SERIES TRANSDUCERS

It has been reported to the Bureau of Ships that after beam patterns have been taken, some Model QHB series transducers have been found locked off the correct point of alignment by as much as 14 degrees. Accordingly, it is recommended that these transducers should not be locked permanently into position until after a beam pattern has been taken.

Kirchhoff's Laws



BASIC PHYSICS

PART 17

Ohm's law expresses the relationships between currents and voltages in series and parallel circuits that exist regardless of the number or the values of the resistances. However, when applying Ohm's law to a particular part of the circuit, only the voltage, current and resistance values actually associated with that particular part of the circuit should be used.

Series and parallel circuits of a simple nature are easily solved by the proper application of Ohm's law, but in complex networks of resistances and several sources of emf, the solution is often difficult in some cases and impossible in others. This limitation of the use of Ohm's law has been overcome by Kirchhoff's laws.

Kirchhoff's Laws

In 1847, G. R. Kirchhoff extended Ohm's law by two important statements which have become known as Kirchhoff's laws. An understanding of Kirchhoff's laws, plus the ability to apply them in analyzing circuit conditions, furnishes the student with a method that enables him to solve circuit problems that are often impossible with just a knowledge of Ohm's law.

Kirchhoff's laws may be stated as follows:

1—The algebraic sum of the currents at any junction of conductors is zero. That is, at any point in a circuit, there is as much current flowing away from the point as there is flowing toward it.

2—The algebraic sum of the electromotive forces and the voltage drops around any closed circuit is zero. That is, in any closed circuit, the applied emf is equal to the IR drops around the circuit.

These laws are straightforward, for the first is self-evident from the study of parallel circuits and the second thoroughly proven in connection with series circuits. When properly applied, they permit setting up equations for any circuit and solving for any required current, voltage or circuit component.

The two laws of Kirchhoff state in a general way the fundamental relationships that must exist between currents and voltages in any electrical circuit. The first law is relative to currents and means that the sum of all the currents coming toward a junction of several conducting branches in a closed electric circuit is equal to the sum of all the currents flowing away from that junction. It means that electrons cannot accumulate at any junction; as many electrons must leave the junction as enter it. This is a reasonable assumption, since a junction has no particular storage capacity for electrons, which in turn repel one another very strongly.

The second law is relative to voltages and means that around any continuous path in a closed electric circuit the algebraic sum of the voltage drops around the circuit equals the sum of the voltages applied to the circuit. This may be likened to Newton's third law in mechanics; namely, action and reaction are equal and opposite. It requires an emf to make the electrons move, therefore the magnitude of the current flow reaches an equilibrium value where the voltage drops throughout the circuit are exactly equal to the impressed emf.

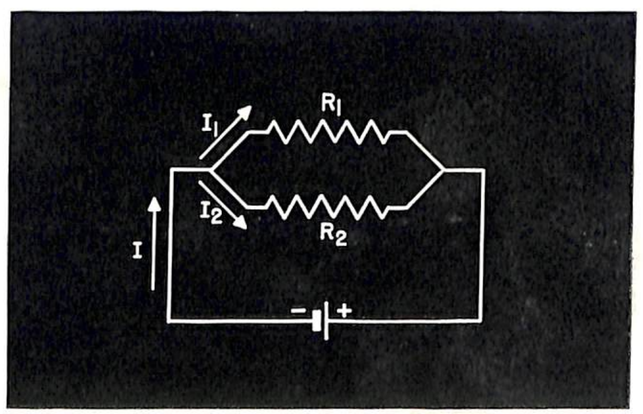


FIGURE 1—*Demonstrating the validity of Kirchhoff's first law.*

To test the validity of Kirchhoff's first law, consider the parallel circuit shown in figure 1.

