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IN THIS ISSUE

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Page

BUY WAR BONDS

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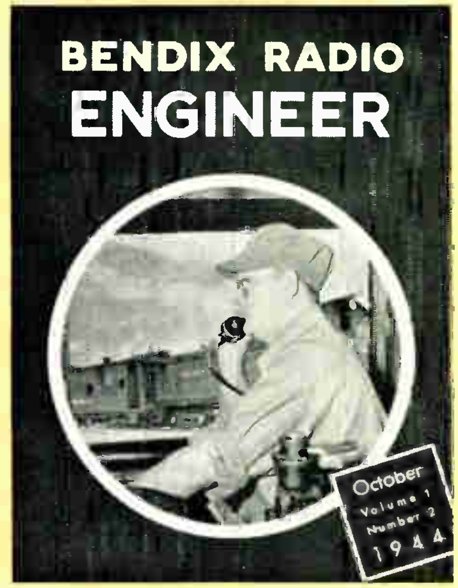


The Cover

W. A. Miller, engineer on the Baltimore and Ohio Railroad, is shown using a handset for radio communication with the yardmaster in one of a series of recent tests to determine the practicability of train radio at frequencies above 150 mc. The results of the tests, which were conducted in cooperation with four of the nation's leading railroads, are discussed in an article on page 6.

BENDIX RADIO

Probably every generation feels that its opportunities are limited by the accomplishments of previous generations. But experience has proved that the untapped possibilities of nature are as limitless as a summer's night sky. The curious and imaginative man can project himself beyond the frontiers of learning and open new realms of investigation for himself and those who follow.

Editorial Staff

BROAD BAND ANTENNA DESIGN

A discussion of some of the practical considerations in designing antennas capable of covering a wide range of frequencies.

By J. P. SHANKLIN
Transmitter Engineering

THE LITERATURE on broad band antennas is far from complete. Accordingly, when it became necessary to design an antenna of this type in Transmitter Engineering, considerable research and experimentation was required. This article is a summary of the more important principles evolved, with some discussion of impedance matching as related to work of this nature.

A broad band antenna can be defined as one which presents an essentially constant impedance over a wide operating frequency range. It is common practice to define the operating frequency range as that range which the antenna will cover in producing a certain maximum standing wave ratio (or percentage of reflection) while fed from a generator through a line having a specified surge impedance.

Calculating Impedance Range

Using this definition, the impedance range presented at the input to the line can be readily determined. The formulas are:

$$\Delta = \frac{E_{max}}{E_{min}} \qquad (1)$$

$$\Psi = \frac{E_{max} - E_{min}}{E_{max} + E_{min}} \qquad (2)$$

where Δ = standing wave ratio,
Ψ = percentage of reflection and
E = voltage.

For example, consider a transmission line with a 2:1 standing wave ratio. Let this line be cut at a point of maximum voltage. It can be seen that a resistive input of 200 per cent line impedance will be presented. If successive 1/16 wavelengths are cut off, the input impedance will vary in accordance with table 1.

Table 1 indicates that the resistive component changes from 200% Z_0 to $\frac{Z_0}{200\%}$ a ratio of 4 to 1, or a total change of 150 per cent Z_0. The reactive component varies from plus 75 per cent Z_0 to minus 75 per cent Z_0 or a total of 150 per cent Z_0. Furthermore, any two impedances one-quarter wavelength apart are reciprocals with respect to the line impedance and bear the relationship:

$$Z_s = \frac{Z_0^2}{Z_r} \qquad (3)$$

The same range of impedances may be covered by terminating the line with any impedance which will create a 2:1 standing wave ratio on the line and varying the generator frequency, or by terminating the line with an antenna which reflects the range of impedances in table 1 over the operating frequencies. These impedances can be conveniently measured with a standing wave indicator and used with a circle diagram.

The foregoing discussion assumes no line losses. In actual practice, at very high frequencies, when solid dielectric lines of practical lengths are employed, the standing wave ratio at the signal source may decrease to much less than at the antenna. This is particularly true when the standing wave ratio at the antenna is high. Under such conditions, line losses will also be high.

So far, we have discussed transmitting antennas. In a receiving antenna system, a good impedance match between the line and the antenna is also desirable since proper matching determines the percentage of received power which will be fed into the line. In this case, however, the standing wave ratio is determined by the match between the line and the receiver input circuit. When receiving high-modulation frequencies, as in television for example, it is important to have proper matching at both ends of the line because of the wide bands employed and because a portion of the signal may be reflected from the receiver back to the antenna, causing a second pulse which will result in images or "ghosts." In a reverse sense, the same situation applies to transmitted signals.

TABLE I

Transmission Line Cut At	*Input Impedance in % of Line Surge Impedance Z_0*
Max. V	200 ±j0
Max. V − $\frac{\lambda}{16}$	140 +j73
Max. V − $\frac{\lambda}{8}$	80 +j60
Max. V − $\frac{3\lambda}{16}$	57 +j28
Max. V − $\frac{\lambda}{4}$	50 ±j0
Max. V − $\frac{5\lambda}{16}$	57 −j28
Max. V − $\frac{3\lambda}{8}$	80 −j60
Max. V − $\frac{7\lambda}{16}$	140 −j73
Max. V − $\frac{\lambda}{2}$	200 ±j0

In the practical design of broad band antennas, three important principles may be used. These principles are:

1) The use of conformations which will decrease the reactive component to a greater degree than the resistive component.

2) Application of reactance correcting circuits or opposing reactances (of opposite polarity) in two or more antennas.

3) Matching the antenna (theoretically) to the ether.

Conformations

Conformations which will decrease the reactive component faster than the resistance may be constructed in one of the following ways: a) by increasing the diameter of the dipole, b) by forming the dipole from two cones with their vertexes together, or c) by attaching suitable discs to the ends of the dipole. Such arrangements result in dipoles considerably less than a half-wave-length long at resonance.

The center-fed dipole has impedance characteristics which are similar to a quarter-wave transmission line section open at the receiving end. It differs from the transmission line in that capacity and inductance are not distributed uniformly over its length. It also differs from the series resonant circuit because the resistive component is not constant but increases with the frequency, while the reactive component increases at a more rapid rate with decreasing frequency. Furthermore, broad band dipoles vary more from the characteristics of series resonant circuits and transmission lines than dipoles made from small wire. The broad band dipoles result in a circuit of lower L/C ratio. Thus, since the radiation resistance will be reduced only slightly, the Q of the antenna will be lower.

Figure 1 is actually an impossibility, but its theoretical acceptance will aid in visualizing the broad band effect realized when the dipole is capacity loaded. We have as-

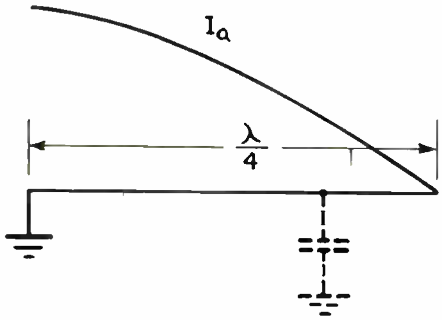


Figure 1—Curve showing current distribution in a theoretical antenna which has been capacity loaded.

sumed a quarter-wave grounded horizontal antenna. The current distribution is approximately sinusoidal and the radiation resistance is proportional to the area underneath the current curve. If some of the free end is cut off and resonance is maintained at the same frequency by means of added capacity to ground, the current distribution in the remaining section will not have changed. We have slightly decreased the radiation resistance, reduced the inductance in proportion to the length cut off, and increased the capacity. It is obvious that the radiation resistance, or impedance, of the antenna has decreased to some extent. This method is sometimes used to match a transmission line of low Z_0 to the center impedance of a small wire type dipole.

