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Editorial

by John E. Remich, Manager, Technical Department

FIELD REPORTS

The importance of field reports is often overlooked by the busy Field Engineer, mainly because he does not fully understand the reason for such a requirement. Too often the individual regards the field report as a Headquarters check on his daily activities. The result is that many reports are merely bits and pieces of information which are difficult to use in analyzing the functioning of an overall program.

The basic purpose of the field report is to keep Headquarters abreast of field experience so that an improvement in a product or in the efficiency of field operations can be effected. Taken individually, each report is comparable to one piece of a complex jigsaw puzzle. However, when the various reports are consolidated, the pattern is clearly evident and can be used to great advantage in establishing policy.

If the Field Engineer were aware of the reliance placed on his report, it would be immediately apparent to him that he is an important cog in the works of a very large machine. The equipment engineers depend upon the material in these reports to increase the reliability and usefulness of their equipment by making desired changes at the earliest moment.

A good report covers all phases of the operation. The data submitted should be complete, concise, and above all, accurate. All failures should be reported, and the report should be accompanied by comments that will indicate the cause of the failure. In many cases the fault is not caused by improper design or manufacture, but, rather, by the human element involved. In such cases this fact should be clearly indicated. By means of careful analysis, the Headquarters group can then intelligently decide what action is to be taken. In addition, comments and ideas that can lead to improvement of an equipment should be included so that they can be properly evaluated with a view toward improving future models.

The Field Engineer should guard against the tendency to neglect the reporting of failures which he feels are commonly understood because they have been reported many times previously, or perhaps because a factory representative has given assurance that corrective action has started. The number of reports received that indicate the same trouble establishes the seriousness of the trouble and the desirability of modification. If the Field Engineer omits mention of repeated failures, the omission may be regarded by Headquarters as proof that the trouble has cleared up, and that corrective action is not required.

Good reports are a must for efficient operation of large organization. Each Field Engineer should realize his responsibility in this respect by submitting carefully written reports.

TRANSISTORIZED RADAR-SCOPE DISPLAY UNIT

by Raymond Markowitz
Formerly Senior Engineer
Philco Government and Industrial Division

An example of the use of point-contact transistors in video circuitry and the related design problems.

A TRANSISTORIZED VERSION of the standard airborne radar indicator unit (figure 1) has been built and tested operationally, and has performed in a manner comparable to the vacuum-tube version, while offering certain specific advantages. Notably, complexity of the circuit has been reduced because fewer components are required. Power consumption has been reduced from 10 watts to 1 watt, and although the unit has been operating from batteries, it can be adapted for use with one of the available supplies, at the same time simplifying the basic power-supply problem. Operating performance of the transistorized unit is comparable with the vacuum-tube version as long as transistors having the required current gain cut-off are employed; no deterioration in performance should be encountered since the transistors are operated well below their ratings. There are also the anticipated advantages of long life (greater than 70,000 hours) and greater mechanical ruggedness (the transistor can withstand approximately 20,000 g's of acceleration), plus the possibility of increased miniaturization to an extent limited only by the size of the components; the components themselves may be derated in many cases because of the lower power and lower internal operating temperature involved.

FREQUENCY RESPONSE

Before describing the equipment in more detail, it is worthwhile to review the basic frequency limitations of presently available point-contact transistors. The base, emitter, and collector resistances are substantially independent of frequency, and the transistor frequency response can be expressed by the variation in r_m, the forward transfer resistance, or by the current gain, alpha, as a function of frequency. Alpha cut-off,

Figure 1. The Transistorized Radar Indicator (Note the four, point-contact transistors mounted around the CRT socket.)

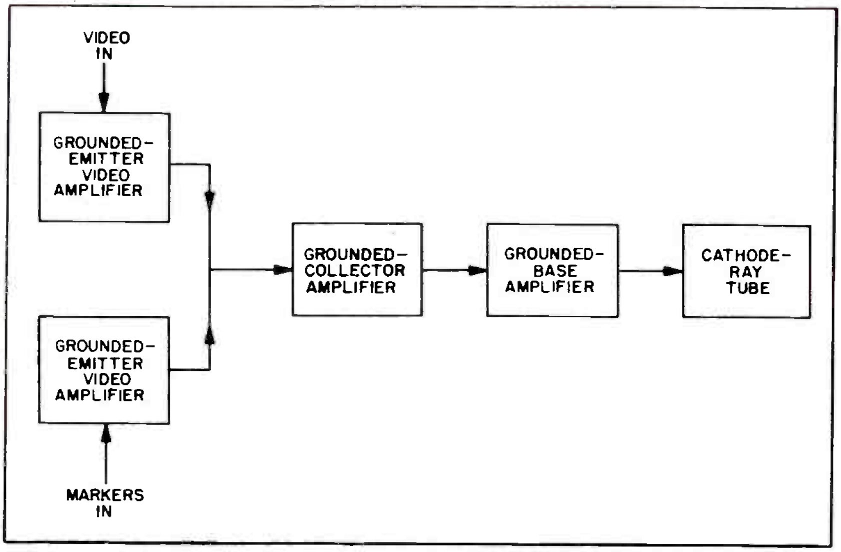

Figure 2. Block Diagram of the Transistorized Radar Indicator

defined as the frequency where alpha is 3 db down from its low-frequency value, occurs as a result of the difference in the path length of the holes arriving at the collector, which causes a cancellation effect at the higher frequencies. An approximation for the transit time in seconds for the hole carriers in n-type germanium to go from emitter to collector is:

$$\tau = \frac{S^3}{\mu\rho I_e}$$

where S = the point spacing in centimeters
μ = the mobility in centimeters^2 per volt-second
I_e = the emitter current in amperes
ρ = the germanium resistivity in ohm-centimeters
τ = an inverse function of frequency response

Collector capacitance is generally negligible in point-contact transistors, except in the case of very high impedance circuits, and the low emitter impedance makes the emitter capacitance negligible. Available point contacts for video application are rated at about 5 mc., but considerable selection is necessary to obtain usable transistors. W. E. 1698 transistors were employed in the indicator unit, although other transistors having equally good high-frequency characteristics, but much improved temperature coefficient, will be available shortly.

GENERAL DESCRIPTION

The unit was designed to handle a peak maximum positive pulse of 2 volts, and to drive the cathode of a 5BP7 display scope requiring approximately 20-30 volts drive for blooming. The indicator is powered from a +45-volt and −45-volt d-c supply, since it was not considered worthwhile to power it from the internal power supply. The original model employed four tubes (six tube functions, including two d-c restorers), while four transistors and a crystal diode (only one d-c restorer is needed) are used as the replacement. In the block diagram of figure 2, it can be seen that video and marker signals are separately amplified and combined, amplified again, and coupled to the CRT.

The operating controls employed are the MARKER BRILLIANCE and the MASTER BRILLIANCE, the latter controlling both marker and signal level. The unit is essentially a video voltage amplifier. The major design problem is that of obtaining stability at all levels and with all changes in operating point without overload and with minimum distortion, while still achieving the required gain and bandwidth (4 mc.) with polarity inversion. No attempt was made to achieve unrestricted transistor interchange, although design centers were chosen to allow a maximum of replaceability, at least without the introduction of instability among transistors having the required alpha cut-off.

VIDEO CIRCUITRY

Two grounded emitter amplifiers (see Figure 3) working into a common load impedance (the input impedance of the grounded collector stage) are employed for video mixing, giving at the same time the required 180° phase reversal. The signal input stage is directly coupled to the base of the grounded emitter, whereas the marker stage is a-c coupled. This was done to minimize the collector dissipation of the grounded collector stage, and make it easier to establish the optimum operating points of the respective stages. The mutual loading that was introduced between the grounded emitter stages necessitated the insertion of isolating impedances in the respective collector circuits. Since this reduced the gain somewhat, a more efficient mixing system employing a diode coupling network has been devised.

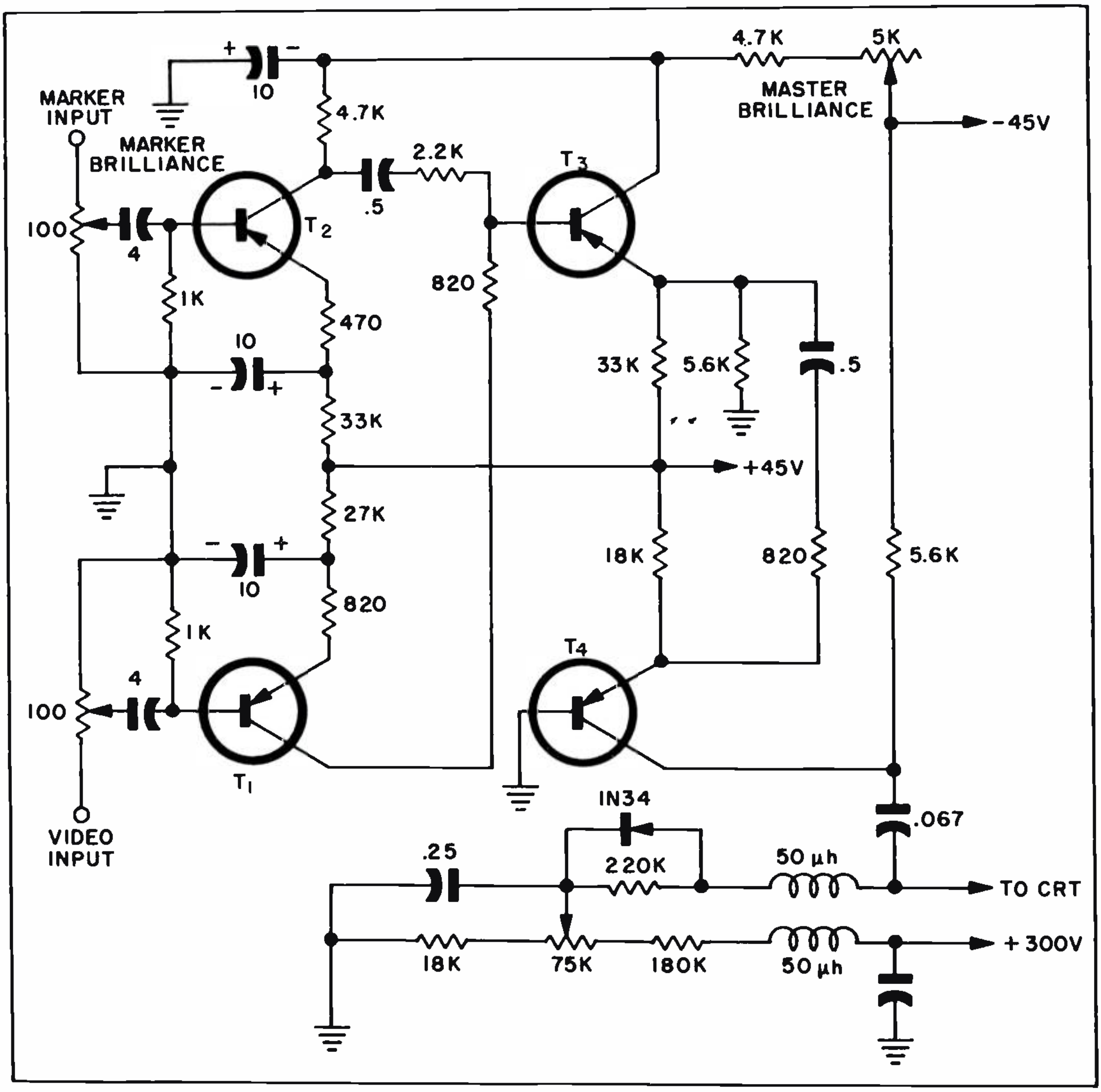

Figure 3. Schematic Diagram of the Transistorized Radar Indicator

The MASTER BRILLIANCE control varies the collector potential of both the grounded collector and the marker grounded emitter stages, and though the control variation is rather nonlinear, it is the simplest method of variation in which the signal does not appear on the control itself (and no tendency toward instability is encountered). The grounded collector stage, having a relatively high input impedance and low output impedance, is loaded by the grounded base input impedance plus the series emitter impedance, which establishes the saturation level with a 3-ma. emitter current bias. The last stage has a voltage gain of 16 db, and can deliver a pulse of approximately 25 volts amplitude to the CRT.

The video signal is brought to the indicator through a cable terminated in 100 ohms. The problem of a-c coupling into the low input impedance (300 ohms) of the grounded emitter stage arises here. The immediate solution is the use of tantalum capacitors having high-capacity and low-voltage ratings plus small size. Future designs, however, will incorporate d-c coupling, but this is now difficult because of the nature of the operating bias at the cathode follower in the receiver video amplifier.

TEMPERATURE TEST

The indicator was tested in accordance with standard temperature specifications. When the over-all unit was operated at 70°C, a marked deterioration in gain resulted (18 db). This deterioration was due to the shift in operating point, which resulted in a decrease in r_c and an increase in alpha. As was expected, the greatest change occurred in the grounded-emitter and grounded-collector stages. Up to about 60°C, the grounded-base stage remained practically unchanged. It appears that temperature-compensating circuitry plus optimization of operating point as a function of variation of alpha and r_c might stabilize the unit up to 60°C. However, the reports of the developmental W. E. 1689 and W. E. 1729 point-contact transistors, having a temperature variation of -1% per degree for r_c as compared with -5% per degree in the W. E. 1698, indicate that when they are performing a similar function, satisfactory operation at 70°C should be obtainable. However, temperature specifications on transistorized equipment might be subject to change; the present model is rated at a 50°C maximum temperature.

The application of transistors to radar video circuitry, with the advantage of reduction in components, and ease of adaptability to printed circuitry, printed wiring, and unitized construction, is a logical starting point for attacking the problem of transistorization.*

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* See "Transistors and the Military"—Obenchain and Galloway, IRE, Nov. '52.

AN/ARC-27 AUXILIARY POWER SUPPLY

by Gordon Ness
Philco Field Engineer

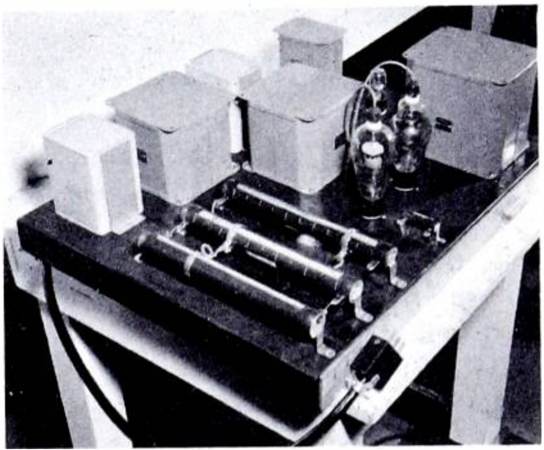
A simply constructed a-c power supply for replacement of the dynamotor unit normally used with the AN/ARC-27 transceiver.