The total circuit current I flows from the negative terminal of the battery toward the junction where the current divides, part of it, I_1, flowing through R_1 and the remainder, I_2, flowing through R_2. The actual values of I_1 and I_2 will be determined by the applied emf and the values of R_1 and R_2 but their sum will always equal I. The power supplied by a source of emf is EI and the power dissipated in a load is I^2R, therefore in accordance with the law of the conservation of energy, this may be stated:

$$EI = I^2R$$

and simplified to: $E = IR$

It is evident that the total current supplied by the source of emf will be determined by the ratio E/R, where R is the resistance represented by the parallel branch R_1 and R_2, therefore:

$$I = I_1 + I_2$$

The validity of Kirchhoff's second law was adequately proven in the study of series circuits where it was shown that in any closed series circuit the applied emf is equal to the voltage drops around the circuit. For instance, neglecting the internal resistance of the battery and interconnecting wires of figure 2, the current as obtained by Ohm's law is:

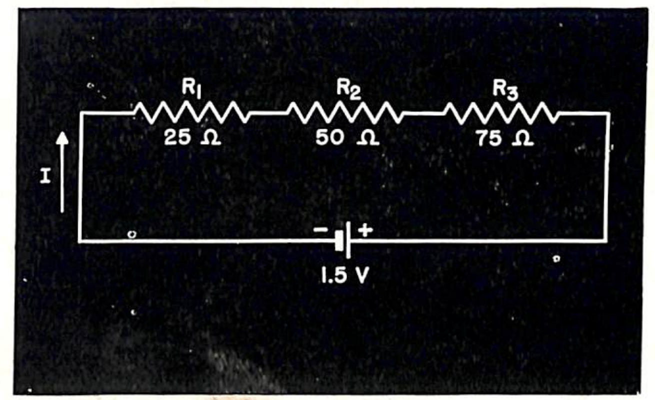


FIGURE 2—*Demonstrating the validity of Kirchhoff's second law.*

$$I = \frac{1.5}{150} = 0.01 \text{ amperes;}$$

and by Kirchhoff's second law:

$$E = IR_1 + IR_2 + IR_3$$

$$1.5 = 25I + 50I + 75I$$

$$I = \frac{1.5}{150} = 0.01 \text{ amperes.}$$

In considering the circuit from the viewpoint of voltage relationships around the circuit, we can proceed around the circuit from the negative terminal of the battery back to the positive terminal. When current passes through a resistance there is a voltage drop in the direction of current flow that represents a loss and therefore is subtractive. Also, in going around the circuit, sources of emf represent a gain in voltage if they tend to aid current flow and therefore are additive. Thus, a complete circuit of figure 2 may be written:

$$-25I - 50I - 75I + 1.5 = 0$$

substituting the value of I, we obtain:

$$-0.25 - 0.5 - 0.75 + 1.5 = 0$$

$$-1.5 + 1.5 = 0$$

The point at which to start around the circuit is purely a matter of choice, for the algebraic sum of all voltages around the circuit is equal to zero.

Circuits of a series, parallel or combined series-parallel nature across a single source of emf may be solved by the application of Ohm's or Kirchhoff's laws. Complex circuits containing bridge networks of resistances or those containing several sources of emf become increasingly difficult of solution by Ohm's law alone. These circuits are solved by simplification with Kirchhoff's laws, then obtaining the solution by Ohm's law.