The foregoing discussion applies to center-fed dipoles. The end-fed dipole performs in a somewhat similar manner with respect to broad band applications. However, the end-fed dipole has more nearly the characteristics of a parallel resonant circuit and a shorted quarter-wave line. The impedance of this type of dipole is high and falls off rapidly when it is capacity loaded for broad band use. This is because of its similarity to the parallel resonant circuit for which the following relation applies:

$$R_p = \frac{X_L{}^2}{R_s} \qquad (4)$$

where

R_p = end impedance of the dipole,

R_s = center impedance of the dipole and

X_L = inductive (or capacitive) reactance at resonance of analagous circuit.

Capacitive loading decreases X_L more rapidly than R_s and, since R_p varies as the square of X_L, the end impedance falls off quickly.

Selection of a particular conformation for broad band use is affected more by mechanical limitations than electrical properties. Obviously, the double cone dipole cannot be end-fed nor is it practical to center-feed a cylinder of very large diameter.

One interesting type of dipole which has inherently broad band characteristics is the folded dipole illustrated in figure 2. It is, in effect, two dipoles in parallel, one of which is center-fed. This type is often used for impedance matching by changing the diameter ratios of the fed and unfed legs. By such an arrangement, the impedance theoretically can be varied from that of a single center-fed dipole on to infinity. If the legs are of equal diameter, half of the current will flow in each leg and the input impedance will be about four times that of a center-fed dipole. Using small diameters and with distance X also small, the impedance will be 73.3 × 4 = 293.2 ohms.

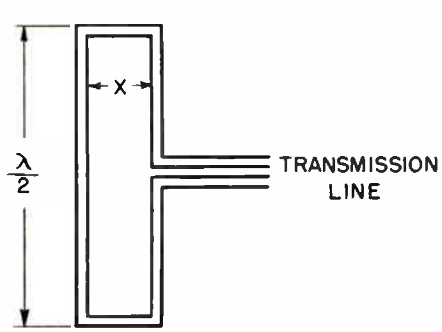


Figure 2—Folded dipole antenna in which broad band characteristics are inherent.

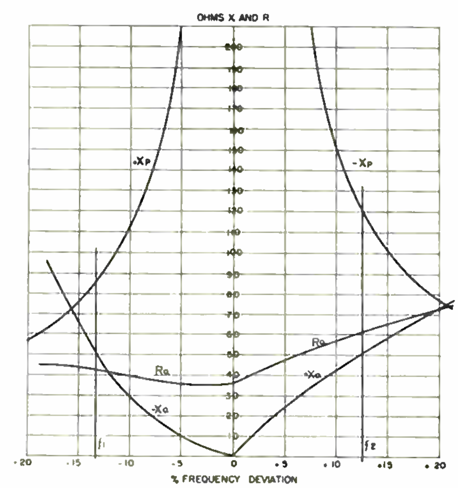


Figure 3—Impedance characteristics of the double cone dipole shown in figure 4. R_a and X_a are resistance and reactance of antenna without corrector. X_p is reactance of corrector alone.

To give the folded dipole broad band characteristics, it is necessary to increase the diameter of the legs and also to increase the distance X. As X increases, the radiation pattern becomes slightly irregular and some horizontally polarized signal appears. If X is less than one-sixteenth wavelength, these effects are small.

It should be noted that placing a broad band dipole in a directive array or near metal or other reflecting surfaces will decrease its broad band characteristics since mutual coupling decreases the radiation resistance and increases the reactive component.

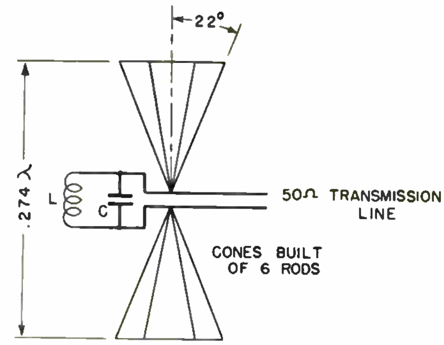


Figure 4—Double cone dipole antenna equipped with reactance corrector circuit.

Correction Circuits

Figure 3 represents R_a and X_a as experimentally obtained resistive and reactive characteristics of the double cone dipole shown in figure 4. The X_p curves are the L and C reactances of figure 4. The Q of this antenna is so low that the circuit L/C may be considered as having infinite Q.

Curves R and X in figure 5 show the resistive and reactive characteristics of a dipole with reactance corrector circuit. It will be seen that near resonance, the characteristics differ very little from those of the dipole alone. Near the frequencies f_1 and f_2 the resistance has increased considerably. This is because at these frequencies we have a condition of parallel resonance between the reactance of the dipole and that of the corrector circuit which results in a high impedance caused by the circulating current.

A more practical application of the principles involved is given in figure 6. In this case, the dipole of figure 4 is fed by a 50-ohm coaxial line through a "bazooka" balancer. The "bazooka" functions to transfer the antenna from a balanced to a coaxial or single-sided load without changing the im-

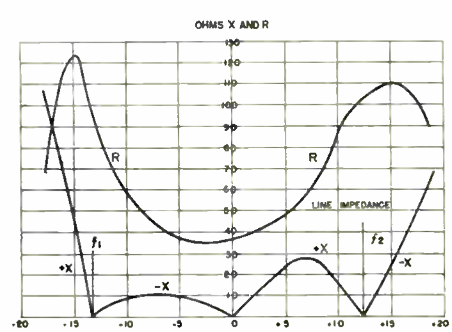


Figure 5—Impedance characteristics of the double cone dipole antenna equipped with reactance corrector circuit.

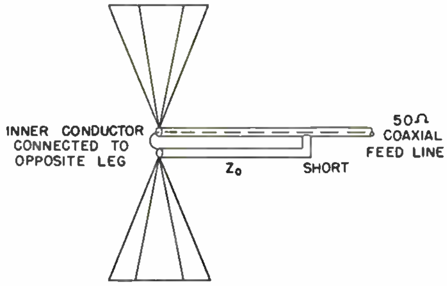


Figure 6—Double cone dipole fed by a "bazooka" balancer acting as reactance corrector.

pedance. If the Z_0 of the "bazooka" is made equal to $\sqrt{\frac{L}{C}}$, the balancer will also replace the function of the L/C circuit in figure 4. The reactance characteristics of a line and lumped constant circuit is almost identical over the range of frequencies a dipole may be made to handle satisfactorily. Reference to figure 5 will show that the antenna impedance at the band center is lower than the line impedance, while at points f_1 and f_2 the reverse is true. This is because the antenna was designed so that its average impedance will approximate that of the line. Such an antenna will give a standing wave ratio of 2:1 at f_1 and f_2 with a 1.40:1 ratio at the center frequency (see figure 7). If it is desired to cover a wider frequency range and to maintain less than a 2:1 standing wave ratio, some resistance can be introduced in the "bazooka" short. This resistance will absorb very little energy at the center frequency and will reduce the impedance at the edges of the band. This procedure must not be carried too far, but if one quarter of the power is absorbed at the extremes, frequencies may be extended considerably. Figure 8 is a model of this antenna built in Transmitter Engineering.