AIR BASES USING MOBILE CONTROL towers may find a ready use for an auxiliary power supply developed at Hamilton Air Force Base for use with the AN/ARC-27 u-h-f communications equipment, especially at stations where reliability is of prime importance.

Realizing that the almost continuous operation to which the AN/ARC-27 would be subjected at times might cause dynamotor breakdown at a critical moment, Colonel Ross T. Sampson, Western Air Defense Director of Communications and Electronics, requested that a more reliable power pack be designed to replace the dynamotor.

Basically, the design considerations were simple enough. The auxiliary supply was to be capable of operating on a 24-hour basis from a 115-volt, 60-cycle source. The output was to be the same as that of the dynamotor. If possible, no wiring changes were to be made on the AN/ARC-27 radio set other than the removal of the dynamotor and the plugging in of the auxiliary supply in its place.

To meet the heavy current demands of the set, two mercury-vapor rectifiers (866's) were chosen. To eliminate human error, a time-delay relay was wired into the plate-supply circuit of these tubes. This delays application of plate voltages for 30 seconds, long enough for the filaments to heat the mercury in the rectifiers.



Completed AN/ARC-27 Auxiliary Power Supply, Showing Location of Major Components

Good regulation was desired in the filter section to keep transit-time effects (present at ultra-high frequencies) from disturbing the frequency stability of the set. If the output voltages were to drop greatly when the power supply was heavily loaded, the lowered plate voltages would affect the amount of phase shift between the grid and plate in the oscillator stages and conceivably could stop oscillation. A swinging-choke input was found sufficient to obtain the necessary regulation. Use of the swinging-choke input instead of a capacitor input also eliminated the possibility of damage to the mercury-vapor tubes from heavy instantaneous charging currents.

Referring to figure 1, notice that two, 200-watt resistors were placed in parallel in the output voltage divider network. These large-wattage resistors were necessary to give an ample safety factor, since T.O. AN16-30ARC27-3

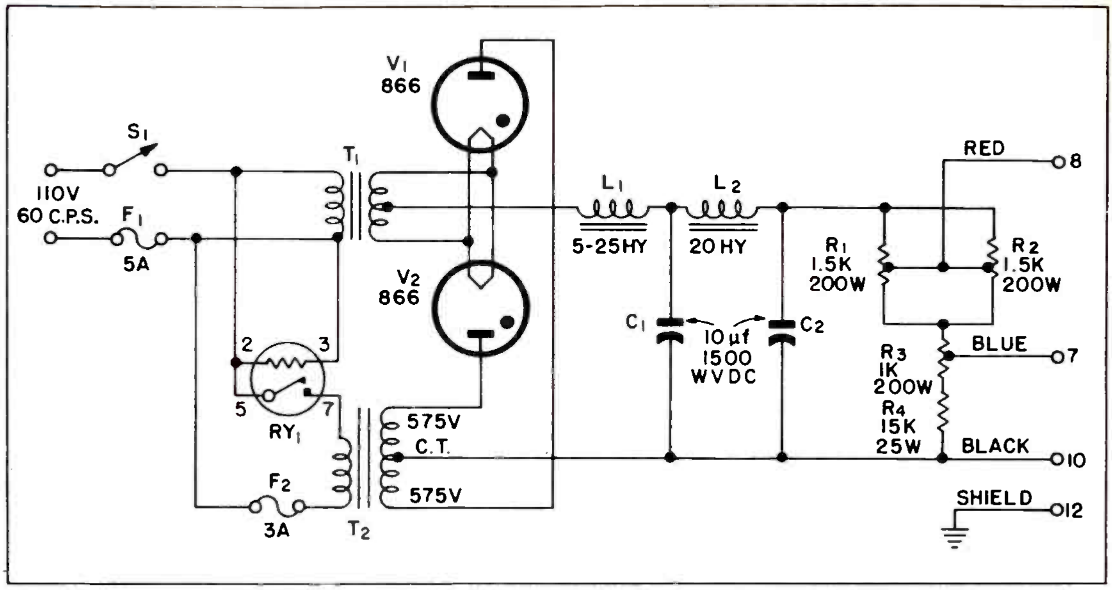


Figure 1. Schematic Diagram of AN/ARC-27 Auxiliary Supply

lists the maximum output current at 450 milliamperes. With the transmitter plate voltage at 400 volts and current at 450 ma., dissipated power would equal 400 volts x .450 amperes, or 180 watts. A safety factor of 100% would mean selecting a 360-watt resistor. Since 360-watt resistors are not listed in commercial catalogs, two 200-watt resistors were paralleled instead, for a total of 400 watts. Incidentally, these resistors are of the tapped-output type so the output voltage can be set to exactly duplicate the dynamotor output voltage.

The assembling and testing of the auxiliary power supply was done under the supervision of Mr. Marle Johnston, Philco Technical Instructor with the 566th Field Maintenance Squadron. Tests run in the shop by Mr. Johnston showed that correct output voltages with no measurable ripple were available. When the auxiliary supply was then plugged into the AN/ARC-27 to replace the dynamotor, the radio set operated normally. An additional advantage noticed was a lower noise level in the receiver.

Final tests will be run by the 84th Fighter-Interceptor Squadron as soon as an AN/ARC-27 is available for lengthy tests to determine whether an auxiliary blower will be necessary. The two power amplifier tubes (2C39A's) are driven hard, and require forced ventilation. Normally they are cooled by the fan blades attached to the dynamotor shaft, but these are removed along with the dynamotor when the auxiliary power supply is plugged in.

In reply to a letter containing specifications on the completed power supply, Collins Radio Company, manufacturer of the AN/ARC-27, stated:

> "We have examined your design for an AN/ARC-27 Auxiliary Power Supply and feel that it will do the job quite well. With regard to a blower to replace those on the dynamotor, it is rather certain that such will be required. This is especially true with regard to the 2C39A cooling."

Thus, to be on the safe side, unless the AN/ARC-27 is being operated in a very cool place with adequate ventilation, it would be best to mount an additional blower.

Mr. J. L. Dalton of Collins' engineering division suggested one method of mounting this blower:

"One possible solution to the above problem might be to devise a bracket and fittings to employ a blower such as is used on the AN/ARC-27 front panel. One outlet could cool the 2C39A's and the other could be used for general internal circulation. The present internal blower adjacent to the 829B modulator should also be retained to reduce hot-spot possibilities. With a surplus of inside air it is possible that the temperature rise might be such that the thermostat controlling the external blower might always remain open. This would reduce ambient noise and maintenance of the blower."

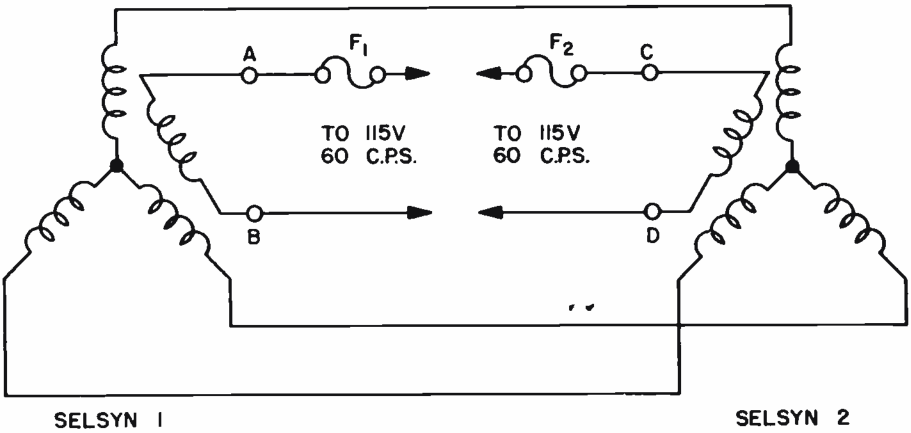
To keep maintenance on the blower to a minimum, it might also be wise to wire it into the circuit so it operates only while transmitting, since the 2C39A's operate only during that time.

A final word of caution was included in the letter from Mr. Dalton:

> "Caution should be taken that only radio sets which have the high voltage and the plus 225 V. fuse modification are used in conjunction with the auxiliary power supply. If this cannot be done, fuses in the d-c output voltages from the supply should be provided."

(Continued on next page)

What's Your Answer?



This month's problem was submitted by Philco Field Engineer Robert M. Fink.

The selsyn system shown in the figure was operating in a normal manner until a trouble occurred wherein the rotor of the #2 selsyn developed a 180-degree ambiguity and showed a lack of torque when the #1 selsyn rotor was rotated.

The stator voltages were measured and found to behave in a normal manner as the #1 selsyn rotor was turned. The voltage at AB measured 115 volts, and the voltage at CD measured 115 volts. As a last resort, the #2 selsyn rotor was checked for binding and found to be free. What is the trouble?

(Solution next month)

TABLE I. REQUIRED PARTS AVAILABLE FROM AIR FORCE SUPPLY

QUAN. REQ.	SCHEM. SYMBOL	DESCRIPTION	STOCK NO.
2 ea.	C_1, C_2	Capacitor, fixed, paper, 10 µf., 1500 w.v.d.c.	3330-317440988
1 ea.	SW_1	Switch, toggle, s-p-s-t	3360-398000268
2 ea.	....	Clip, plate (for 866's)	3370-147000-5635
2 ea.	V_1, V_2	Tube, electron, transmitting rectifier, gas, type-866	3370-433000-8665
2 ea.	....	Post, fuse, extractor (fuse size 4AG)	8800-619706
1 ea.	F_1	Fuse, 5a., 4AG	....
1 ea.	F_2	Fuse, 3A., 4AG	....
1 ea.	....	Plug, power	8850-216900
1 ea.	....	Plug, Jones	8850-301080
2 ea.	....	Socket, 4 contact, med.	8850-874520
2 ea.	....	Socket, octal	8850-890123
9 ft.	....	Cable (a-c input)	8860-261000-485
9 ft.	....	Cable, special purpose, electrical, 6-conductor (high-voltage output)	8860-419000

TABLE II. REQUIRED PARTS WHICH MUST BE LOCALLY PURCHASED

QUAN. REQ.	SCHEM. SYMBOL	DESCRIPTION	MFGR's NO.
1 ea.	L_1	Reactor, swinging, 5-25 hy., 550-ma., 60-ohms d.c., insul. 6000 V.	Universal Xfmr. Co., S-38
1 ea.	L_2	Reactor, smoothing, filter, 20 hy., 55 ma.	Universal Xfmr. Co., S-37
1 ea.	T_1	Xfmr., power, filament; pri. tapped 105/115 V., 50-60 cycle; sec'd. 2.5 V.C.T., 10 A.	Universal Xfmr. Co., S-57
1 ea.	T_2	Xfmr., power, plate; pri. 115 V., 60-cycle; sec'd. 575-525-0-525-575 V., 500-ma.	Universal Xfmr. Co., S-44
2 ea.	R_1, R_2	Resistor, 1500-ohm, adj., 200-W.	Ohmite, #1362B
1 ea.	R_3	Resistor, 1000-ohm, adj., 200-W.	Ohmite, #1362
1 ea.	R_4	Resistor, 15,000-ohm, adj., 25-W.	Ohmite, #0387
1 ea.	RY_1	Relay, time-delay, 30-sec.	Amperite, #115 NO-30
As req.	....	Misc. nuts, bolts, lock washers, spaghetti, underchassis wiring, grommets, solder lugs, clamps, etc.	....

* * *

MEASUREMENT OF MULTIMEGOHM RESISTORS

A very interesting technique for the precision measurement of extremely large values of resistance.

(Editor's Note: The information contained in this article was supplied by the National Bureau of Standards, U. S. Department of Commerce, and appears here through the courtesy of that agency.)

A THREE-YEAR STUDY of multimegohm resistors—resistances greater than 10 million ohms—has recently been completed by the National Bureau of Standards. The technique for measuring the resistances to accuracies of 0.1 percent, a modification of the Higgs method,* was developed by Dr. A. H. Scott, of the Bureau's inductance and capacitance laboratory. It utilizes an electrometer as a null detector in a bridge network, and involves the use of standard resistors either directly as components in the circuit or as auxiliary calibrating units to replace the unknown resistor. The results of the study indicate that many resistor types have erratic fluctuations that vary from 1 or 2 percent to more than 10 percent. Even the best resistors have variations of from 0.5 to 1 percent. The study also showed that voltage changes of from 1.5 to 180 volts cause resistance variations ranging from 0.4 percent to 26.9 percent.

The growing application of X-ray techniques in industrial inspection processes and the expanded utilization of X-rays and radioactive isotopes in medical therapy and diagnosis has been accompanied by a need for precise and accurate radiation monitoring equipment. Because the radiations are usually monitored by small current reactions within such devices as ion chambers and survey meters, multimegohm

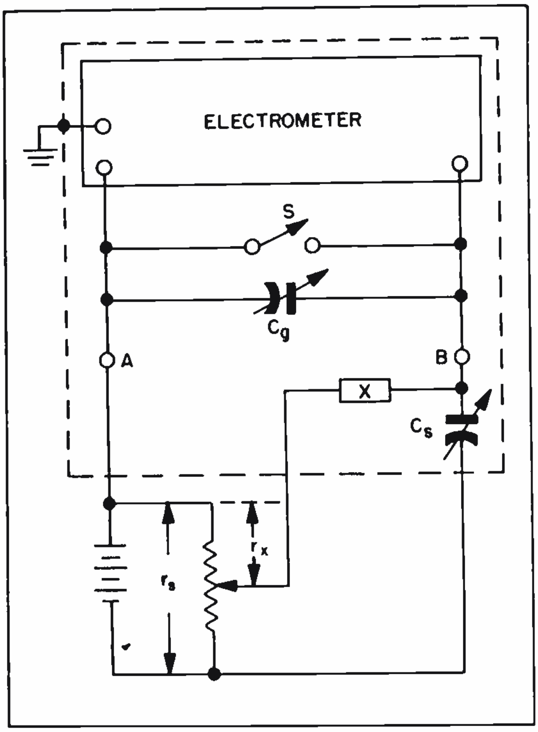


Figure 1. Circuit Diagram of Method Used by the National Bureau of Standards to Measure Multimegohm Resistors (Resistance is measured to accuracies of 0.1 percent by utilizing an electrometer as a null detector in a bridge network. Standard resistors are used either directly as components in the circuit, or as auxiliary calibrating units to replace the unknown resistor. In the diagram, S is a switch that places the electrometer into the circuit when a measurement is to be made. C_g is an auxiliary capacitor, and C_s is a precision variable air capacitor. X is the position in the circuit taken by the unknown multimegohm resistor. The potentials supplied to the variable capacitor and the resistors are produced across r_s and r_x.)