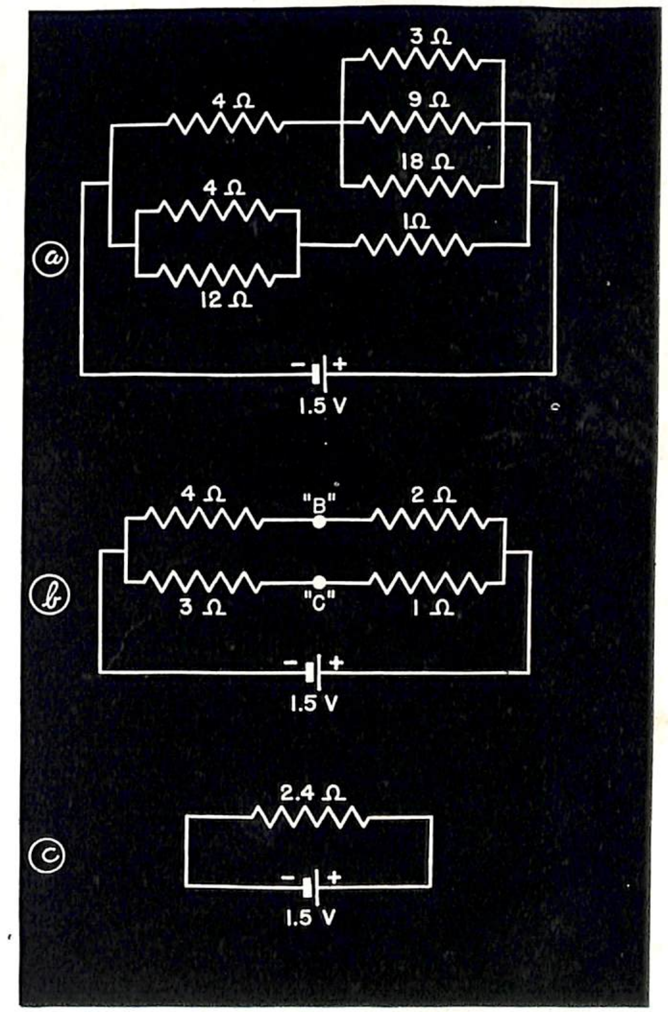


FIGURE 3—*Network simplification to a single equivalent resistance.*

Network Calculations Simplified

A circuit which includes a number of resistances arranged in series and parallel groupings forms a network. In order to find the current in each of the resistances of the circuit shown in figure 3, the circuit must be simplified step by step as shown in the successive diagrams. By repeated application of Ohm's law, it is then possible to compute the total current supplied by the battery, the current in each branch or each resistance, and therefore the potential drop across each resistance.

The simplification of strictly series-parallel networks is comparatively easy as shown in figure 3, and previously explained in Parts 9 and 10, Basic Physics; however, circuits of the Wheatstone bridge type are of a more complicated nature and cannot be simplified as easily.

Equivalent Star and Delta Circuits

A method of reducing complicated networks to simpler equivalent circuits will be derived here. First, the nomenclature of such type circuits. A *delta* circuit is shown in figure 4a, and consists of three resistance

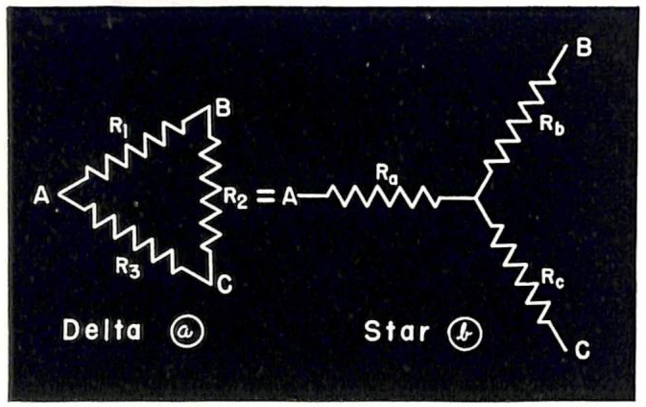


FIGURE 4—*Delta connection and equivalent star or Y.*

branches connected in the shape of a triangle. This may be recognized as part of a Wheatstone bridge circuit. An equivalent circuit, shown in figure 4b, is called the *star* or *Y*, where the resistances are connected from a center common junction to points A, B, and C.

If one of these circuits is to be made equivalent to the other, then the resistance between points A and B, B and C, and A and C must be the same in either circuit. Let us analyze the delta network. In figure 4a, the resistance between points A and B is the parallel resistance with R_1 with R_2 and R_3.

$$R_{AB} = \frac{R_1 \ (R_2 + R_3)}{R_1 + R_2 + R_3}$$

similarly:

$$R_{AC} = \frac{R_3 \ (R_1 + R_2)}{R_1 + R_2 + R_3} \quad \text{and} \quad R_{BC} = \frac{R_2 \ (R_1 + R_3)}{R_1 + R_2 + R_3}$$

Now, take the star or Y connection in figure 4b. The resistance between points A and B is the series resistance of R_a and R_b.

$$R_{AB} = R_a + R_b$$

similarly: $R_{AC} = R_a + R_c$ and $R_{BC} = R_b + R_c$

Up to this point we have merely expressed the resistance relationship between points A, B, and C for each of the networks. Since we are making an equivalent set of circuits, the equivalent resistances between points A and B, B and C, and C and A may be tabulated for the two circuits.