The "bazooka" is a very convenient balancer for broad band antennas. If it is not desirable for the "bazooka" in figure 6 to act as a parallel resonant circuit, it is merely necessary to make its surge impedance between 200 and 300 ohms. Then its impedance will be so high that it will have

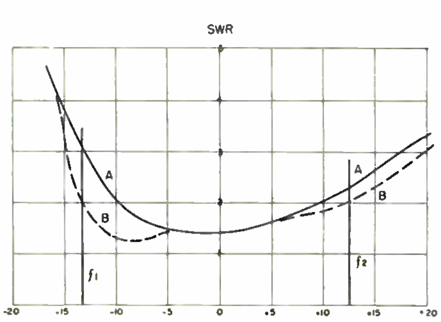


Figure 7—Standing wave ratio of double cone dipole antenna. A. Without reactance corrector; B. with reactance corrector.

very little effect over the frequency range involved while still acting as a balancer.

Just as the center-fed dipole may be corrected by shunting a parallel resonant circuit across its input, so the end-fed dipole may be corrected by placing a series resonant circuit in series with its input. The antennas in figure 9 employ two end-fed dipoles. The fundamental circuit is shown in figure 9*a*. In figure 9*b* the series resonant circuit is composed of a quarter-wave open-end section of line consisting of a rod (quarter-wave long) acting as the center conductor and a cone which serves as the outer conductor of a coaxial line. Figure 9*c* is another application of the same principle. A quarter-wave supporting stub is added at *a*. Since the broad band dipole will be less than a half-wave long, a capacity has been added to increase the inner line to a half-wave effective length.

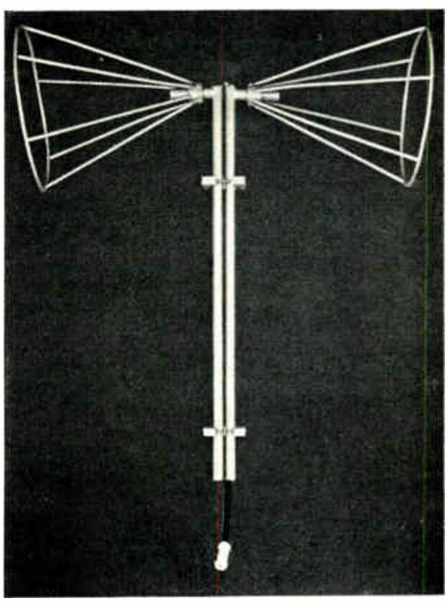


Figure 8—Model of double cone dipole fed by a "bazooka" balancer, built in Transmitter Engineering.

A second method of increasing frequency range is by the use of opposing reactances of opposite sign in two or more antennas. Figure 10 shows a turnstile or rotating phase antenna composed of dipoles crossed at right angles. These dipoles have a center impedance of approximately 200 ohms, determined by their proportions, and are fed by two 200-ohm lines. The 200-ohm lines are, in turn, fed by a single 100-ohm line. The former are arranged so that they differ by a quarter wavelength. This type antenna radiates a horizontally polarized wave of practically uniform intensity in all directions. It has broad band characteristics because of the folded dipoles and because the quarter wavelength difference between the feeders results in the antenna impedances appearing as reciprocals with

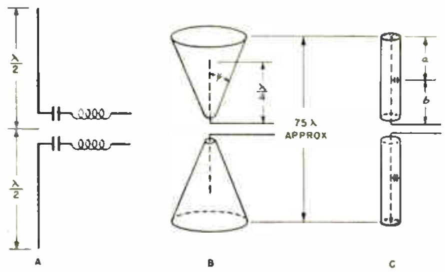


Figure 9—End-fed dipoles with resonant circuit in series with input. A. Fundamental circuit; B. rod and cone acting as series resonant circuit; C. quarter-wave supporting stub at a and added capacity to form resonant circuit.

respect to line impedance at their junction point. The following relationship then holds:

$$Z_s = \frac{Z_0^2}{Z_r} \qquad (5)$$

In general, if one dipole appears inductive at the junction, the other will appear capacitive, and if one dipole appears resistive but higher than the line impedance, the other will appear resistive and lower than the line impedance. The compensation would not be perfect even with the difference in feeder lengths maintained at a quarter wavelength over the operating range. Some idea of the improvement which can be expected, however, was demonstrated by RCA when the television antenna atop the Empire State Building was found to cover double the range of a single antenna when connected in this manner. There are a number of versions of rotating phase antenna systems to which the principle of the quarter-wave difference in length is inherently applicable.

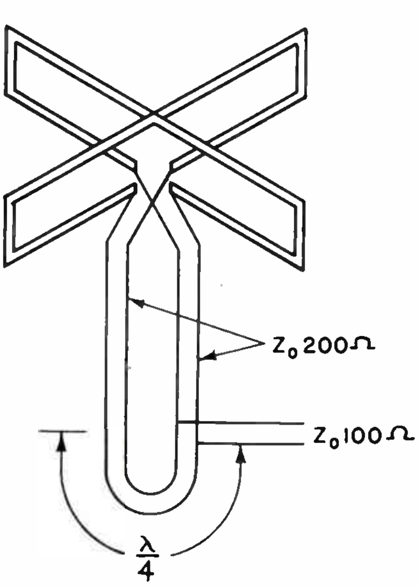


Figure 10—Turnstile or rotating phase antenna composed of folded dipoles crossed at right angles.

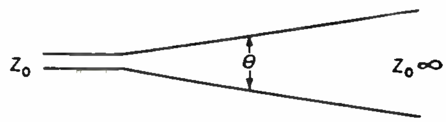


Figure 11—Impedance of transmission line shown increasing with length by expanding line at a fixed angle.

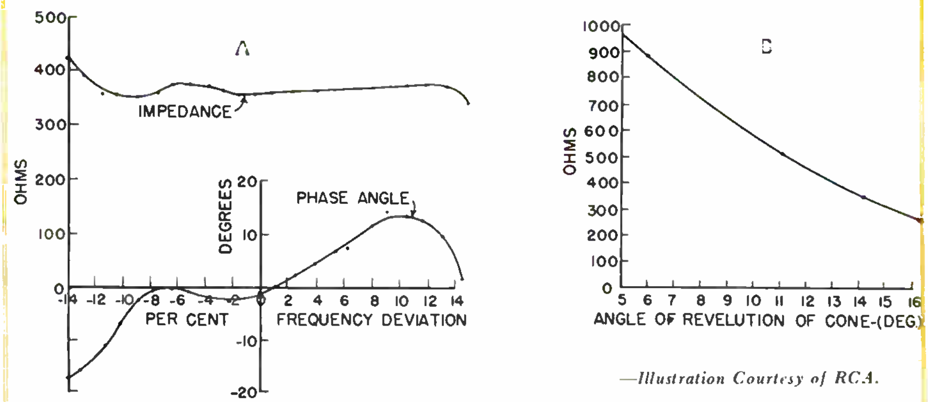
Matching Line to Ether

Figure 11 illustrates a transmission line whose impedance increases with length by expansion of the line at some fixed angle. If θ is small (so that the line impedance does not more than double in the first half wavelength of expansion) and the line is very long, all of the energy will be radiated and there will be no reflection. Accordingly, with increased spacing, the radiation increases. This figure will be recognized as half of a rhombic antenna which explains the inherent broad band characteristics of the rhombic type.