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* "A Method of Measuring High Insulation Resistance," by P. J. Higgs, J. Scien. Inst., *10,* 169 (June 1953).

resistors are utilized as voltage dividers. The dividers absorb practically no current and leave a large proportion to operate the metering components. The current flowing through the resistors may be as small as a micromicroampere, requiring a resistance of a thousand billion (10^{12}) ohms to yield a 1-volt operating potential. Thus, the requirements for accurately measured resistance are firmly established by the nature of the measurement itself.

The technique by which multimegohm resistors are measured at the National Bureau of Standards is a null method using a vibrating reed electrometer as the null detector. The charge flowing through the resistor during the time of the measurement is obtained from a variable air capacitor maintained at a fixed potential. The potentials across the capacitor—and thus across the resistor—are monitored by the electrometer. A null condition is maintained by decreasing the capacitance at the proper rate by a speed-controlled d-c motor geared to the shaft of the capacitor. Consequently, the only variables involved in the measurement are the change in capacitance and the time interval over which the change occurs. A potential divider, rather than direct battery potentials, is used to provide the voltages for the resistor and capacitor; the system permits a more accurate determination of the ratio of the voltages applied to the network.

In principle, the method depends upon keeping the potential difference across the terminals of a null detector very small (essentially zero), and furnishing the energy being dissipated in the unknown resistance from a variable capacitance. Initially, the electrometer (null detector) is out of the circuit and the variable capacitor is charged to the full battery voltage (1.5 to 180 volts, d.c.). A steady current that is a function of the applied voltage and the known and unknown resistances flows through the circuit. When the electrometer is placed in the circuit, the tendency is for the capacitor to discharge exponentially to a voltage value established by the potential divider. However, the capacitance is decreased continuously and smoothly so that the potential difference across it remains at the initial charging value. The rate at which the variable capacitor is decreased is such that the potential difference across the open switch (which puts the electrometer into the circuit) remains essentially zero. Because the current through the unknown resistance is maintained at its initial charging value and the energy dissipated by the resistance is supplied by the capacitor, the resistance of the specimen becomes a function of the change in capacitance, the time consumed to make this change, and the ratio of the resistance in the potential divider.

The sensitivity of the vibrating reed electrometer used as a null detector is such that a potential of one millivolt produces a meter deflection of 50 scale divisions. The response is almost instantaneous. One of the three variable air capacitors may be incorporated into the circuit, permitting capacitance ranges of 9.5 to 20.5, 15 to 125, and 100 to 1100 micromicrofarads. The capacitors are of the three-terminal type, with each set of plates insulated from the frame and case. No dielectric is placed directly between the plates; but it has been found that when the relative humidity is greater than 40 percent, appreciable conduction takes place between the plates. It is assumed that fine fibers normally floating in the air settle on the plates and occasionally bridge them. A drying agent placed inside the capacitor case causes the conduction to disappear.

The speed of the d-c motor, which is insulated from the shaft and frame of capacitor, is controlled by a series resistance. A coarse control maintains the

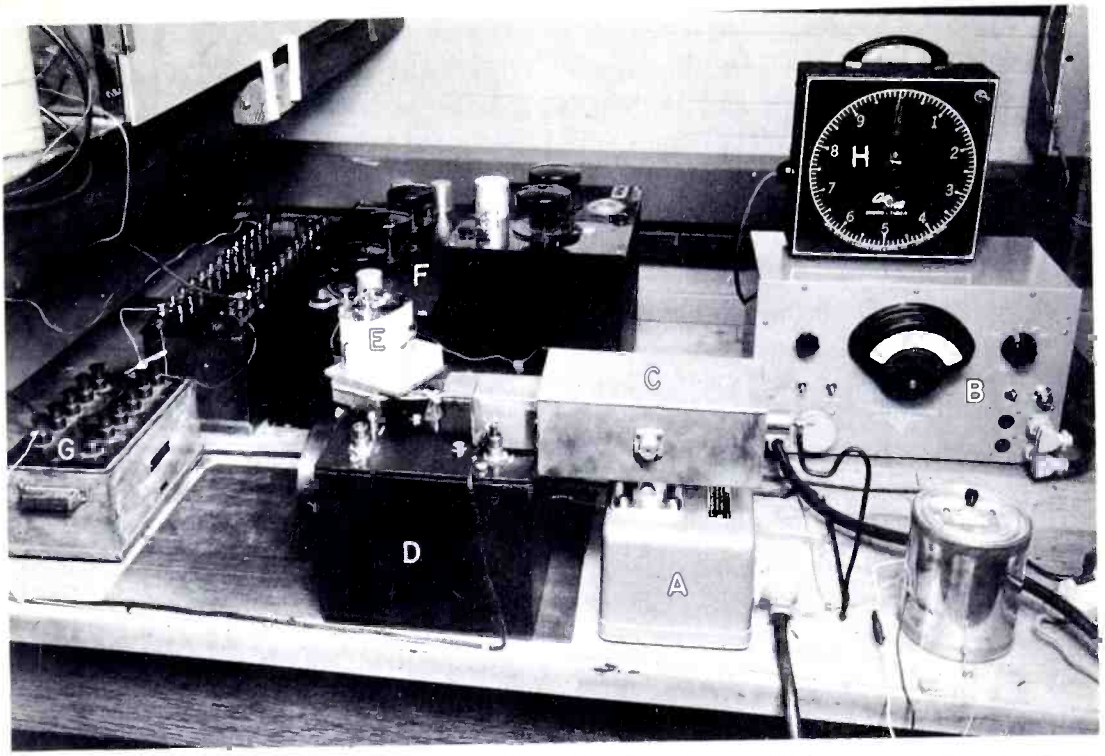

Figure 2. Laboratory Equipment Utilized by the National Bureau of Standards to Measure Multimegohm Resistors to Accuracies of 0.1 Percent (The charge flowing through the multimegohm resistor, shielded by can C, during the time of the measurement, determined from microtimer H, is obtained from a variable air capacitor, D, maintained at a fixed potential. The potentials across the capacitor—and thus across the resistor—are obtained from a potential divider, F, and are monitored by a potentiometer. A null condition, indicated by A and B, is maintained by decreasing the capacitance at the proper rate by a controlled-speed d-c motor, E, geared to the shaft of the capacitor. An auxiliary capacitor, G, is connected across the terminals of the electrometer to produce the desired charge sensitivity.)

motor speed to a small value below that which is desired; a shorting key provides the fine control by cutting out part of the resistance. It is possible, by this control method, to keep the potential across the electrometer within ±1 millivolt.

The changes in time are measured with an electric "microtimer," which indicates to tenths of a second. The circuit is arranged so that simultaneously as the timer is started, the switch across the electrometer is opened, and the motor drive for the air capacitor is started.

The measurement procedure used by the National Bureau of Standards can best be described by an example. Consider a resistor of ten thousand megohms to be used at 1.5 volts. A convenient time interval of 300 seconds and a capacitance change of 900 micromicrofarads are chosen. These parameters require a voltage across the variable capacitor of 50 volts. Because the maximum stable current from the battery supply can be no greater than 0.5 ma., the resistance of the potential divider is adjusted to 100,000 ohms and the tap from which the specimen is supplied with 1.5 volts is set at 3000 ohms. The voltage values are monitored by a potentiometer. An auxiliary capacitor, connected across the electrometer, is adjusted until the potential difference across the open terminals of the electrometer changes at a rate of about 20 millivolts per second when the capacitance remains fixed.

To make the measurement, the switch is closed, the capacitor is set at its highest value, and the battery is connected to the potential divider. At zero time the electrometer is put into the circuit, the motor is energized, and the timer starts. With practice, the potentail difference across the electrometer terminals can be kept to less than 0.4 millivolt by keying the motor series resistance. At the end of 300 seconds, the electrometer is removed from the circuit and the timer and driving motor are stopped. The difference in capacitance is determined from the original and final readings of the capacitor, and the timer gives the time interval. The resistance of the specimen is then computed from:

$$R = \frac{V_x \Delta_t}{V_c \Delta C} = \frac{1.5 \times 300}{50 \times 900 \times 10^{-12}} = 10^{10} \text{ ohms}$$

The potential across the divider is reversed and the measurement repeated. An average of this pair of readings is considered a single determination.

The variable air capacitors are calibrated to 0.01 percent of their maximum range. Because only about nine-tenths of the maximum range is used in a determination, and inaccuracies are unavoidable in stopping the drive motor, the change in capacitance can be considered to have an accuracy of 0.04 percent. The error due to synchronization of the switch-timer-motor arrangement is no greater than 0.1 second; thus, the timer interval (300 seconds) can be determined with an accuracy of 0.03 percent.

The multimegohm resistors measured by the National Bureau of Standards were all of the carbon compound type. One resistor consisted of a small coated rod sealed in a glass envelope which was treated to reduce surface conductance. Another was made of molded carbon composition with a large cross section. Other resistors included those which have a spirally cut film of carbon on a glass rod. Still another resistor had a narrow strip of carbon painted on a glass rod which could be cut to the proper length depending on the amount of resistance desired. It should be noted that the wire-wound resistors are probably the most stable type, but because of the small currents—and consequently large resistances—required for X-ray and radiation monitoring apparatus, the amount of wire needed to make the proper resistance would make its size too large for practical applications.

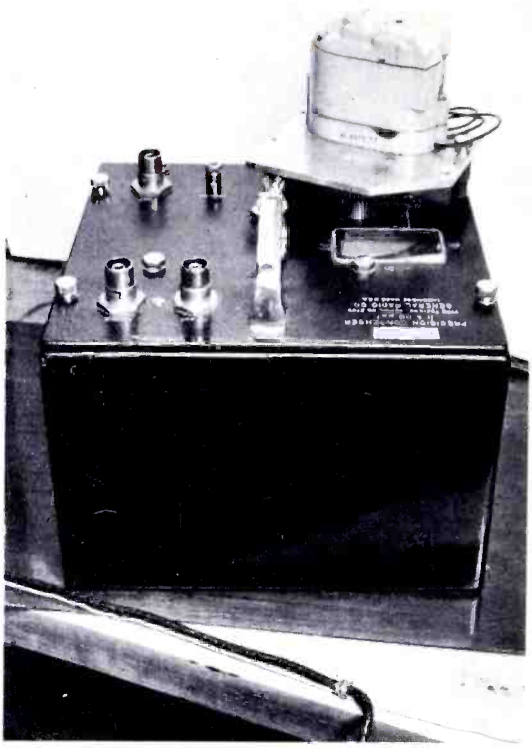

Figure 3. Precision Variable Air Capacitor Used by the National Bureau of Standards for Measuring Multimegohm Resistors (The change in capacitance necessary to maintain an essentially zero potential across the terminals of an electrometer is a measure of resistance. A controlled-speed d-c motor, which is insulated from the shaft and frame of the capacitor, changes the capacitance at some predetermined rate. It is possible to keep the potential across the electrometer within ±1 millivolt.)

The accumulated data indicates that the resistance of the multimegohm resistors fluctuates with time, and is a function of the voltage at which they are measured (1.5 to 180 volts). The values of the molded carbon composition resistors of large cross section fluctuate more with time than do those of the best glass-sealed type. One of the molded composition resistors now has twice the resistance it had when it was received by the Bureau 12 years ago. There is some indication that the resistance fluctuations of some of the sealed resistors are decreasing with age. But even the best of the resistors have erratic fluctuations of the order of 0.5 percent. The effect of voltage change is often very dissimilar for different resistors, regardless of whether they represent the same type of resistor.

Although the null-electrometer method used by the Bureau is capable of measuring resistances up to 10^{12} ohms with a limit of error of 0.1 percent, no multimegohm resistors above 10^9 ohms have been observed that are stable with time to that accuracy. They all seem to have voltage coefficients. All of these facts considered, the presently available resistors may not be relied upon for accuracies greater than 0.5 to 1.0 percent. Thus, there seems to be a great need for the development of more stable, low-current resistors in the multimegohm range.

NOTE: For additional details see: "Measurement of Multimegohm Resistors," by A. H. Scott, NBS J. Research 50, No. 3 (March, 1953), RP 2402.

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PHILCO TECHREP DIVISION PUBLICATIONS

In recent months Philco Technical Publications have attracted a great deal of interest. These training and trouble-shooting publications were originally prepared primarily for use by Philco Field Engineers engaged in instructional work with the Armed Forces. However, there has been such widespread acceptance of these publications throughout the electronics industry, and in educational institutions, military organizations, and governmental agencies, that Philco is now making them available to interested persons at reprint costs.

Orders should be addressed to Philco Technical Publications Department, 18th & Courtland Streets, Philadelphia 40, Pennsylvania. Remittances should be in cash, check, or postal money order, made payable to Philco Corporation.

Philco Field Engineers whose duties require certain publications should continue to obtain them from Potter Hallinger. There is, of course, no charge involved in such requests.

The group of manuals listed in Table I represents the Philco Trouble-shooting Series. The Philco method of trouble-shooting is applied to each equipment, so that a complete procedure (that will permit the user to locate any fault) is available. Test points are displayed on wall charts that are large enough for group instruction.

The Philco training-manual series is divided into two classes, the general-subject type and the equipment type. The equipment-type manuals cover theory, operation, alignment, maintenance, and trouble-shooting with the Philco method. These training manuals are designed mainly for instructor use, and are broken down into lectures and experiments (where applicable). Typical examinations provide a guide for both reviews and actual examinations. Each manual has supplementary sections on Teaching Suggestions and Safety Precautions. Text material is profusely illustrated, and is presented with careful attention to detail. A mini-

TABLE I. TROUBLE-SHOOTING MANUALS

PUBLICATION	COST	EQUIPMENT	PP	ILLUS.	WALL CHARTS	DATE	SECURITY CLASSIFICATION
AN-103	$ .86	AN/FGC-1, 1X	23	9	3 Schematics	1947	RESTRICTED
AN-104	$ .54	T-4/FRC	27	13	1 Schematic	1947	RESTRICTED
AN-110	$1.01	AN/FRR-3, 3A	23	9	4 Schematics	1947	RESTRICTED
AN-120	$1.48	AN/APQ-13A	59	31	4 Schematics	1947	DECLASSIFIED
AN-133	$1.56	CF-1-A	78	9	2 Schematics 1 Block Diagram	1948	RESTRICTED
AN-136	$1.56	CF-2-B	79	13	2 Schematics 1 Block Diagram	1948	NONE
AN-142	$ .92	AN/TXC-1	50	17	1 Schematic 1 Facsimile Test Chart	1948	RESTRICTED

mum of mathematics is used, and every attempt is made to slant the material toward practical applications.