Resistance	*Delta*	*Star*
Between A and B	$\frac{R_1 \ (R_2 + R_3)}{R_1 + R_2 + R_3}$	$R_a + R_b$
Between B and C	$\frac{R_2 \ (R_1 + R_3)}{R_1 + R_2 + R_3}$	$R_b + R_c$
Between C and A	$\frac{R_3 \ (R_1 + R_2)}{R_1 + R_2 + R_3}$	$R_a + R_c$

These equations express the basic relationships between the delta and star method of electrical connections that will be encountered many times in the study of electricity and electronics. Calculations of complicated networks are often simplified by converting a delta connection to its equivalent star connection, or vice versa. To provide working formulas for such conversions, the basic equations are solved simultaneously, in terms of either the delta or the star.

Solving the simultaneous equations to obtain the three branches of an equivalent star network, expressed in terms of the delta resistances R_1, R_2 and R_3, we obtain:

$$R_a = \frac{R_1 \ R_3}{R_1 + R_2 + R_3}$$

$$R_b = \frac{R_1 \ R_2}{R_1 + R_2 + R_3}$$

$$R_c = \frac{R_2 \ R_3}{R_1 + R_2 + R_3}$$

Each equivalent branch of a star connection is equal to the product of the adjacent legs of the delta divided by the sum of the three legs of a delta.

The three equations for R_a, R_b and R_c are working formula for converting a delta connection to its equivalent star.

Transformation of Star to Delta

The basic equations may also be solved simultaneously in terms of the star resistances R_a, R_b and R_c, thus providing a means of converting from a star to its equivalent delta.

$$R_1 = \frac{R_aR_b + R_bR_c + R_cR_a}{R_c}$$

$$R_2 = \frac{R_aR_b + R_bR_c + R_cR_a}{R_a}$$

$$R_3 = \frac{R_aR_b + R_bR_c + R_cR_a}{R_b}$$

Using this set of formulas, a conversion can be made from a star connection to its equivalent delta connection having the resistances R_1, R_2 and R_3. Remember that the relationships of the branches of the delta and star networks as given in figure 4a and b must be maintained when using either set of conversion formulas.

Transformations from a delta circuit connection to its equivalent star connection, or vice versa, are often necessary in reducing a complicated network to simpler series-parallel branches. Once this is accomplished, Ohm's law may be used to calculate the current flow or the total resistance. For example modification of the series-parallel network in figure 3b, by the addition of a 5-ohm resistance between points B and C changes this simple network into a Wheatstone bridge circuit. Methods of solution learned in the study of series-parallel circuits are not applicable in this case, but a delta-star transformation would reduce this circuit to another series-parallel combination that may be solved by Ohm's law.