Figure 12 shows a double cone antenna fashioned of sheet metal. If this type is made several wavelengths long on a side, there will be no reflection for the same reason pointed out in the discussion of the expanding transmission line. In this case, however, the impedance of the line does not increase since the cones have a definite Z_0 depending on the angle of revolution Ψ. Therefore,

$$Z_0 \text{ of cones } = 276 \log_{10} \cot \frac{\Psi}{2} \qquad (6)$$

Cones do not have to be extremely large to exhibit satisfactory broad band properties. When proportioned to resonate as a dipole, they have the properties previously described. Carter* found that when proportioned as two end-fed half-wave dipoles, the over-all length of the cones was approximately 0.73λ and that they presented the impedances of figures 13^a and 13^b.



—Illustration Courtesy of RCA.

Figure 13—A. Curves showing impedance-frequency characteristic of sheet cones; B. curve showing effective impedance as function of the angle of revolution of the cones.

John P. Shanklin

John Shanklin's interest in radio dates from 1920. Started as a hobby, it developed into a vocation and, from 1921 on, he owned his own amateur radio station. After his graduation from Virginia Polytechnic Institute in 1929 with a Bachelor of Science degree in Electrical Engineering, he was employed by RCA Communications, Incorporated, and worked at the Rocky Point shortwave transoceanic transmitting station and the Riverhead, Long Island, receiving station. Two years later, other business interests interrupted his career in radio and the next eleven years were spent as manager of a family-owned concern. Shanklin did not entirely lose contact with the radio industry through this period however, but acquired two radio patents and contributed articles to "QST." He came to Bendix Radio in March, 1943, took the engineering training course, was assigned to the Transmitter Engineering Section as a junior engineer, and is now an assistant project engineer engaged in designing antennas.

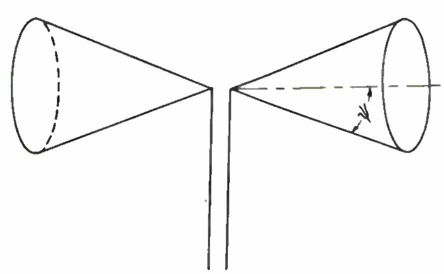


Figure 12—Double cone antenna fashioned of sheet metal. Reflection will not occur if antenna is several wavelengths on a side.

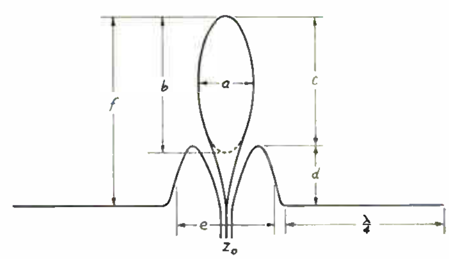


Figure 14—"Football" antenna whose impedance is determined by the c/d ratio.

The surface of the cone can be simulated with metal rods as in figure 4. Here six rods proved sufficient. Twelve rods were tried with no improvement. For half wave cones, however, Carter found twelve rods satisfactorily simulated the solid surface.

The RCA television antenna on the Empire State Building is a configuration which exhibits characteristics between the quarter-wave and half-wave cones in so far as band width is concerned. It is half of a dipole or a grounded quarter-wave antenna fed at an intermediate point. Its impedance is determined by the ratio c/d in figure 14.

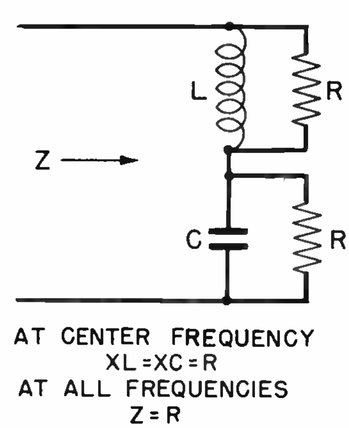


Figure 15—Network resonant at all frequencies.

* "Simple Television Antennas," *RCA Review*, October, 1939.

The smaller this ratio, the higher the impedance. The proportions of the Empire State Building antenna were reached after considerable experimentation. All curved surfaces are elliptical. The conformation is such that the reactance is reduced without decreasing the radiation resistance greatly and it is said to approach the combination of L, C, and R of figure 15 which is resonant at all frequencies.

The antenna illustrated in figure 14 was reconstructed, in the Transmitter Laboratory, to the dimensions shown in figure 16. Rods were used to simulate the solid metal surfaces. The extension of the outer conductor of the coaxial line and the ground plane was composed of eight rods. The "football" or extension of the center conductor was made of six rods. This antenna gave impedance characteristics which were quite similar to those of the cones in figure 3 but covered a considerably broader band.

It is not known to what extent the rods simulated the antenna surfaces. Broad band characteristics may have been limited because of the finite size of the ground plane. The antenna built to the dimensions of figure 16 had a resonant impedance of 33 ohms. Figure 17 shows the characteristics of the antenna with a parallel resonant circuit containing some resistance which is used for correction purposes. This antenna exhibits very good characteristics and maintains a standing wave ratio of less than 2:1 from +19 per cent to −19 per cent of the resonant frequency. The correction is not quite complete at the frequencies where a 2:1 standing wave ratio exists, indicating a lower L/C ratio is needed in the correction circuit.

(The mathematics for determining proper L and C constants used in corrector circuits will be found in an appendix to this article on page 33.)

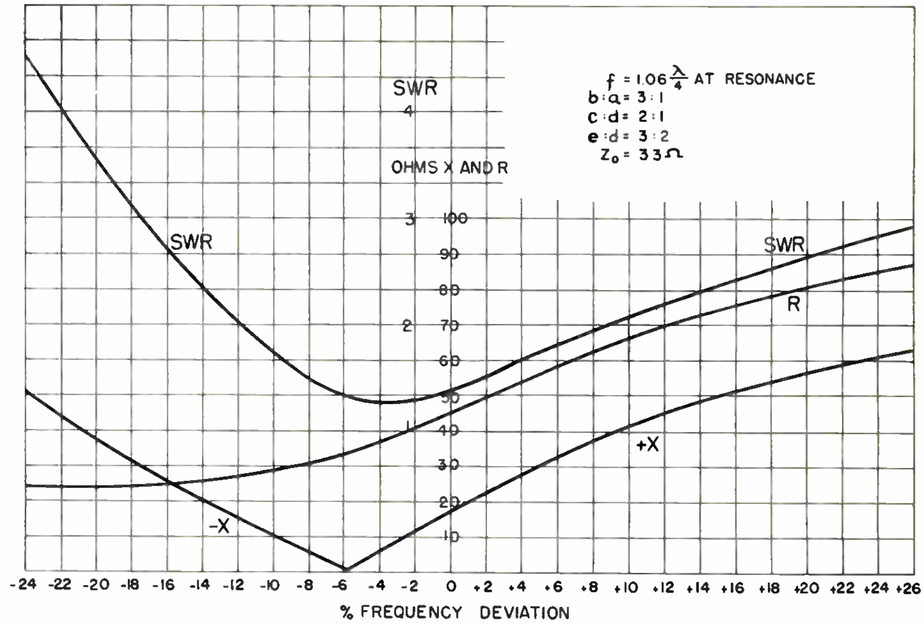


Figure 16—(Above) Impedance characteristics of standing wave ratio of "football" antenna without corrector.