Tables II and III list the salient features of the two classes of training manuals. Dates shown are copyright dates.

It will be noted that the Philco Microwave Radio Relay, CLR-6, is not included in the tables. This manual is currently being revised for the Code 123 equipment, and will be published this summer.

One very interesting new manual is being reprinted at this time. It is AN-255, the "Philco Handbook for Users of Signal Corps Tactical Radio Communications Equipment." This 142-page, pocket-sized (4½ x 7 inches) manual is priced at $1.00, and is intended to provide operating personnel

TABLE II. EQUIPMENT MANUALS

PUBLICATION	COST	EQUIPMENT	PP	ILLUS.	LECTURES	EXP.	EXAMS	WALL CHARTS
AN-171	$1.59	BC-639A (1949)	95	28	15	12	2	1 Block Diagram 1 Schematic
AN-172-A	$1.66	BC-640A, B (1949)	82	41	16	13	2	1 Block Diagram 2 Schematics
AN-182	$4.70	AN/TRC-1, 3, 4 AN/TRA-1 (1951)	228	75	29	22	4	1 Systems Block Diagram 1 Equip. Block Diagram
AN-194	$1.64	AN/APN-1, 1A 1B, 1X (1951)	99	68	13	11	2	1 Block Diagram 1 Schematic
AN-251**	$3.80	AN/APN-9 (1951)	196	48	25	19	5	1 Block Diagram 1 Indicator Presentations 1 Schematic
AN-244*	$5.59	CMT-4 (1952)	210	71	29	2	3	1 Block Diagram 2 Waveforms 5 Schematics

* Has Glossary of Terms
** Has Index

with a ready reference guide to Radio Communications equipment that is used at tactical levels. The propagation of radio waves and the principles of antennas and transmission lines are explained in sufficient detail to aid operational personnel in determining whether a reduction in operating efficiency is due to malfunctioning of equipment or to the inherent nature of radio waves as they are affected by conditions of terrain, weather, or other natural phenomena. Since the efficiency of any mechanical or electrical equipment depends to a great extent upon the care it receives, preventive maintenance techniques are explained. Specific equipments are described briefly for the benefit of personnel who may be unfamiliar with a particular equipment; the descriptions cover size, weight, power requirements, operating frequency, and other general characteristics. The field expedients described are, for the most part, suggestions which may improve operations under certain special conditions, or enable an equipment to operate on a temporary or make-shift basis in the absence of some part or component not readily available.

Other new manuals will be announced in the BULLETIN as they become available.

TABLE III. GENERAL-SUBJECT MANUALS

PUBLICATION	COST	TITLE	PP	ILLUS.	LECTURES	EXP.	EXAMS	DESCRIPTION
AN-150B	$1.43	Antennas (1948)	184	286	30	......	4	Complete coverage on antennas and pertinent related subjects. Has index.
AN-161	$ .62	How to Prepare and Present a Maintenance Training Course on Electronic Equipment (1949)	46	10	......	......	......	Presents detailed training procedures. The Philco trouble-shooting method is presented and explained.
AN-167	$1.48	Cable Fabrication (1949)	52	69	7	6	2	Discusses various phases of cable fabrication, and includes detailed assembly instructions on difficult items. Includes 4 wall charts for group instruction.
AN-169	$1.16	Shop Practices (1949)	86	87	14	12	2	Explains how to handle and care for equipment and tools found in the average electronics shop. Safety aspects are emphasized.
AN-195	$2.45	Electrical Power Equipment (1951)	164	242	24	......	2	Covers theory and maintenance, trouble-shooting of motors, generators, and associated equipment. Has glossary of terms and index.

TABLE III. GENERAL-SUBJECT MANUALS (Cont.)

PUBLICATION	COST	TITLE	PP	ILLUS.	LECTURES	EXP.	EXAMS	DESCRIPTION
AN-230	$1.47	Radar System Measurements (1951)	93	98	13	......	3	Covers theory and practice of radar system measurements. Has expanded safety section, glossary of terms, and index.
AN-234	$4.32	Antenna Construction Handbook (1951)	76	28	......	......	......	Construction data on communications antennas in the 3 to 30 mc. range. Includes detailed parts lists and erection procedures. 14 wall charts present expanded versions of important drawings throughout the book.
AN-252	$2.60	Radio Communication System Measurements (1952)	179	199	14	......	6	Companion to AN-230. This volume has an extensive review of Radio Fundamentals in addition to a wide coverage of the theory and practice of radio measurements. A safety section describes the new artificial respiration method.

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ERRATA

May issue, page 11, second sentence under COUPLING: "For magnetrons operated below about 3 cm.," should read "above about 3 cm."

May issue, page 39, Schematic: C_3 should be labeled C_1, R_9 should be labeled R_4.

SIMULTANEOUS TRANSMISSION SYSTEMS

Part II (Conclusion)

by F. R. Sherman

Headquarters Technical Staff

The second half of the article which began in the May, 1953 issue of the BULLETIN. Additional data is presented on re-entrant networks, and several methods of coupling two or more transmitters into a single r-f transmission line are described.

(EDITOR'S NOTE: *Portions of this article are based on various Radio Engineering Reports published by the Electronics Establishment Branch of the Civil Aeronautics Administration, U. S. Department of Commerce. Grateful acknowledgement is made to that agency for its assistance in supplying technical data and for permission to extract material from its reports on simultaneous transmission.)*

THE FIRST HALF OF THIS ARTICLE (May, 1953 BULLETIN) covered the general theory of typical simultaneous transmission systems, including types of antennas, characteristics of transmission lines, and methods of detecting unbalance in lines. It also presented a detailed explanation of several methods used for matching the input impedance of a multi-wire rhombic, or other broadband antenna, to the impedance of an r-f transmission line at two or more frequencies. This concluding installment discusses the remainder of the system: namely, the methods which may be used to achieve coupling of two or more transmitters to the common transmission line without interaction between transmitters.

COUPLING THE TRANSMITTERS TO THE TRANSMISSION LINE

When the antenna has been matched to the r-f transmission line at all assigned frequencies, the transmission line is fed from the various transmitters through discrimination networks that prevent interaction between the transmitters.

There are only two prerequisites that any discrimination network must have to permit simultaneous transmission of more than one frequency on one antenna:

A. Each branch transmission line to each of the individual transmitters must contain a filter to block the flow of radio-frequency power from the other transmitters.

B. Each filter must be made to produce a negligible effect on the transmission line while transmitting the power from its associated transmitter.

It is clear that these two simple prerequisites make possible the use of many types of coupling networks; however, in practice, only three types are used to any great extent:

A. Coplanar Sections—used with low power (to 5 kw.) and when there is 6% or more difference in frequency.

B. Building-Out Sections—used with high power (5 to 25 kw.) and

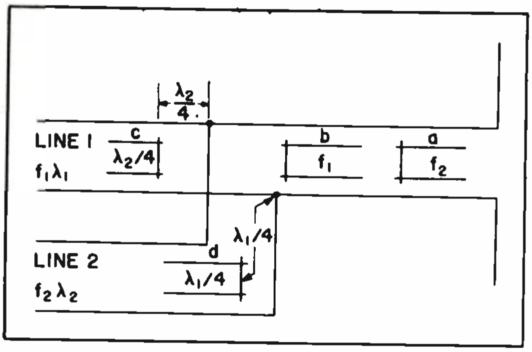


Figure 1. Matching and Filtering System for Two Frequencies, Using Coplanars

when there is 10% or more difference in frequency.

C. Conjugate Re-entrant Network—used with high power (5 to 25 kw.) and when frequencies differ by 6% or more.

Although definite limits of power have been stated in the preceding list of networks, the actual limit will depend upon the maximum power that can be applied to these sections and not cause arcing.

TWO-FREQUENCY COPLANAR NETWORK

The simplest type of network for the simultaneous transmission of two frequencies consists of a matching section and filter section for each frequency, as shown in figure 1.

Matching Sections

Coplanars a and b (figure 1) are matching sections which flatten the line (match the impedance of the r-f transmission line and antenna) at the desired frequencies.

Filter Sections

Transmission line 2 is attached to the main r-f transmission line at any convenient point, and coplanar c (cut to $\lambda_2/4$) is attached to line 1 $\lambda_2/4$ from the point of attachment of line 2. Similarly coplanar d (cut to $\lambda_1/4$) is attached to line 2 at a point $\lambda_1/4$ from its point of attachment to line 1.

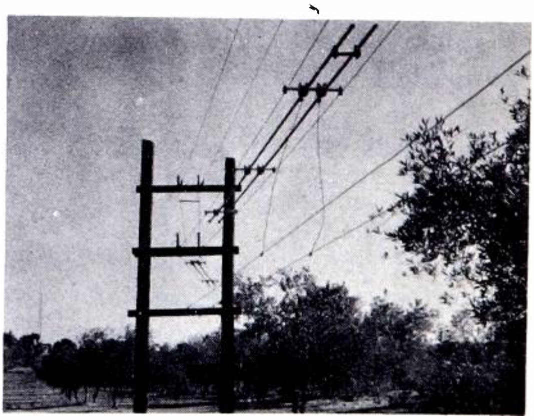
Coplanars act as parasitic elements which are excited only at the frequency for which they are cut; therefore, maximum reflection will occur at this frequency, and no voltage at this frequency will appear on the transmitter side of the transmission line from the point where the filters are hung. (Coplanars may be hung with the open ends facing either way as long as the minimum spacing requirements are met to prevent interaction by proximity.)

Tuning

In figure 1, line 2 is energized at f_2, and a trolley meter is placed on line 1 on the transmitter side of coplanar c and tuned to f_2. The coplanar's position on line 1 and the position of the short are then varied until there is minimum or zero indication on the trolley meter at frequency f_2, at its lowest scale setting—thus, all f_2 energy is being transmitted towards the antenna, where it sees a matched line.

Line 1 is then energized at f_1, the trolley meter is placed on line 2, and coplanar d is adjusted, following the same procedure as used for coplanar c.

The preceding example shows how requirements A and B are fulfilled. The discrimination provided is ample for most modern low-powered communications stations.



View of H-Frame, Showing Coupling Coplanar

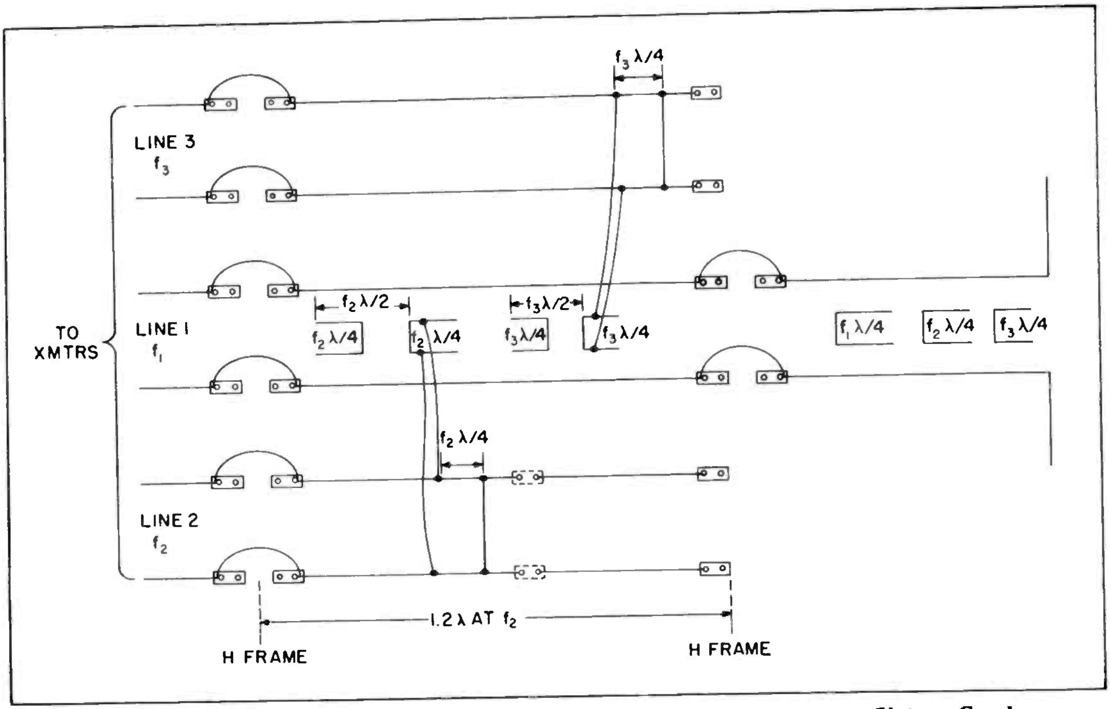


Figure 2. Matching and Filtering System for Three Frequencies, Using Coplanars

THREE-FREQUENCY COPLANAR NETWORK

In a three-frequency discrimination network using coplanars (figure 2), the transmission lines from the individual transmitters are not attached directly to the main r-f transmission line. Instead, the signal is inductively coupled to the main line by means of coupling coplanars, which means that there will be three kinds of coplanars—a matching, a coupling, and a filter coplanar, required for each frequency except the lowest frequency, which requires only a matching section.

This system calls for the construction of H-frames to properly separate and support the transmission lines; therefore, the construction of these H-frames is described at this point.

Construction of Lines and Supports

The H-frames and poles supporting the transmission-line system must be tall enough so that the lowest line will not endanger personnel, yet will be accessible. The height of the frames will depend upon how many circuits are to be incorporated into the system. The bottom line should not be more than twelve feet above the ground.

As stated previously, the minimum separation between pairs of transmission lines (to prevent unbalance) must be at least four or five times the separation between the lines in each pair; i.e., if the separation between wires in a pair = 12″, then the vertical separation of pairs (minimum) = four times separation between crossarms = 48″. Therefore, the vertical spacing of the crossarms on the H-frames is based on this figure.