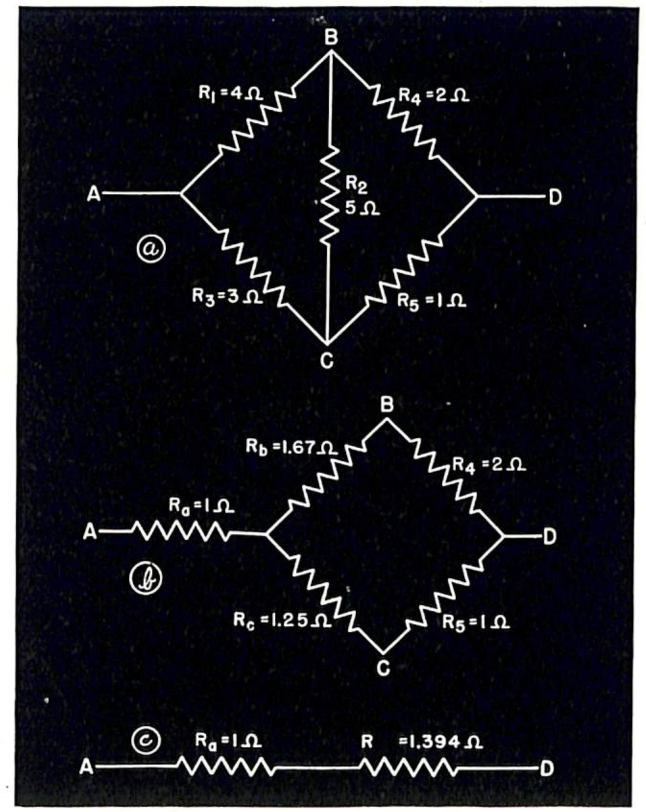


FIGURE 5—*Network simplification by use of delta-star conversion.*

The resistances R_1, R_2 and R_3 of the bridge circuit in figure 5a form a delta network that may be converted into its equivalent star, R_a, R_b and R_c as shown in figure 5b.

$$R_a = \frac{3 \times 4}{3 + 4 + 5} = 1 \text{ ohm}$$

$$R_b = \frac{4 \times 5}{3 + 4 + 5} = 1.67 \text{ ohms}$$

$$R_c = \frac{3 \times 5}{3 + 4 + 5} = 1.25 \text{ ohms}$$

The star connection, in conjunction with R_4 and R_5, forms a series-parallel network as shown in figure 5b. This may be converted to a series circuit AD as follows:

$$R_{AD} = R_a + \frac{(R_b + R_4) \ (R_c + R_5)}{(R_b + R_4) + (R_c + R_5)}$$

$$R_{AD} = 1 + \frac{(1.67 + 2) \ (1.25 + 1)}{(1.67 + 2) + (1.25 + 1)}$$

$$R_{AD} = 1 + 1.3941 = 2.3941 \text{ ohms}$$

This method simplifies the calculation of the total resistance between points A and D, but is of little value if the magnitudes of current flow in the individual branches of the network are to be determined. When the magnitude and direction of current flow in a particular part of a network are required, the application of Kirchhoff's two laws becomes mandatory.

Procedure for Applying Kirchhoff's Laws

In applying Kirchhoff's laws to electrical networks, a systematic procedure is invaluable in reducing errors and saving time. In common with all other problems, the solution of a circuit or network should not be started until the conditions are analyzed and it is clearly understood what is to be found. In order to facilitate solving networks by means of Kirchhoff's laws a large diagram of the network should be drawn, marking all known values and polarities of voltage sources.

Indicate the assumed direction of current flow in each branch of the network. Polarities of the voltage drop across each resistance should be marked, the end of a resistance at which the current enters being negative and the end of the resistance where the current leaves being positive. The number of unknown currents may be reduced by assigning a direction to all but one of the unknown currents at a junction, and expressing the remaining current in terms of the other currents by applying Kirchhoff's first law to the junction.

Using Kirchhoff's second law, as many equations as there are unknowns to be determined should be set up. Each circuit path followed should cover some part of the circuit not used for other paths; then each equation will contain some relationship that has not been expressed in another equation. The equations thus set up are simultaneous and therefore can be solved as such to obtain the values of the unknown quantities.

All solutions should be checked by substituting the values of calculated currents in a circuit path that had not been previously used in setting up the simultaneous equations.

The bridge circuit in figure 6 is an excellent example that may be used to demonstrate the application of Kirchhoff's laws to determine current values that would be extremely difficult to determine by calculations using Ohm's law alone.