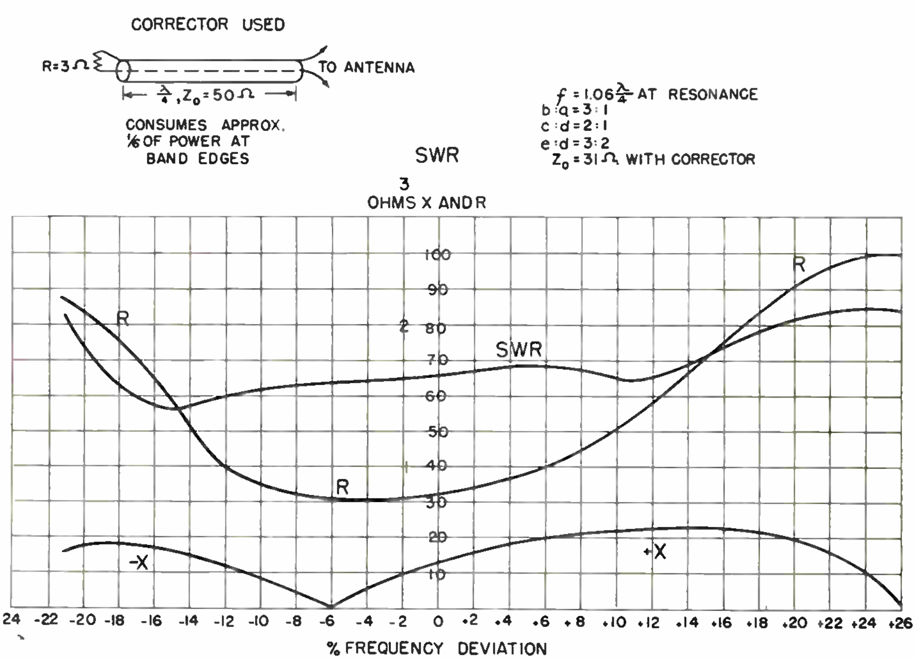


Figure 17—Impedance characteristics of standing wave ratio of "football" antenna with corrector.

The Cranks Give First

When Harold A. Varley of the West Coast Branch, visited the Fort Worth Army Air Base, he was surprised at complaints of excessive breakage of tuning cranks on BC-434-A Control Boxes. Inquiry revealed that, in all aircraft in which the control box was mounted on the ceiling of the cabin, breakage was caused by flight personnel bumping their heads on the crank arm. Further inquiry about what happened to the heads disclosed that, since a small impact breaks the crank, no serious injury to personnel resulted.

—Photo Courtesy Baltimore and Ohio Railroad

Roy B. White, Baltimore and Ohio president, using remote control facilities in Camden Station. A. S. Hunt, general superintendent of communications, looks on.

—Photo courtesy of Santa Fe Railway

Inside the cab of switch engine 2311, Santa Fe Engineer R. B. Brown answers a radio telephone call from the yardmaster's office at Los Angeles.

TRAIN RADIO GOT ITS first tryouts at a frequency above 150 mc in a series of tests conducted by Bendix engineers working in cooperation with four major railroads.

To determine whether existing means of end-to-end and yard communications can be supplemented with vhf equipment, a license and a frequency allocation were secured from the FCC on an experimental basis. Train facilities were made available by the Atchison, Topeka and Santa Fe, the Baltimore and Ohio, the Chicago, Burlington and Quincy, and the Seaboard.

Equipment Design

Amplitude modulated equipment, set up to operate on 156.525 mc, was used in all tests. The mobile transmitter-receiver unit is crystal-controlled, and combines facilities for receiving speaker call signals along with the handset transmission and reception characteristic of the ordinary telephone. The unit, with its dynamotor power supply, is inclosed in a case measuring 24 x 21 x 18 inches, and weighs approximately 75 pounds.

Transmitter power output of approximately six watts is available at the operating frequency. Receiver sensitivity is approximately three microvolts for ten milliwatts audio output at a signal-to-noise ratio of ten to one. The unit, pre-wired and interconnected by means of removable cables to a handset designed for push-to-talk operation, is placed in the engine and caboose in a position convenient for the train crew. The handset is wired into a desk-type extension hookswitch, as well as into a permanent-magnet type speaker.

In actual operation, an incoming signal is heard on the speaker. The operator then removes the handset from its position and answers the call by pressing the push-to-talk button on the handset to transmit, and by releasing the button to receive. A gain control permits adjustment of the volume level.

Road Tests

For the Chicago, Burlington and Quincy tests held in Chicago last June, L. B. Gilmer, sales engineer, supervised the installation of two such units, one in a Diesel switch engine and the other in a caboose. An additional unit powered by commercial mains, and equipped with handset and speaker was placed in the yardmaster's office to provide communication with both ends of the train. A "J" type antenna, mounted approximately 120 feet above the ground, was connected to this unit by a flexible coaxial cable about 100 feet long.

In a demonstration of the equipment, radio messages directed the entire movement of a train. Starting from the passenger station, the train moved over the tracks within the Chicago switch yards, and then over the tracks of an electrified system to prove the lack of electrical interference at the operating frequency. The absence of external electrical disturbance throughout these tests is noteworthy.

A 2200-Mile Run

On the Santa Fe, end-to-end communication was of prime interest. The same type of equipment used in the Burlington test was installed in an engine and caboose. Experiments under the direction of R. B. Moon, manager of the Bendix Radio West Coast Branch, have been particularly valuable for the information yielded on the problem of antennas. Antennas, of course, must be short enough to clear bridges and tunnels. Straight quarter-wave vertical types of a suitable length for operation at 156.525 mc were first used, but permitted only a limited range of signals. They were replaced by others of a coaxial type with somewhat improved results. The final version was a vertical quarter-wave element, with four horizontal quarter-wave elements at its base to serve as a ground plane.

Following tests in and near the switch yard, a fast freight train, Diesel-powered and equipped with these units, maintained radio communication between engine and caboose for the entire 2200 miles of its run between California and Chicago.

This train started on July 14 with 75 cars, and during the five-day trip sometimes carried as many as 96 cars. Its average length was three-quarters of a mile. Good results were obtained on the entire run although the route of the train passed through mountain regions as well as over flat terrain, and included half-circle curves, sharp curves with whole mountain sides between locomotive and caboose, long tunnels and cuts. As in the Burlington tests, no electrical disturbances occurred during the entire trip.

The Seaboard Railway

The test run made on the Seaboard Railway in July between Richmond and Miami was pronounced by W. L. Webb, chief engineer of Bendix Radio, to have been "a complete success from the viewpoint of satisfactory end-to-end railroad communication." Mechanical installation of equipment was made partially by Seaboard personnel but completed by A. L. Bohn, C. M. Dorsey, Max Fernbach, R. F. Hoover, and Anthony Pickman, Bendix engineers assigned to the project. Howard Walker, W. H. Sims, Jr., and A. R. Perong were also closely associated with the development of the equipment.