The spacing between the H-frames is governed by the size and number of coplanars to be hung between them as shown in figure 3. Each frequency, except the lowest frequency, requires two coplanar sections (one filter network and one coupling network) to be placed in that part of the main r-f transmission line which lies between the H-frames. Thus, if three frequencies (8 mc., 10 mc., and 16 mc.) are to be transmitted, four coplanar sections will be hung between the H-frames, the

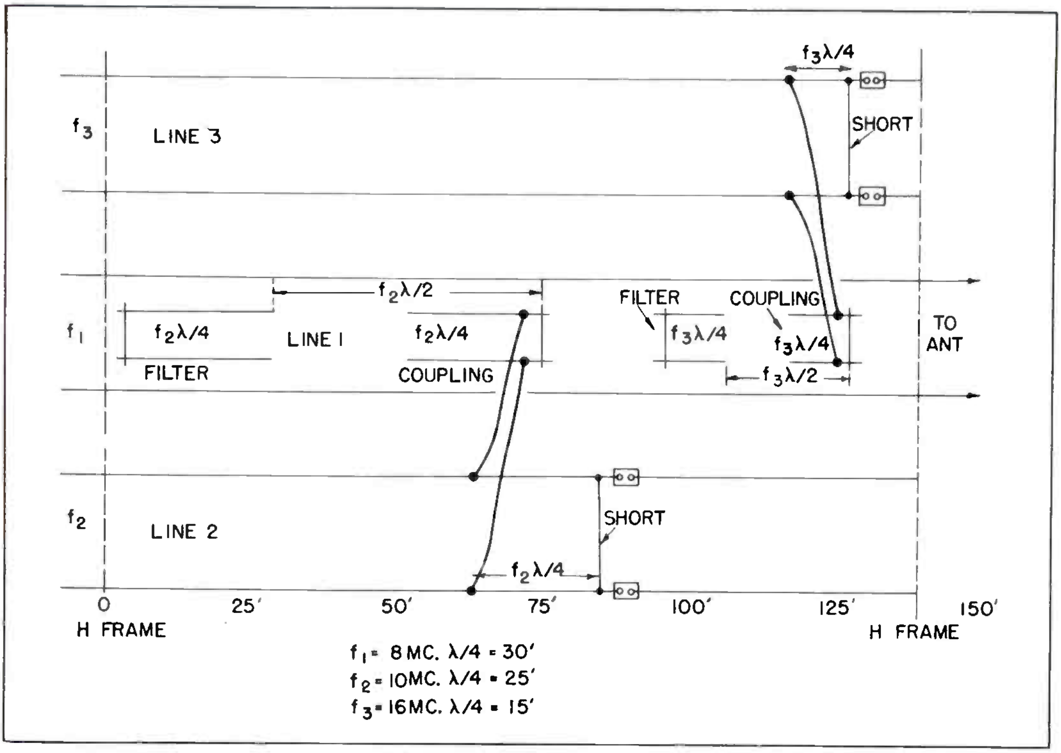


Figure 3. Typical Example of Three-Frequency System, Showing Approximate Distances

length of each section is computed according to the following formula:

$$\text{Length (in feet)} = \frac{246}{\text{f (in mc.)}}$$

Therefore, the sections for the 10-mc. frequency will each be 25 feet long, those for the 16-mc. frequency will be 15 feet long, and those for the 8-mc. frequency will each be 30 feet long. The filter coupler for each frequency must be separated by one-quarter wavelength from short to short, and the separation between the 10-mc. and the 16-mc. sections must be at least one-half the length of the larger section. By studying figure 3, it can be seen that the minimum separation between the H-frames under these particular circumstances will be 125′.

Actually, the length of each coplanar section should be made about one foot longer than a quarter-wavelength to allow for tuning and any slight deviations in frequencies.

Since the transmission line, especially the portion of the main line between the H-frames, must have sufficient tensile strength to support the weight of the coplanar sections used for tuning and coupling, it is recommended that #6 B & S or AWG copperweld wire be used.

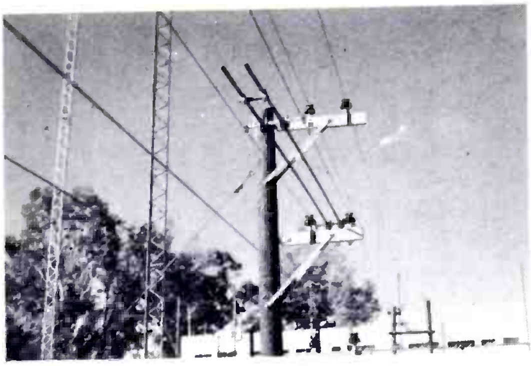
R-F lines, for each of the frequencies are strung as follows (see figure 2):

A. Between the main termination frame of the transmitter house and the first H-frame.
B. Between the two H-frames.

All lines are terminated at the H-frames with insulators and dead-ends. The lowest-frequency line is loop-connected through to the antenna transmission line at both H-frames, and the other lines are loop-connected through to the second H-frame.

INSTALLATION OF COUPLING AND FILTER COPLANARS

It may be possible to install the discrimination network (coupling and filter coplanars) without using the matching



Filtering Coplanar Mounted Upon a Support Pole

coplanars and have the SWR within the limits of 1.1/1. However, if matching sections are to be used, they must be installed and tuned, as described in the first article, before the coupling and filter sections are attached to the line. Refer to figure 3 in the following discussion.

A short is placed across line 3 at the second H-frame, and, at a point $\lambda_3/4$ from the short, the f_3 coupling coplanar is placed in the main transmission line. Jumpers are then run from the $\lambda_3/4$ point on line 3 and tapped onto the coupling coplanar at from one-fourth to one-third the distance from the short toward the open end. The filter coplanar section is placed in the main transmission line $\lambda_3/2$ from the coupling section (short to open), toward the transmitter.

The trolley meter is placed on line 1, two or three feet toward the transmitter from the filter section. With line 3 energized, the trolley meter is tuned to approximately 3/4 deflection, and the short on the filter section is then varied until the meter reads minimum on the lowest scale.

The SWR on line 3 is now checked and reduced to a minimum by the following method:

A. Measure $\lambda_3/4$ from the taps on the coupled section and mark that point on line 3.

B. Place the trolley meter on line 3 and find a current maximum or minimum, whichever is nearest the mark on line 3.

C. Vary the short on the coupling section until the I_{max} or I_{min} point is on the mark.

D. Read the SWR and vary the position of the taps on the coupling section until the SWR is reduced to a minimum.

The f_2 coupling coplanar is located on line 1 a suitable distance from the f_3 filter coplanar (so that interaction is minimized), and jumpers are connected from the f_2 coplanar (at a point one-third to one-fourth the distance from the short toward the open ends) to a point directly below on line 2. The line-2 short is located $\lambda_2/4$ toward the second H-frame, away from the jumper connections. The f_2 filter coplanar is installed as shown ($\lambda_2/2$ from short to open between coplanars). Adjustment of the f_2 coupling and filter coplanars is performed in a manner exactly like that used to adjust the f_3 coplanars.

When the installation is complete and all fine adjustments have been made to the coupling and filter coplanars, there may be more than a tolerable amount of voltage at another frequency built up on the auxiliary lines, particularly at the higher power levels.

Referring to figure 2, it can be seen that the main transmission line is sufficiently filtered against any disturbance caused by the frequencies being fed into it by the auxiliary lines. The auxiliary lines, however, depend for their discrimination upon the fact that the coupling coplanars are resonant at one frequency only.

Figure 4 shows two additional coplanar filters (1 and 2) that will assist in the rejection process. A quarter-wavelength coplanar section cut to the interfering frequency may be installed

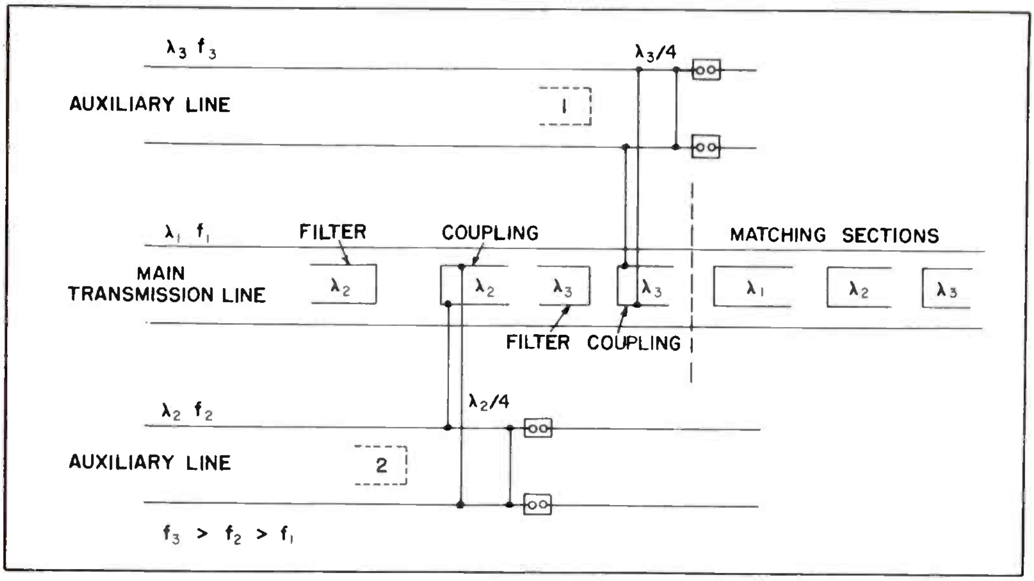


Figure 4. A Three-Frequency System, Showing Two Additional Filters (1 and 2)

in either or both of the auxiliary lines. Since the amount of filtering required will involve only the small amount of voltage not filtered by the coupling coplanars, it is not necessary for the filters to be of rugged construction.

Improved filtering may be obtained by varying the spacing of the elements of the coupling coplanars, but this is not recommended because it may lead to excessive voltage building up on the open end of the coplanars, with resultant arcing.

TWO-FREQUENCY DISCRIMINATION NETWORK USING BUILDING-OUT SECTIONS

A discrimination network that will handle greater power than a coplanar network may be fabricated with ordinary transmission line, but the separation between the frequencies involved must be at least ten percent of the higher frequency.

It is assumed that during construction of the transmission line care was taken to see that the system was balanced physically, and checked for electrical balance before proceeding with tuning of the antenna. The main transmission line is then matched at the desired frequencies.

Referring to figure 5, it can be seen that at point A, line 2 is attached to line 1. At point B, which is separated from point A by a quarter-wavelength (at f_2), a shorted half-wavelength stub (cut to f_2) is attached to line 1.

Similarly on line 2 at point C, which is spaced a quarter-wavelength (at f_1) from point A, a half-wavelength shorted stub (cut to f_1) is attached.

The operation of this system is based on the theory that a shorted half-wavelength stub will reflect a short at multiples of a half-wavelength. The impedance at the short will be practically zero because the voltage will be minimum and the current maximum. Furthermore, at odd quarter-wavelength multiples from the short circuit, a condition of very high impedance (open circuit) will exist.

At point B, the impedance to f_2 is practically zero and this reflects to point A as a very high impedance. Thus, any signal at f_2 on line 2 will see the junction at A as consisting of a very high impedance in the direction of line 1 and a match in the direction of the antenna

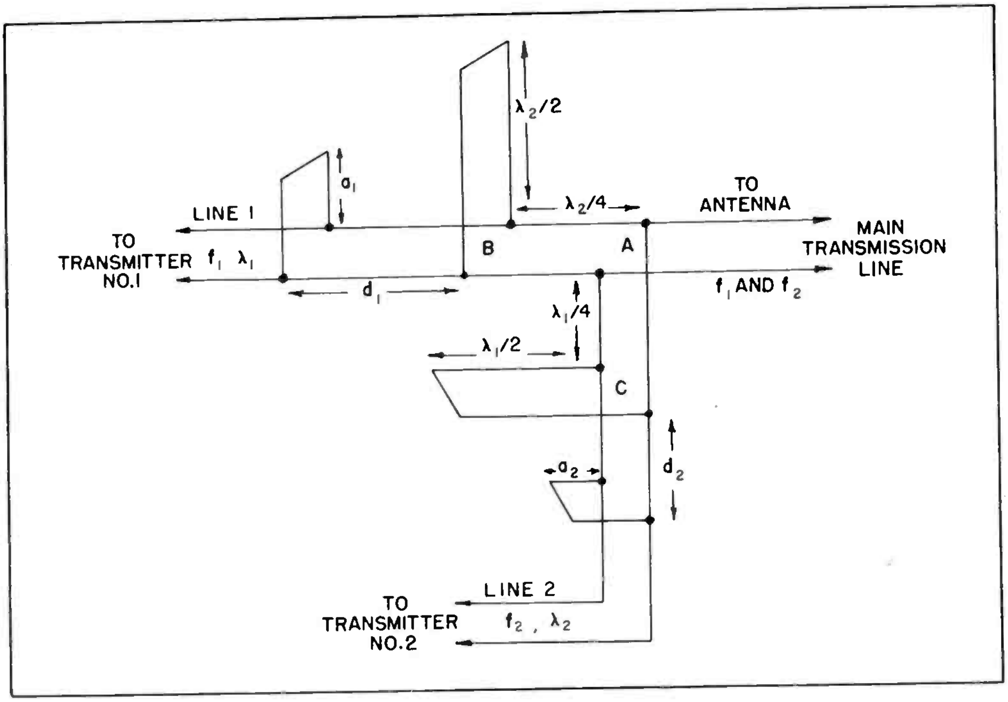


Figure 5. Matching and Filtering System for Two Frequencies, Using Building-Out Sections

—the signal will obviously be directed to the antenna.

The reflected short (for f_1) at point C discriminates against f_1 in a similar manner; therefore, line 2 is not disturbed on the transmitter side of point C by any voltage induced by f_1, and all of the signal from line 1 is directed, with little loss, to the antenna.