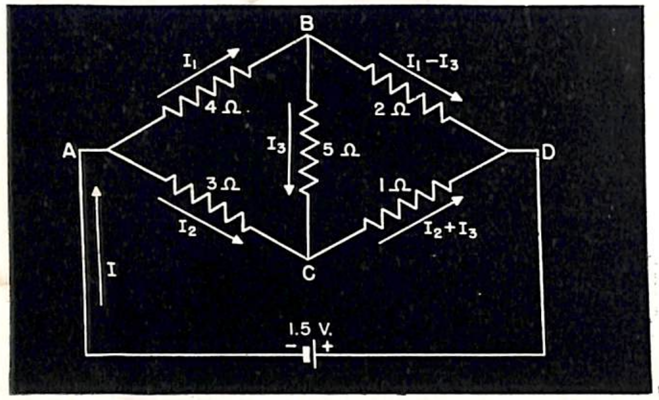


FIGURE 6—*Application of Kirchhoff's laws to the bridge circuit.*

Application of Kirchhoff's Laws to a Bridge Circuit

The values of the resistances in figures 5 and 6 were purposely made identical to permit a comparison of results obtained by both methods of solution.

The directions of current flow in each branch of the circuit in figure 6 are assumed and each arrow labeled. To keep the unknown currents to a minimum, Kirchhoff's first law is applied to each junction, so that at junction A, the current I flowing toward the junction divides into I_1 flowing to junction B, and I_2 flowing toward junction C. The current in branch BC is labeled I_3 and the current in branch BD is expressed in terms of I_1 and I_3, so that the current in branch BD is $I_1 - I_3$. As a means of check at this point, Kirchhoff's first law is applied to junction D. $(I_1 - I_3) + (I_2 + I_3) = I_1 + I_2$, which equals the current I leaving the other terminal of the battery.

Let it be desired that the magnitude and direction of the current through the 5-ohm branch BC be found. This would simulate the condition existing in an unbalanced Wheatstone bridge.

Kirchhoff's second law is applied to the network and sufficient equations are set up to include all the unknown currents. When proceeding in the direction of assumed current flow, each resistance causes a potential drop and is subtractive; each source of emf is additive if it tends to aid current flow, but subtractive if it tends to oppose the current flow.

Branch ABDEA $\quad -4I_1 - 2(I_1 - I_3) + 1.5 = 0$

simplified $\quad -6I_1 + 2I_3 + 1.5 = 0$

Branch ABCDEA $\quad -4I_1 - 5I_3 - 1(I_2 + I_3) + 1.5 = 0$

simplified $\quad -4I_1 - I_2 - 6I_3 + 1.5 = 0$

Branch ABCA $\quad -4I_1 - 5I_3 + 3I_2 = 0$

Note that in branch ABCA the voltage drop across the 3-ohm resistance is additive when going from C to A in opposition to the assumed direction of current flow. When the equations are solved for the values I_1, I_2 and I_3,

$$I_1 = 0.2558 \text{ amperes}$$
$$I_2 = 0.3712 \quad "$$
$$I_3 = 0.0176 \quad "$$

The current I_3 through the 5-ohm resistance was found to be 17.6 milliamperes, and the direction as assumed was correct because the answer had a positive value. When the answer for an unknown current results in a negative value, it merely means that the assumed direction was incorrect, but the magnitude is correct regardless of the sign.

By Kirchhoff's first law, the total current supplied by the battery was found to be equal to $I_1 + I_2$.

$$I = I_1 + I_2 = 0.2558 + 0.3712 = 0.627 \text{ amperes.}$$

The total resistance represented by the network is equal to the applied emf divided by the total current.

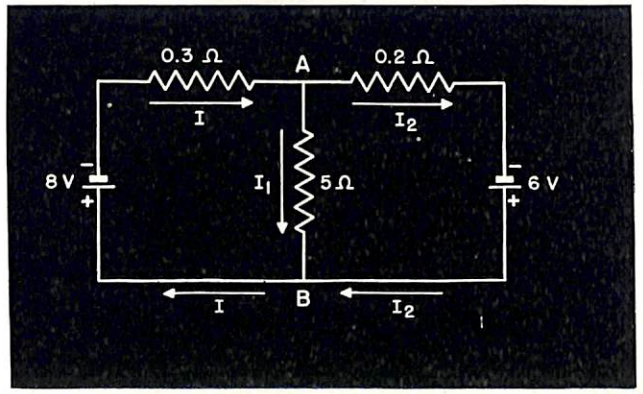


FIGURE 7—*Circuits containing two sources of EMF.*

$$R = \frac{1.5}{0.627} = 2.392 \text{ ohms}$$

This may be checked with the total resistance of the same circuit as obtained by delta-star conversion, as described in connection with figure 5.