The installation in the nose of the freight-type Diesel engine operated on 156.525 mc. The handset and loud speaker were on the

Radio

—*Photo courtesy of Santa Fe Railway*

In the Los Angeles yards of the Santa Fe, yardmaster O. M. Soderberg hangs up the receiver after completing a radio telephone conversation with the engineer of a switch engine.

—*Photo courtesy St. Petersburg Times*

Aboard a Seaboard Railway's Diesel-electric powered freight, Engineer C. W. Tennant uses radio telephone for communication with conductor.

wall directly behind the engineer. The antenna, mounted about twelve feet from the front of the locomotive, was adapted from the Santa Fe antenna by S. J. Holland, and was also used later on the Baltimore and Ohio runs. This antenna has eight instead of four horizontal ground plane elements. The installation in the caboose was the standard setup, with loud speaker and handset on the wall in the cupola. The train, which was about three-quarters of a mile long, went around many "S" turns with low hills interposed between cab and caboose.

"At no time during the trip was any interference encountered from power lines, signal systems, train equipment or terrain," commented Mr. Webb. "The crew had no trouble making themselves understood, and found the experiment very similar to using dispatch telephones."

In the course of this trip one incident demonstrated the value of end-to-end train communication. A hotbox developed on a freight car. "It was seen from the rear end," relates Mr. Webb, "and the engineer was informed of its location by radio. He was able to stop at the next siding and cut the car out of the train. The crew told us they believed the radio saved them fifteen minutes of actual time in detaching the faulty car from the train after arrival at the siding."

B & O Yard Tests

The Baltimore and Ohio program was supervised by S. J. Holland. Besides the equipment provided for experiments on other railroads, central station transmitting and receiving units, with remote control facilities, were installed atop the Baltimore and Ohio Office Building, Baltimore. The transmitter is 73 x 21 x 18 inches, and weighs 600 pounds. Power output is approximately 50 watts. It operates from the 110-volt, 60-cycle single-phase line with a total power consumption of approximately 860 watts at 100 per cent modulation. The receiver is a superheterodyne, 19 x 10½ x 13½ inches, weighing 38 pounds. It uses a separate power supply also operating on the 110-volt, 60-cycle power. The sensitivity is better than 5 microvolts for 10 milliwatts output at a signal-to-noise ratio of 10 to 1. A dial control unit permits placing the equipment in operation from a remote position by use of a telephone line connection between the two points. The remote control unit includes handset and push-to-talk control provisions, together with a small speaker for the reception of calls when the handset is resting in the cradle.

Use for Walkie-Talkie

During a run between Baltimore and Hyattsville, Maryland, the operation of a local freight revealed that it might be advantageous for the conductor and brakeman to have some form of walkie-talkie to direct the movement of the train when picking up empty cars and spotting loaded cars on sidings. While the local freight is on a siding it is necessary that the flagman have an unobstructed view of the main line tracks. He may even be obliged to go off into an adjacent field for a better view in both directions. According to Steve Holland, the advantages to be gained by the use of more efficient communication between members of the train crew were apparent even in this short interval of observation.

Following a series of trial tests, the remote control facilities were demonstrated on the Baltimore and Ohio in the latter part of July by the chief dispatcher, who directed a switching crew to proceed from within the metal-covered train shed at Camden Station, pick up thirteen loaded freight cars, and take them to the Curtis Bay yard. Normally it would be necessary for the train crew to stop the train, walk across the tracks to the signal tower, ask which track could be used, and wait for the proper signal before proceeding. This would be repeated at each signal tower, a practice which has been in use for years.

By means of the equipment installed on the engine and caboose, this information was radioed to the engineer and conductor by the chief dispatcher, and the complete train movement and dispatching were carried on by radio communication. The chief dispatcher in his office on the second floor of Camden Station, by using the remote control unit installed there, controlled the transmitter on top of the Baltimore and Ohio Building in the center of the city. The transmissions from the engine and caboose were received in the same manner, the interconnecting link between the fixed station equipment and the remote control unit being a telephone line. The antenna used at the fixed station was a vertically mounted "J" type.

Uniform Results

The interesting thing about the vhf tests run in the four different localities is that the results obtained were identical. Each instance showed that the questions remaining to be cleared up center around engineering details involved in various types of installations rather than proof of the practicability of radio for railroad communications. By the time this is published additional tests will have been made in conjunction with the Baltimore and Ohio with equipment operating at 300 mc. Data on field strength and signal-to-noise ratio will also have been gathered, furnishing further helpful engineering information.

CRYSTAL CHARACTERISTICS

Familiarity with the various low temperature coefficient cuts obtainable from quartz crystals will help engineers obtain more efficient circuit performance.

By R. S. BAILEY
Microwave Engineering

THE QUARTZ CRYSTAL, with its piezo-electric property by which mechanical energy is transformed into electrical energy, is a well-known unit to radio engineers. Generally less familiar, however, are the significance of the various types and cuts and the important characteristics of each. An understanding of what crystal cuts can be made and what each will do, will help the design engineer to obtain maximum performance of equipment and to eliminate unnecessary circuit components.

Perhaps the most important characteristic of a quartz crystal unit is its temperature coefficient. It is well known that a quartz oscillator will produce a fairly constant frequency as long as there is no change in temperature. This condition, however, is rarely achieved and it is desirable, therefore, to obtain a crystal whose oscillation frequency is independent of temperature changes.

As the temperature of a quartz plate is varied, its dimensions, density, and elastic constants also tend to change. This causes a change in the natural resonant frequency of the plate. The temperature coefficient of frequency for quartz plates of the usual Y cut, or parallel face cut, varies from +80 to +90 cycles per million per degree centigrade at ordinary temperatures; while that of the X cut, or perpendicular face cut, ranges from −20 to −30 cycles per million per degree centigrade. It is at once apparent that, to obtain any degree of stability with the use of such plates, some elaborate form of temperature control is necessary.

It has been found that the variations in frequency caused by temperature changes can be reduced to practically zero over a limited range of temperatures by proper cutting of the plate from the mother crystal. The dimensions of the plate, its density, and its elastic constants are affected by changes in temperature; and it is necessary only to orient the plate through various angles in relation to the crystallographic axes of the mother crystal to obtain a compensatory relationship between these components which, acting together, are responsible for the temperature coefficient of the plate. This involves a rotation or orientation about one or more of the three axes, X, Y, or Z, of the mother crystal so that the principal faces of the finished plate are inclined the required number of degrees to at least two axes of the crystal.

The AT and BT Cuts

An ordinary Y cut plate rotated about the X axis of the crystal will exhibit different characteristics at various angles of orientation. Figure 1 is a curve showing how the temperature coefficient of the plate is affected as the plate is rotated. It can be seen that at an angle of +35°15′, we have a point where the temperature coefficient is zero. A plate cut at this angle is designated the "AT" cut and can be conveniently ground to almost any frequency between the limits of 300 to 5000 kilocycles. Its temperature coefficient can be held to $1/10^6/°C$ throughout a temperature variation of 80 to 90 degrees centigrade. This stability is an important factor in the selection of frequency control units for aircraft use where such extremes of temperature are encountered.