Although the transmission line was matched at the desired frequencies, attaching the building-out sections will cause a mismatch which will set up standing waves at the desired frequency. This means that each line will require a second stub to provide correction. In the following example, the assumed frequencies are:

$$f_1 = 8 \text{ mc. } \therefore \lambda_1 = 123'$$

$$f_2 = 10 \text{ mc. } \therefore \lambda_2 = 98.4'$$

To determine dimension a_1, use formula:

$$a_1 = \frac{\lambda_1 - \lambda_2}{2}$$

$$a_1 = \frac{123' - 98.4'}{2} = \frac{24.6'}{2} = 12.3'$$

Since d_1 is a half-wavelength at f_1:

$$d_1 = \frac{\lambda_1}{2}$$

$$d_1 = \frac{123'}{2} = 61.5'$$

Since $a_2 = a_1$:

$$a_2 = 12.3'$$

d_2 can be found with the aid of figure 8 in the first installment of this article (page 29 of the May, 1953, BULLETIN). First, find a_2 in terms of wavelength at f_2 as follows:

$$\frac{a_2}{\lambda_2} = \frac{12.3'}{98.4'} = 0.125 \text{ wavelength}$$

Find the point on curve A corresponding to 0.125. Drop vertically from this point to curve P and read N on the vertical coordinate. It will be found that in the example N = 0.088.

d_2 is found as follows:

$$d_2 = \frac{\lambda_1}{2} - 2N\ {}_2$$

$$d_2 = \frac{98.4'}{2} - 2 \text{ x } 0.088 \text{ x } 98.4' = 31.9'$$

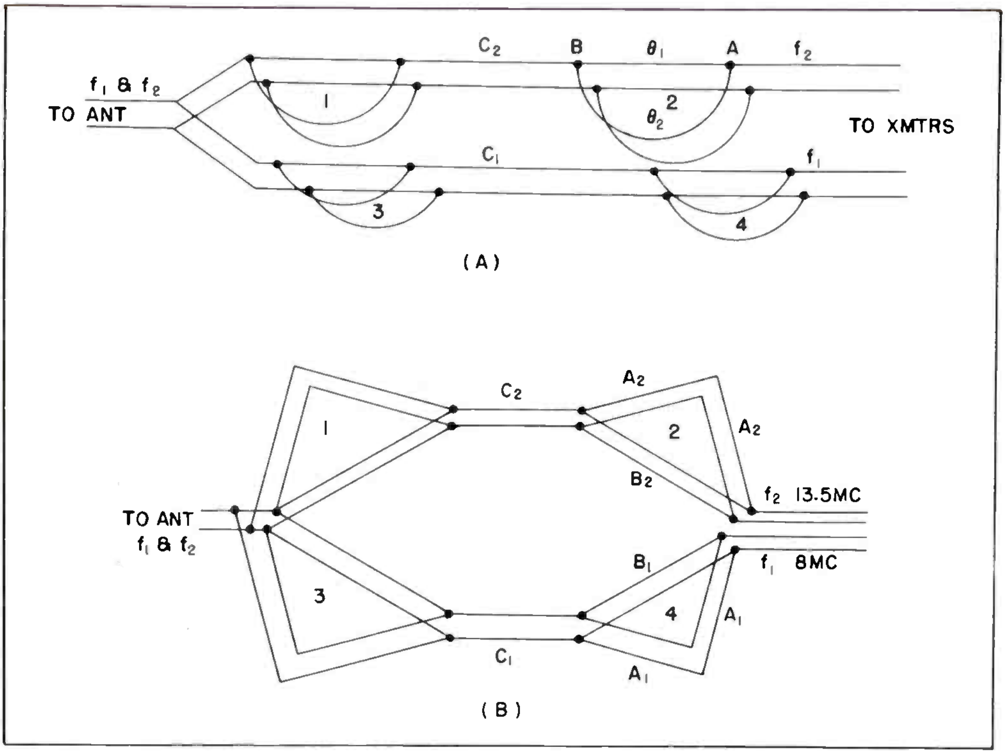
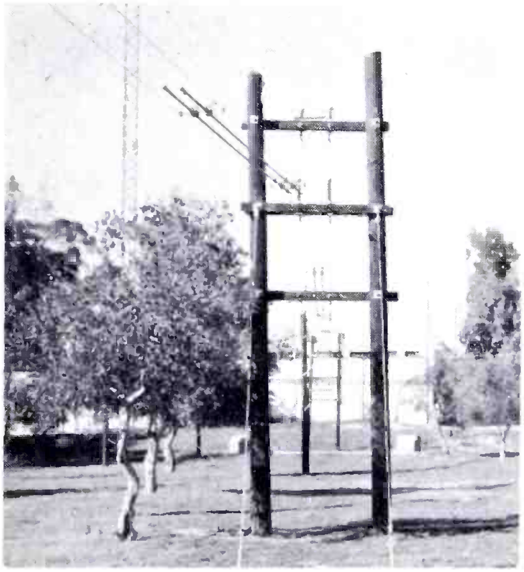


Figure 6. Matching and Filtering System for Two Frequencies, Using Re-Entrant Networks
A. Schematic Representation
B. Typical Construction

To check the efficiency of the discrimination networks and to make any final adjustments required, the following procedure is applied:

A. Place a temporary short across line 1 at any convenient point.



View of H-Frame, Showing Transmission Line Leading to Antenna

B. Set the trolley meter near the short and tune the meter to f_2.

C. Energize line 2 and vary the taps at point B until minimum or zero voltage is obtained at f_2 on the transmitter side of the building-out sections on line 1.

This procedure is repeated on line 2, checking for minimum voltage at f_1.

The placement of a_1 and a_2 are then checked, using the trolley meter to determine that the SWR is at a minimum, making any slight adjustments necessary to approach an SWR of 1.1/1.

CONJUGATE RE-ENTRANT NETWORK

The re-entrant networks shown in figure 6 can also be constructed from lengths of transmission line. The current from the transmitter splits at point A (part A of figure 6) and recombines at point B. By varying the length of θ_2, it is possible to obtain any degree of im-

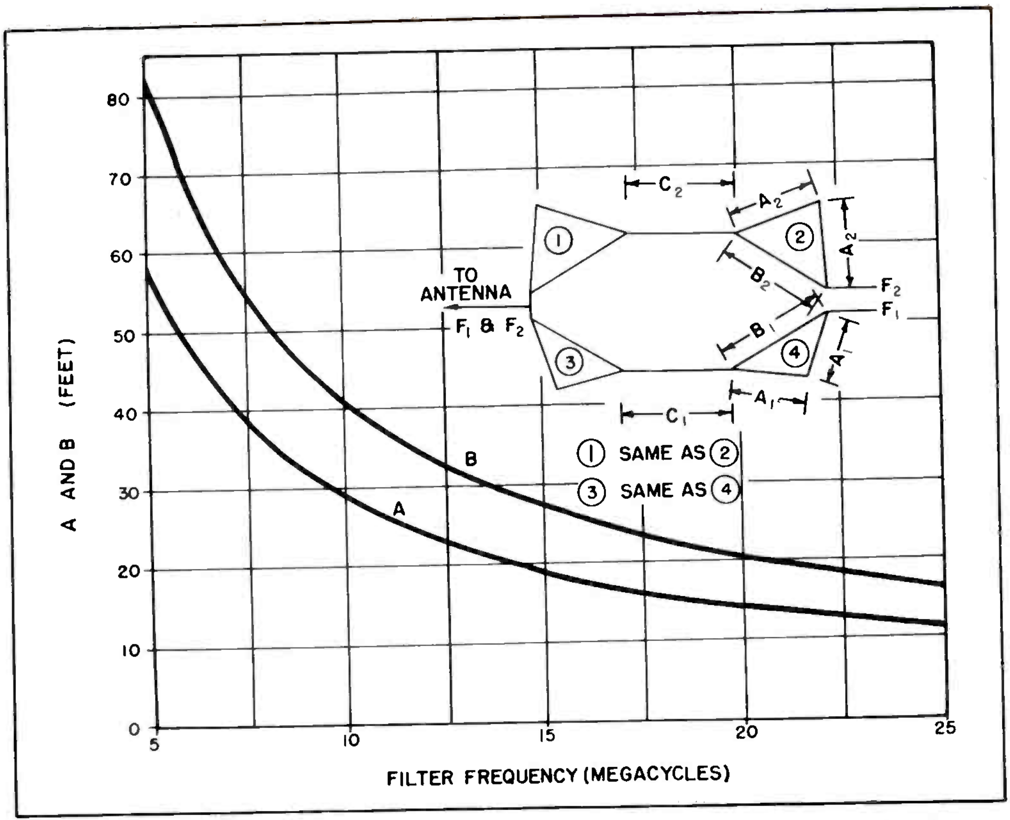


Figure 7. Curves Used to Determine Dimensions of Re-Entrant Sections

pedance from very nearly zero to almost infinity (see first installment of this article for theory).

When re-entrant networks are used for the simultaneous transmission of two frequencies on one antenna, each individual re-entrant section is made to have a very high impedance for one of the two frequencies (and thus it serves as a filter); but, since it does not have a characteristic impedance equal to that of the transmission line at the other frequency, another matching device must be used. Therefore, either two re-entrant networks or one re-entrant network and a building-out section (see figure 10) are used conjugately in the transmission line to each transmitter to provide a filter at the filtered frequency and an impedance match at the transmitted frequency. (The theory of conjugate networks was thoroughly covered in the first installment of this article.)

There are two types of re-entrant networks that may be used as filters: the difference type and the summation type. The difference type is one in which the difference between the length of the re-entrant network and the spacing between its two points of attachment to the transmission line equals 180 degrees. Since this type produces high reactance for the frequency to be transmitted, it is preferable to use the summation type in which the sum of the length of the re-entrant loop and the distance between the two points of attachment to the transmission line equals 360 degrees. (In the summation type, the loop formed by the re-entrant section is resonant, and no reactance is present. This has no effect upon its rejection function and makes the mismatch at the desired pass frequency easier to correct.)

Three curve sheets are used in the installation of the summation type of re-entrant networks. Figure 7 lists the dimensions of the two sets of re-entrant networks; figure 8 shows the spacing between networks that will render them

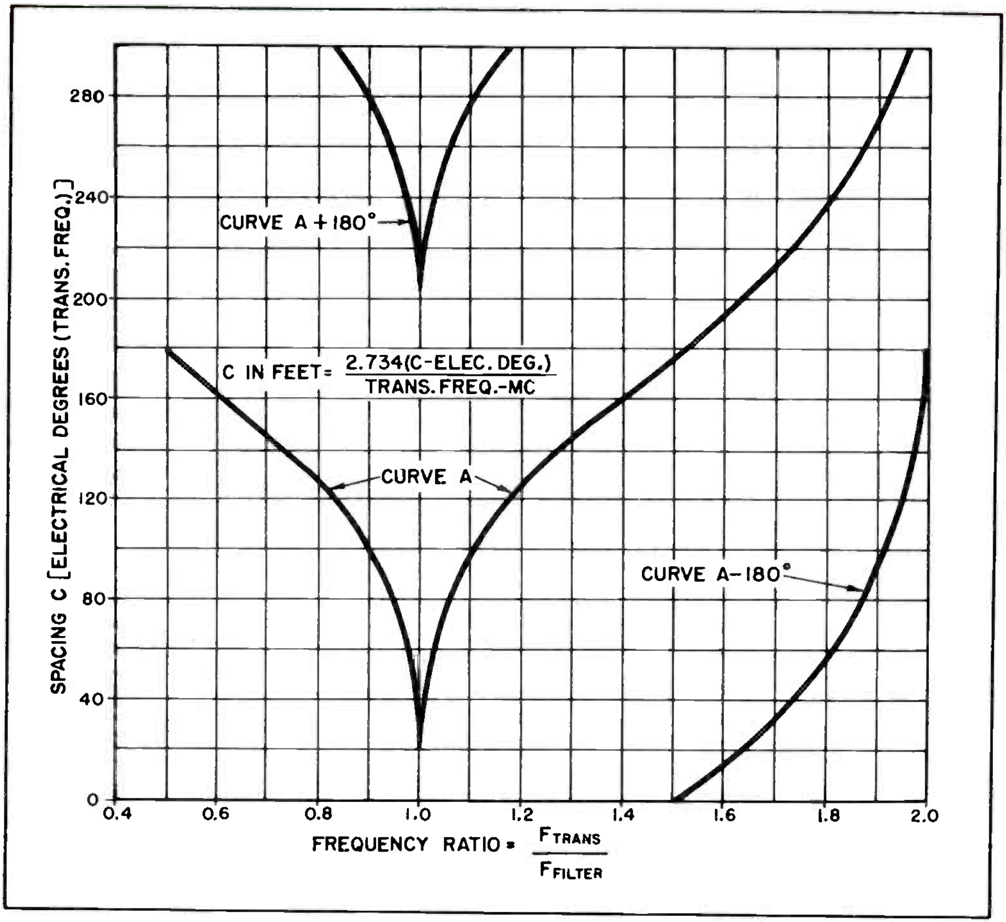


Figure 8. ***Curves Used to Determine Spacing Between Re-Entrant Sections***

conjugate to each other for their particular frequency; and figure 9 shows how to convert ratios obtained from sheet 2 into electrical length, and, by means of a given formula, to obtain the physical separation of the conjugate sections.

An example of the use of these charts in designing a discrimination network for the simultaneous transmission of 8 mc. (f_1) and 13.5 mc. (f_2) is applied to part B of figure 6 as follows:

Re-entrant sections 1 and 2 must be designed to block f_1, and re-entrant sections 3 and 4 must be designed to block f_2.

Figure 7 shows that dimension A equals the length of each side of each re-entrant section, and dimension B equals the distance between points of attachment on the transmission line of the two ends of each section. For example:

Curve A	*Curve B*	*Sections*
A_1 = 36′/side	B_1 = 51′	3 & 4
A_2 = 21′/side	B_2 = 30.5′	1 & 2

Figure 8 is now used to determine the ratio of transmitted frequency to blocked frequency, as follows:

Frequencies
Transmitted/Filtered = Ratio
13.5/8 = 1.7
8/13.5 = 0.6

Figure 9 consists of three curves—curve A, curve A − 180°, and curve A + 180°.