Circuits Containing Two Sources of EMF

The magnitude and direction of current flow in a circuit containing two sources of emf such as that of figure 7 may be solved by the proper application of Kirchhoff's two laws. The currents are assumed to flow as indicated by the arrows, each unknown current being given a designation, I, I_1 and I_2. Remember that any direction may be assumed when the problem is originally set up, since an answer with a negative sign will indicate the assumed direction is in error.

Applying Kirchhoff's first law to junction A establishes the equality of current I flowing toward the junction and the two currents I_1 and I_2 flowing from that junction. Kirchhoff's second law is used to set up simultaneous equations containing all the unknown values of current. Branch A to B, through the 8-volt source to A:

$$-0.3I - 5I_1 + 8 = 0$$

since $I = I_1 + I_2$, this simplifies to:

$$-5.3I_1 - 0.3I_2 + 8 = 0$$

Branch A to 6-volt source to B to A:

$$-0.2I_2 - 6 + 5I_1 = 0$$

When the equations for the two branches are solved simultaneously,

$$I_1 = 1.3281 \text{ amperes}$$
$$I_2 = 3.2025 \quad "$$

therefore: $\quad I = 4.5306 \quad "$

All answers were obtained with positive values. Therefore the assumed directions were correct. As a means of check, these values of current should be substituted when applying Kirchhoff's second law around the entire circuit, thus

$$8 - 0.3I - 0.2I_2 - 6 = 0$$
$$8 - 0.3\,(4.5306) - 0.2\,(3.2025) - 6 = 0$$
$$8 - 7.99968 = 0$$

Circuits Containing Three Sources of EMF

Figure 8 shows a network that contains three sources of emf. Kirchhoff's laws may be utilized in calculating the magnitudes of the various currents and determining the actual directions of current flow. The direction of current flow in each branch is first assumed, and marked by arrows each given a different designation. By Kirchhoff's first law, $I = I_1 + I_2$ at junction A or B.

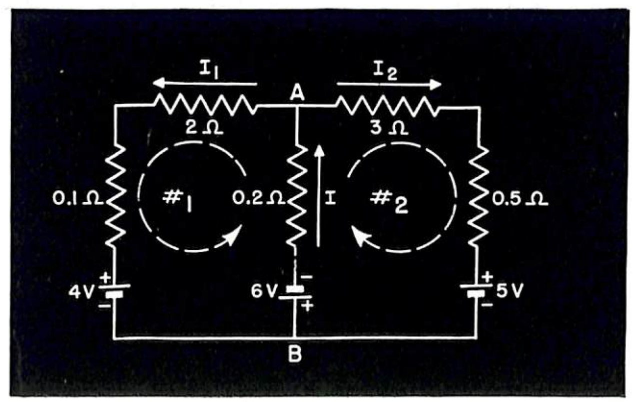


FIGURE 8—*Circuit containing three sources of EMF.*

Using Kirchhoff's second law, simultaneous equations are set up for circuits 1 and 2.

Circuit 1: $\quad -2.1I_1 + 4 + 6 - 0.2\,(I_1 + I_2) = 0$

Circuit 2: $\quad -3.5I_2 + 5 + 6 - 0.2\,(I_1 + I_2) = 0$

The equations are simplified and solved simultaneously.

$I_1 = 4.1086$ amperes

$I_2 = 2.7509 \quad "$ $\qquad$ therefore, $I = 6.8595$ amperes.