It can be seen that, by rotating the plate in the opposite direction, we obtain a point at −49° when the temperature coefficient again becomes zero. This portion of the crystal has been designated the "BT" cut and is generally used for frequencies in the range of 4500 to 10,000 kilocycles. The cut is not as active as the AT, since the AT angle of orientation is near the Y cut which has the largest piezoelectric constant and, hence, is the most easily excited. However, the BT is thicker than the AT angle for a given frequency and can, for this reason, be ground to higher frequencies. It cannot be ground to have as good a temperature coefficient as the AT cut, since the shape of its drift curve is more parabolic than that of the AT. The relationship of the two cuts can be seen from the curves of figure 2, which shows the frequency change in parts per million versus temperature changes for a number of the most frequently used cuts. The manner in which these plates are dis-

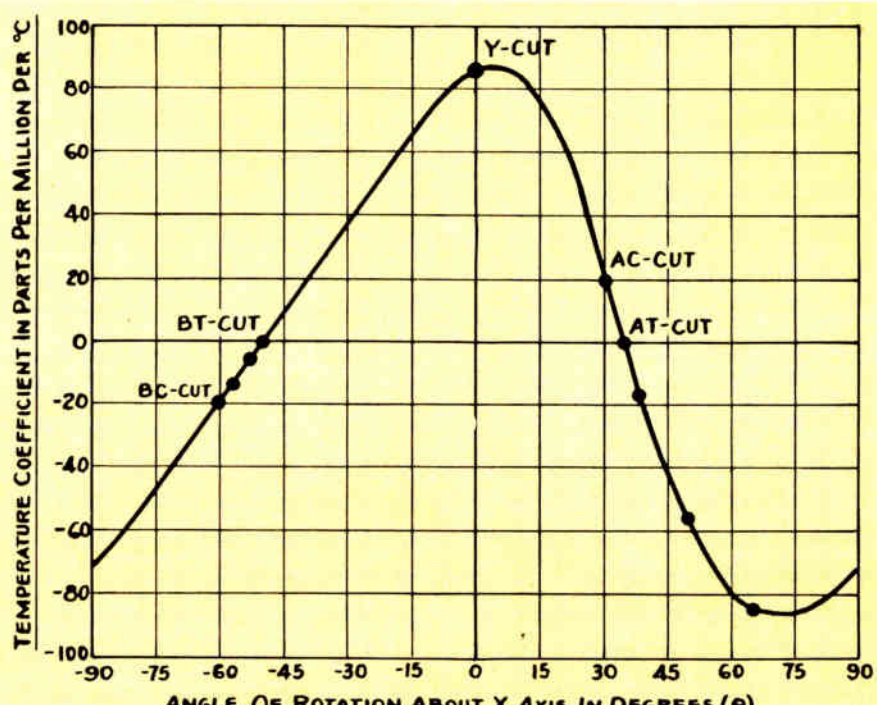


Figure 1—Variations in temperature coefficient for high frequency plates plotted as a function of the angle of the cut.

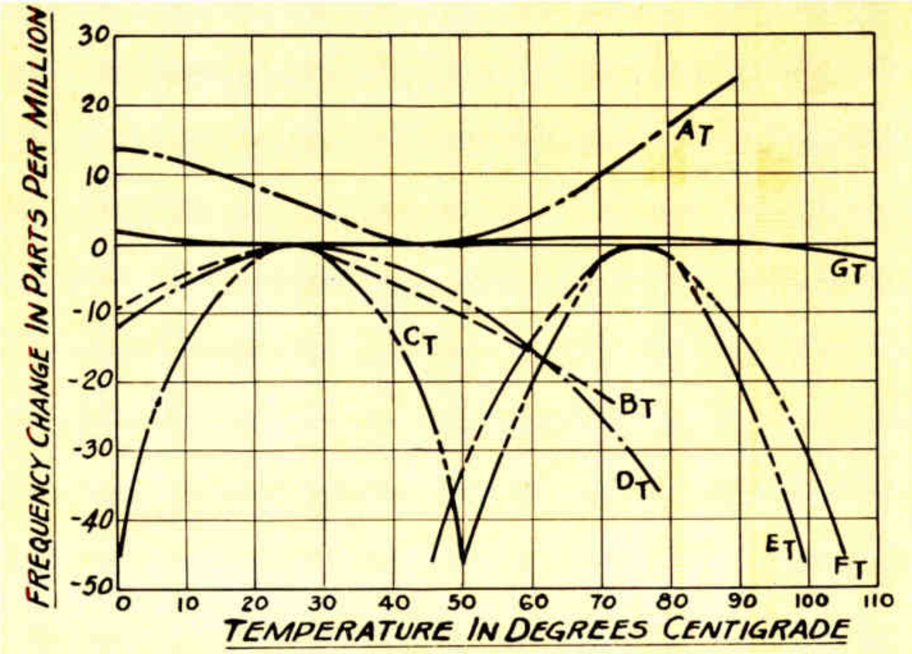


Figure 2—Variations in temperature coefficient for various cuts of crystals.

torted during oscillation can be seen from figure 3*a*.

Referring to figure 1, notice two points marked "AC" and "BC," occurring at +31° and −59° respectively. While these cuts are seldom used, it is interesting to note that they have some significance since their frequency spectrum is very clean. The elastic behavior of plates cut at these angles is such that we have zero coupling between the high and low frequency shear modes of vibration. During a variation in temperature, therefore, the crystal will maintain uniform activity and will not be subject to frequency jumps or hops. This advantage is offset to some extent by the fact that the temperature coefficients are respectively +20 and −20 parts per million per degree centigrade.

The CT and DT Cuts

At frequencies below 500 kilocycles, it is sometimes difficult to produce a crystal of the AT type of cut which will operate over a wide temperature range without serious elastic couplings between the desired and undesired modes of vibration. This difficulty occurs because the thickness of the plate becomes comparable to the length and width dimensions.

A number of cuts have been developed which are related to the AT and BT type, but which do not depend on thickness for a frequency determining dimension. Two of these cuts are termed the "CT" and the "DT." They are related to the AT and BT since they develop a low temperature coefficient by using the same shearing motion. Their frequency is determined by the length and width dimensions. Figure 3*b* shows the manner in which this type of plate vibrates. Two diagonally opposite corners move radially outward, while the other two move radially inward. The angles of cutting for these two plates are +38° and −52°, respectively, for the "CT" and "DT" cuts. The "CT" is the more active, and is used in the frequency range of about 100 to 500 kilocycles. Below 100 kilocycles, the DT cut is more practical since it is smaller in area than the CT for a given frequency. Comparison of drift characteristics of the two cuts is shown in figure 2. The curve for the DT is flatter and, therefore, possesses the better temperature coefficient over a range of temperatures. At present, the CT type of cut is used extensively in tank crystal sets for military applications.

The ET and FT Cuts

It is well known that AT and BT cut plates have harmonics which can be used to control an oscillator. The same condition applies to the low frequency shear type of vibration, CT and DT, and a plate of this type vibrating in a harmonic mode of motion is designated an "ET" or "FT," depending on the angle of cut. The ET is cut at +66°30′ and the FT at −57° to obtain a low temperature coefficient. Figure 2 shows how their temperature coefficients compare over an extended temperature range. Note that the frequency constant for this type of plate is nearly twice that of the low frequency shear mode (CT and DT) and, hence, can be used for frequencies twice as high as the CT and DT. However, the CT and DT possess the better temperature coefficient. Figure 3*c* shows the displacement which occurs during vibration.