If the ratio obtained from figure 8 should fall on curve A − 180°, it is preferable to use this curve instead of curve A, both from the standpoint of minimizing losses and of conserving

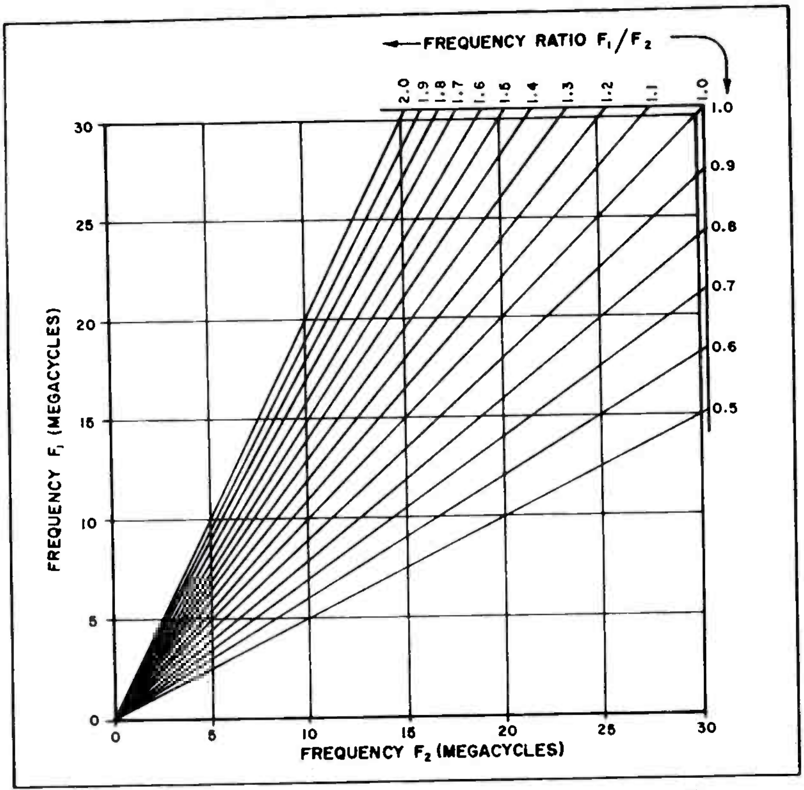


Figure 9. Curves Used to Determine Frequency Ratios

material. Curve A + 180° should be used in case the value of C (to be found shortly) is very low, which would result in the conjugate sections being close enough to cause undesirable coupling effects. In the case at hand, figure 8 provides the following data:

RATIO	CURVE A	− 180°	+ 180°
1.7	215°	35°	—
0.6	163°	—	—

The following formula will now be used to convert the electrical degrees obtained from figure 8 into physical separation (in feet) between the conjugate sections:

$$\text{C in feet} = \frac{2.734\ (\text{C in elect. deg.})}{\text{f in mc. (transmitted)}}$$

Applying this formula to the data obtained from figure 8:

$$C_1 = \frac{2.734\ (35^\circ)}{13.5} = 7.1\ (\text{feet})$$

$$C_1 = \frac{2.734\ (215^\circ)}{13.5} = 43.5\ (\text{feet})$$

$$C_2 = \frac{2.734\ (163^\circ)}{8} = 55.5\ (\text{feet})$$

It can be seen from example 1, using Curve A − 180°, that the conjugate sections might be close enough to cause coupling, therefore Curve A (example 2) is used to obtain a greater physical separation.

It is to be understood that the above method will only give a theoretical dimension and that there is generally a necessity for some fine adjustments to be made.

The re-entrant sections should first be tuned to the filtered frequency by means of jumpers that short out a small portion of the re-entrant section. The section nearest the antenna is tuned so that the current (produced by the other transmitter) in the line is at a minimum. The second section is then tuned by adding jumpers to duplicate those used in the first section.

The second pair of sections is then tuned in the same manner.

After both pairs of re-entrant sections have been tuned, it is necessary to make

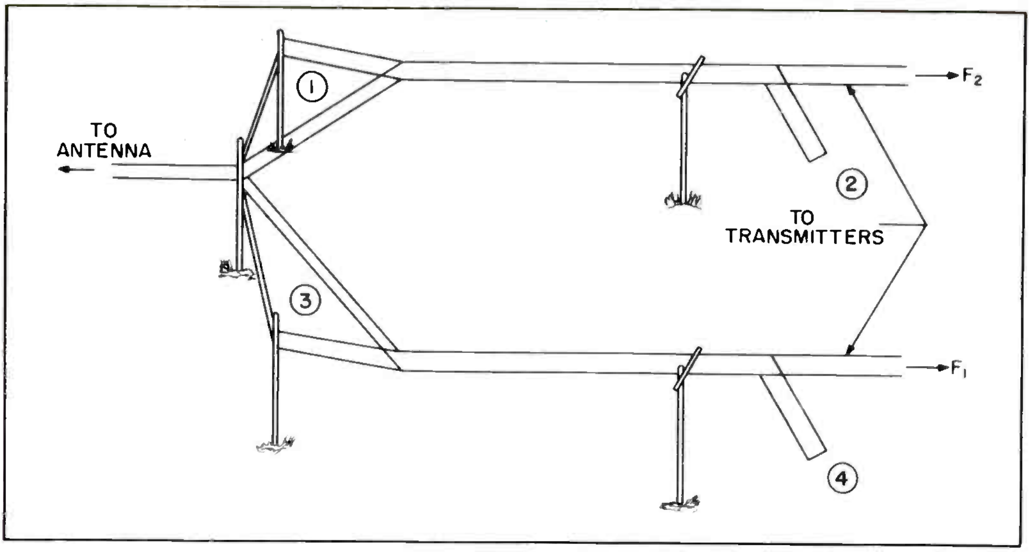


Figure 10. Matching and Filtering System for Two Frequencies, Using Re-Entrant, Filter Sections and Building-Out Matching Sections

the sections of each pair conjugate to each other at the transmitted frequency by varying their positions relative to each other. (Since it may be difficult to change the physical position of the re-entrant sections it is usually more practical to install a small re-entrant section or building-out section on the transmission line to minimize the standing waves caused by the sections not being quite conjugate.)

SIMULTANEOUS TRANSMISSION NETWORK USING ONE RE-ENTRANT SECTION AND ONE BUILDING-OUT SECTION

When the transmitted frequencies are widely separated (at least ten percent at the highest frequency) it is possible to dispense with one re-entrant filter network and substitute a building-out section in its place. However, since two filters in each transmission line are better than one and re-entrant networks for frequencies above ten mc. are relatively small, it is better to use two re-entrant networks above ten mc.

Below ten mc., the networks tend to become bulky; therefore, the re-entrant network towards the transmitter may be replaced by a building-out section located at such a point as to eliminate all standing waves between it and the transmitter, as shown in figure 10.

Figure 7 is used to obtain the dimensions of re-entrant section (1) which is installed and tuned to the filtered frequency by means of jumpers. The previously discussed method can then be used to obtain the dimensions and location of building-out section (2) (see first installment).

Re-entrant section (3) and building-out section (4) are then installed in a similar manner.

The re-entrant sections may be tuned to the filtered frequency by placing a sensitive r-f meter or incandescent lamp in series with a 600-ohm load at the end of the transmission line running to the transmitter generating the transmitted frequency. The transmitter generating the frequency to be filtered is then coupled into the system and the power is gradually increased each time the jumpers are regulated until at full power there is a minimum indication on the meter or lamp.

CONCLUSION

A simultaneous transmission system representing one of the types described in this article was installed by Mr.

Clyde Olsen, of the Headquarters Technical Staff, during an AACS field-engineering assignment. Mr. Olsen was highly commended for this installation, as shown by the following excerpt from a report forwarded to Hq., AACS, Washington, D. C., by the Commanding Officer of the base where the installation was made:

"It is desired to commend Mr. Olsen, Philco Field Engineer, for this outstanding job. The over-all appearance of the installation and the resultant perfect operation of the system are masterpieces of precision engineering, and in every detail measure up to the high standards of AACS and the Philco Corporation."

The system used by Mr. Olsen was developed by Mr. Norman Thomas, of the Civil Aeronautics Administration (CAA), and a regular kit prepared by the CAA was used in the installation. Tests run on this system indicated that its efficiency closely paralleled that obtained with the use of three separate rhombic antennas. The frequencies used were 8 mc., 12 mc., and 18 mc.; moreover, the transmitters operated normally, without any interaction, even when loaded to maximum.

Mr. R. W. Brockman, Philco Field Engineer, made a similar installation, the components being fabricated in the base machine shop. Mr. Brockman states that this system proved very satisfactory during later tests as compared to using individual antennas for each transmitter.

The frequencies used in the second installation were 8 mc., 12 mc., and 16 mc., and there was no interaction between transmitters while individual teletype messages were being transmitted simultaneously on the three frequencies. In addition, all messages were printable at an approximate distance of 2000 miles.

ENGINEERING CHANNEL INTERCOM UNIT FOR USE IN MICROWAVE RADIO RELAY SYSTEMS

by H. S. Newman & C. G. Raymond

Philco Field Engineers

The following discussion covers a method of signaling and talking on Channel 1 of the Philco Multiplex System.

(EDITOR'S NOTE: *Standard equipment for signaling and talking over the system on Channel 1 has not been supplied in the past but such units are now available. However, before the commercial units were available, each user had to provide his own Channel 1 facilities. In the interim, this problem has been attacked by several Philco Field Engineers, and the unit described in this article is the result of one such effort.)*

IN A MILITARY RADIO RELAY SYSTEM, all terminal stations (and possibly repeater stations) will ordinarily have personnel in constant attendance, the prime reason being the security of the system. The attending personnel will have need to talk to other repeater stations and to the terminal control point

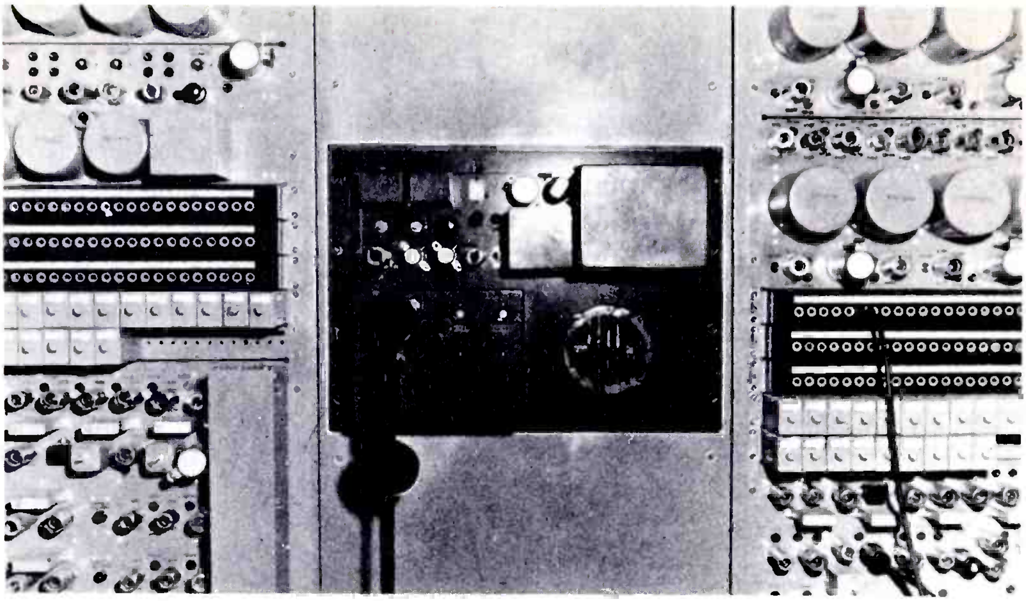


Figure 1. Completed Intercom, Showing Installation

when isolating and clearing up maintenance problems, and for special requests, usually of an emergency nature. Figure 1 shows an intercom unit which was designed by the authors to accomplish this function.

GENERAL

The equipment referred to in this article is the Philco CLR-6 and CMT-4 group. As supplied by the manufacturer, this equipment consists of one rack containing the r-f unit, CLR-6, and one or more racks containing the voice-channel multiplex and the signaling and terminating units (CMT-4).

The multiplex equipment requires that a voice-frequency signal be used for signaling or calling any of the stations in the system. Figure 2 is a block diagram of the equipment used in the method of voice calling to be described.

At the time this problem was under consideration, an amplifier had been designed for another type of intercommunication unit, which will be described in a future issue of the BULLETIN. This amplifier, a dual-input, single-channel type with a self-contained power supply and 24-volt d-c relay supply, has a gain of approximately 55 db. It contains an interstage transformer with a secondary winding for a headphone, and a relay which will cut off the output stage when energized. Since this amplifier contains features which make it ideal for the application at hand, it was decided to construct a complete intercom unit around the amplifier. The equipment is located on a standard rack panel, utilizing dish construction, so that it can be mounted in the CMT-4 rack.

OPERATION

The functions performed by the Basic Amplifier unit and the switching unit (100-Series) are shown in the complete schematic diagram in figure 3. Figure 4 is a simplified schematic of the amplifier and switching system.

Referring to figure 3 and figure 4, several features will be seen, in addition to the normal switching functions. The hookswitch, SW_{101}, breaks the d-c power to relays K_{101} and K_{102}, preventing the Intercom from being blocked off on one channel, provided, of course, that the operator remembered to hang up the handset. Potentiometers R_{101} and R_{102} can be adjusted to provide a variation in the signal level applied to the amplifier from the direction opposite that being used at the moment. This also

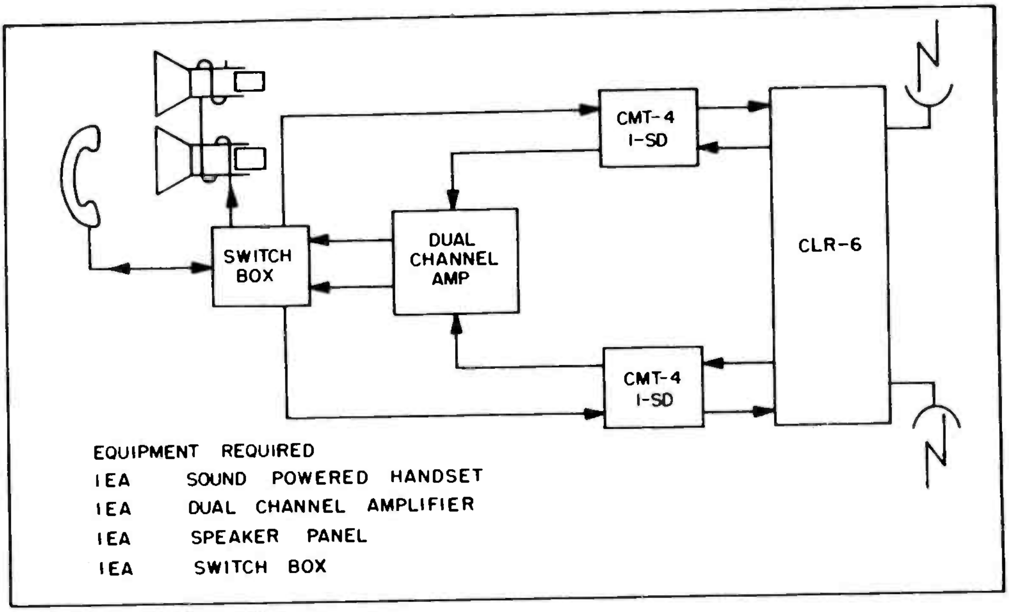


Figure 2. Block Diagram of Intercom Unit

provides sidetone adjustment, since, in the CLR-6 the insertion amplifier is ahead of the dropout. Resistor R_4 establishes minimum amplifier gain at a usable level, so that, if the volume control is accidentally turned down, signals can still be heard.