The solutions obtained may be checked by substituting them in place of the currents flowing in the entire outer circuit, i.e., from A through the 3-ohm resistance, 5-volt source, junction B, 4-volt source, then through the 2-ohm resistance back to junction A.

$$-3.5\,(2.7509) + 5 - 4 + 2.1\,(4.1086) = 0$$
$$-9.628 + 5 - 4 + 8.628 = 0$$
$$-13.628 + 13.628 = 0$$

The application of Kirchhoff's laws to more complicated networks requires that extreme care be used in designating the various currents that flow. Each branch must be followed carefully to insure against duplicating other branch currents. Those branches in which a common current flows must have designations that accurately show the relationships of those currents. Frequent application of Kirchhoff's first law to junctions will reduce the number of unknown values that must be determined, since one of the branch currents may then be expressed in terms of the other two.

All solutions should be checked by substitution in a circuit path not previously used in setting up the original equations. This provides a double check on the current values obtained. Bear in mind, however, it is seldom that the algebraic sum of the voltage drops around the circuit path used for check purposes will exactly equal zero. This is due to the current practice of expressing numerical accuracy to only three significant figures. The examples used in this text were carried out to four decimal places to permit closer comparisons between several methods of solution.

QUESTIONS ON BASIC PHYSICS, Part 17

1—Given a star connection with $R_a = 2.7$ ohms, $R_b = 1.2$ ohms and $R_c = 4$ ohms. Calculate the equivalent delta branches.

2—What is the equivalent resistance of the bridge circuit in figure 5a when R_2 is increased to 12 ohms?

3—Calculate the direction and magnitude of current through the 5-volt battery in figure 8 when the polarity of the 6-volt battery is reversed.

ANSWERS TO QUESTIONS, Part 16

1—0.092 ohms

2—Equal to

3—Increased

4—Ratio 1/100, $R_2 = 714$ ohms.


ELECTRONIC EQUIPMENT FAILURE REPORT
NAVSHIPS 383 (REV. 3-47)
NOTICE:—Read notes interleaved in this pad prior to preparing this report. Report ONE FAILURE ONLY to a sheet.
REPORT NO.
DATE
NAME AND RATE OF PERSON MAKING REPAIR
ORGANIZATION PERFORMING MAINTENANCE
EQUIPMENT INVOLVED
NAVY
USMC
OTHER (Specify)
RADIO
RADAR
SONAR
WIRE
TOOL
TEST
POWER
NANCY
OTHER (Specify)
CONTRACT NO.
NAME OF CONTRACTOR
DATE EQUIPMENT INSTALLED
EQUIPMENT MODEL DESIGNATION
SERIAL NUMBER OF EQUIPMENT
CONTRACT OR UNIT PURCHASE ORDER
TYPE NUMBER AND NAME OF MAJOR UNIT INVOLVED
SERIAL NUMBER OF UNIT
Don't forget your
Navships 383
ITEM WHICH FAILED
TUBE TYPE, INCLUDING PREFIX LETTERS
THIS SIDE FOR TUBES
SERIAL NO. (Note 8)
TUBE MANUFACTURE
CONTRACT NO. (Note 8)
THIS SIDE FOR PARTS (Note 9)
NAME OF PART
CIRCUIT SYMBOL (egR-134)
NAVY TYPE NO.
SERIAL NO.
*CONTRACT DATA
*DATE RECEIVED
*ARMY STOCK NO.
*CHECK-OFF OR TAG DATA (Note 9)
*MANUFACTURERS DATA (Note 9)
FAILURE OCCURRED IN
STORAGE
OPERATION
HANDLING
OTHER (Specify in remarks)
INSTALLING
GUARANTEED HOURS (Note 8)
DATE OF ACCEPTANCE (Note 8)
ACTUAL HOURS
DATE OF FAILURE
TYPE OF FAILURE (Note 7)
TUBE CIRCUIT SYMBOL V—
BRIEF DESCRIPTION AND CAUSE OF FAILURE, INCLUDING APPROXIMATE LIFE (Continue on back)
NATURE OF FAILURE AND REMARKS (Note 10 — Continue on back)
* Not required for reports submitted by Naval Activities
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