In normal operation, with the handset on the hook and relays K_1, K_{101} and K_{102} de-energized, it can be seen that the bottom ends of R_{101} and R_{102} are not connected to ground. This means the full input signal is being applied to both of the control grids of V_1. The handset receiver volume control is R_2, the speaker volume control is R_3.

Now suppose that a call comes in for this repeater station from some other station to the north. Picking up the handset makes d-c power available to relays K_{101} and K_{102}, energizes relay K_1, supplies d-c power to the microphone, and grounds the junction of resistors R_3 and R_8, which effectively cuts off the output amplifier stage. Since the calling party is to the north, the answering party depresses SW_{103} momentarily. This energizes relay K_{101} and lights lamp L_{102}, indicating that the N circuit is in use.

The bottom set of contacts on K_{101} hold this relay in and remove the ground contact from SW_{102}, thus preventing relay K_{102} from being energized. The next two sets of contacts connect the output of the microphone transformer, T_4, to the terminals on TB_{101} which lead to the CMT-4 and then on to the northbound transmitter. The top set of contacts applies a ground to the bottom end of R_{102}. Since R_{102} is in the south receiver circuit, any signal arriving from the south will be reduced in amplitude, the amount of attenuation depending on the adjustment of R_{102}. A signal arriving from the north, however, will be fed to the corresponding amplifier without attenuation. When the call is completed, returning the handset to its hook will return all relays to their normal positions by opening the d-c circuit.

The same procedure is followed if it is desired to originate a call to another station.

CONSTRUCTION

The unit is completely self-contained, and requires external connections to only two circuits: (1) a source of a-c power; and (2) the line terminals of

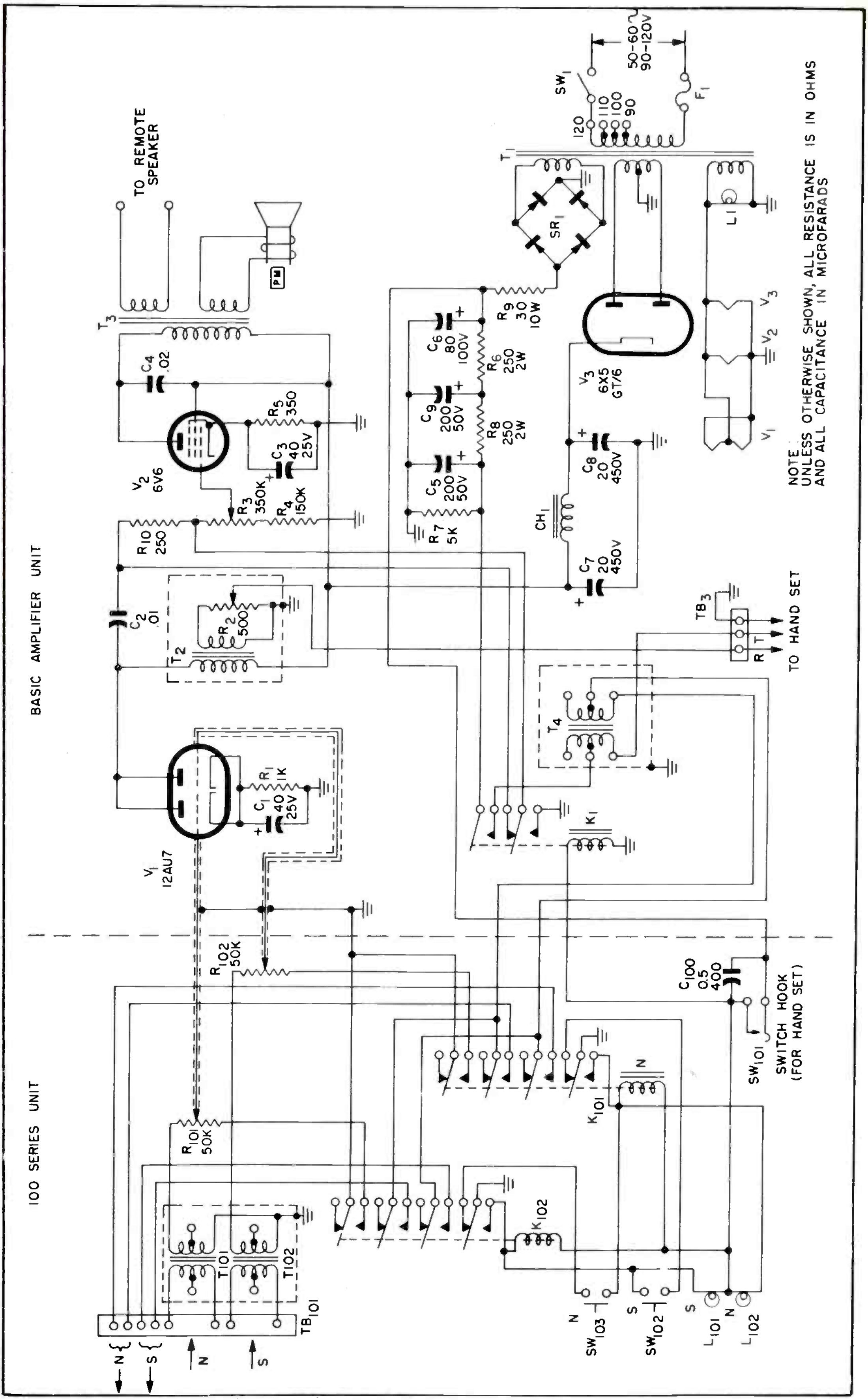


Figure 3. Complete Schematic Diagram of Intercom Unit

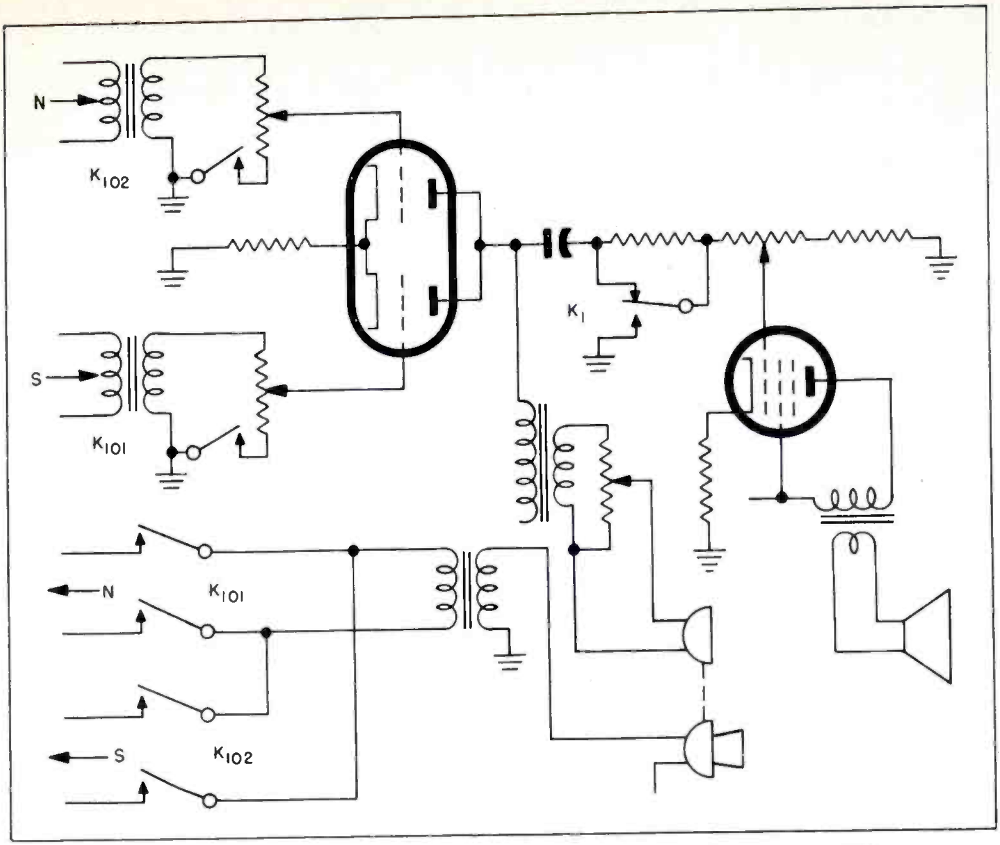


Figure 4. Simplified Schematic Diagram of Intercom Unit

Channel 1 on the terminal blocks at the top of the CMT-4 racks. As shown in figure 5, the unit is mounted on a standard 19-inch panel, 14 inches high. The total depth is 8 inches, and the depth behind the front panel is 2¾ inches. Total power consumption is approximately 62 watts, and stand-by power consumption is about 52 watts.

The following table lists the description of parts not covered in the schematic diagram.

QUANTITY	SYMBOL	DESCRIPTION
1 ea.	K_1	Relay, miniature telephone. Contact arrangement 2-C. 24-volt, 300-ohm coil.
1 ea.	T_1	Transformer, power. Cased and shielded. 90-100-110-120-volt, 50/60-cycle primary. Secondaries: 35 volts, 1 ampere; 225-0-225 volts, 0.1 ampere; 6.3 volts, 3 amperes.
1 ea.	T_2	Transformer, audio interstage. Cased and shielded. 15 K to 500 ohms; 15-ma. primary. Response, ± 1.5 db from 300 to 3000 cycles.
1 ea.	T_3	Transformer, audio output. Cased and shielded. 4 K to 5 ohms and 500 ohms; 50-ma. primary. Response, ± 1.5 db from 300 to 3000 cycles.
1 ea.	T_4	Transformer, audio microphone. Cased and shielded. 100 ohms to 600 ohms; 100-ma. primary. Response, ± 1.5 db from 300 to 3000 cycles.
1 ea.	SR_1	Rectifier, selenium, bridge-type. 24-volt, d-c output at 1 ampere.
2 ea.	T_{101} & T_{102}	Transformer, audio input. Cased and shielded. 600 ohms to 60 K. Response, ± 1.5 db from 300 to 3000 cycles.
2 ea.	K_{101} & K_{102}	Relay, miniature telephone. Contact arrangement 4-C. 24-volt, 300-ohm coil.
1 ea.	SW_{101}	Switch, hook with hanger.
2 ea.	SW_{102} & SW_{103}	Switch, push button, long-frame telephone type.
2 ea.	L_{101} & L_{102}	Lamp assembly, long-frame telephone type.

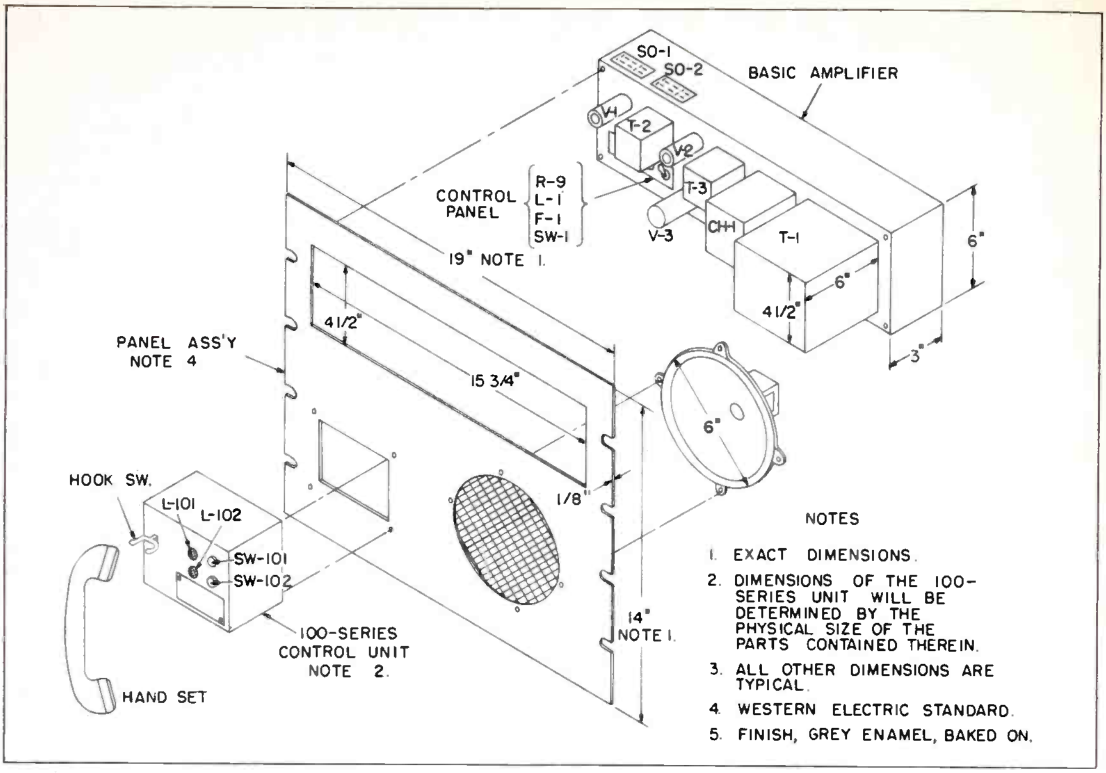


Figure 5. Intercom Unit, Showing Construction and Layout

CONCLUSION

Two Engineering-Channel intercom units were fabricated, and are now installed in a prototype microwave installation at FEALOGFOR Headquarters. The unit has since been redesigned to provide a more orderly parts layout and to effect savings in the metal fabrication required. The electrical characteristics remain the same as in the present models.

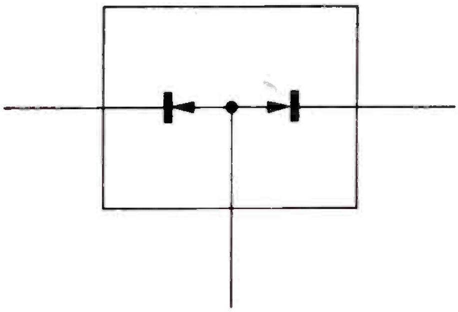
This unit provides the proper termination for the CMT-4 multiplex equipment to enable maintenance and operating personnel to talk over Channel 1. It is compact, neat in appearance, and fits the CMT-4 rack like a glove. Its operation is simplicity itself—just lift the handset, punch the proper button, and . . . "Hey Joe, this is Moe."

Solution to . . .

Last Month's

"What's Your Answer?"

The box contained two crystal diodes, as shown:



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