The GT Cut

All of the low temperature coefficient plates so far described have a zero temperature coefficient through only a very few degrees of change in temperature. At either side of these few degrees, the frequency either increases or decreases, following a parabolic curve with the temperature. This can be seen from figure 2. A type of cut, called the "GT," has been developed. It will maintain a drift of 1/10⁶/°C over a temperature change of 100° centigrade. It is cut at an angle of +51°30′. This plate is made possible by the fact that a face shear vibration, such as the CT or DT, can be

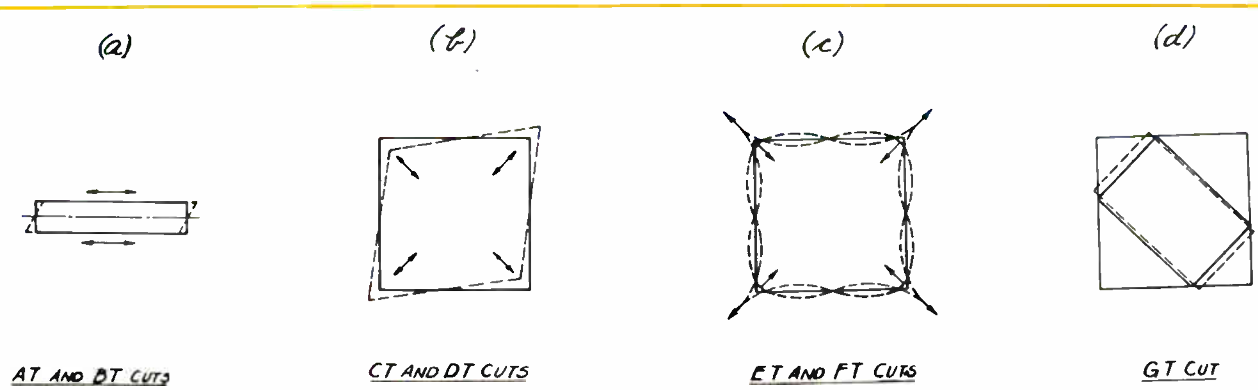


Figure 3—Displacements which occur in various types of crystals during vibration.

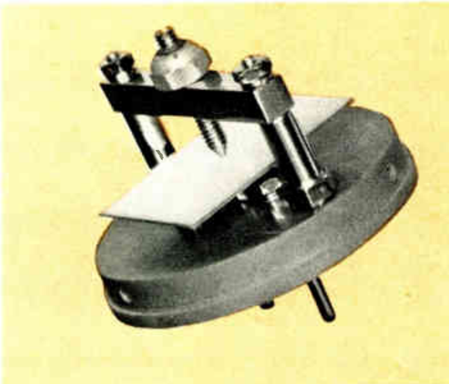


Figure 4—GT cut plate of 100 kc, mounted in holder for use in primary standard of frequency.

TABLE I

Type of Cut	Application (Frequency Range)	Mode of Oscillation	Temperature Coefficient Over 100°C Temperature Variation: Laboratory	Temperature Coefficient Over 100°C Temperature Variation: Production
AT	300-5000 kc	High Freq. Shear	$1/10^6/°C$	$3/10^6/°C$
BT	4500-10000 kc	High Freq. Shear	$2/10^6/°C$	$3.5/10^6/°C$
CT	100-500 kc	Low Freq. Face Shear	$2/10^6/°C$	$3.5/10^6/°C$
DT	50-200 kc	Low Freq. Face Shear	$1/10^6/°C$	$2.5/10^6/°C$
ET	500-1000 kc	Low Freq. Face Shear	$3/10^6/°C$	$5/10^6/°C$
FT	150-500 kc	Low Freq. Face Shear	$3.5/10^6/°C$	$5.5/10^6/°C$
GT	100-500 kc	Longitudinal	$.5/10^6/°C$	$2/10^6/°C$

changed into two longitudinal vibrations coupled together. If a crystal plate is cut at 45 degrees from a face shear vibrating crystal, as shown in figure *3d*, it can be seen that the face shear mode resolves into two longitudinal vibrations. The extremely low temperature coefficient results from the fact that all longitudinal vibrations existing in a quartz crystal, in any direction, will have either a zero or negative coefficient. Since these two modes are strongly coupled in the shear vibrations and possess a positive coefficient, it becomes apparent, as we grind on one side, that the two modes will become farther apart in frequency and finally become negative in temperature coefficient. At some ratio of length to width, one of the modes will possess a zero temperature coefficient. This ratio is quite critical. A crystal plate of this type is unsurpassed as a frequency standard. Figure 4 is a photograph of a 100 kc GT cut plate mounted in holder for use in a primary standard of frequency.

High Frequency Harmonic Plates

Quartz plates vibrating in a high frequency shear mode of oscillation may be excited at their odd harmonics to obtain direct frequency control of an oscillator tube. For example, a plate ground to seven megacycles may be excited at its third harmonic and the grid of the oscillator tube controlled at a frequency of twenty-one megacycles. Similarly, the fifth, seventh, or higher harmonics may be used. However, for operation higher than the fifth harmonic, the crystal plate cannot be used in the conventional circuits since the crystal must exhibit a positive reactance. This condition cannot be satisfied for harmonics higher than the fifth since the ratio of the shunt capacitance to the series capacitance of the crystal plate increases as the square of the harmonic, and its Q must be greater than twice the value of this ratio.

Figure 5 shows the manner in which a high frequency crystal plate vibrates at its third harmonic. The motion resembles a number of individual plates (corresponding to the order of harmonic) in parallel. The temperature coefficient of a plate vibrating at one of its harmonics will be the same as that of its fundamental mode of oscillation. Both AT and BT cuts may be excited in this manner.

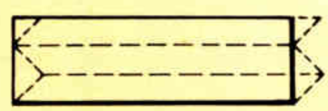


Figure 5—Displacement occurring in high frequency plate vibrating at third harmonic.

Conclusions

It becomes apparent that a number of characteristics should be considered in selecting the type of quartz oscillator for a particular application. The degree of slope to the frequency drift curve must meet the tolerances established by the specification. The type of cut chosen must have sufficient activity to excite the oscillator circuit properly, and the selected cut must have a frequency constant of such value that its physical dimensions will be of a size practical for production.

It must be remembered that quantity production means some sacrifice in the maximum attainable performance, and that the temperature coefficient specified for each of the various cuts referred to in this article is generally considered a maximum, and possible only under laboratory conditions. Table I shows characteristics of various cuts and comparison of performance under laboratory and production conditions.

Richard S. Bailey

TALL, RESERVED DICK BAILEY has been with Bendix Radio from its inception. An employee of the Radio Research Company in Washington, D. C., when it became part of the Radio Division in 1936, he was made foreman of the Crystal Department at the Fort Avenue plant. Later, he was project engineer on crystals in Instrument Engineering and, currently, is project engineer in the Microwave Laboratory. A tennis and flying enthusiast, with fifty hours' solo flying time to his credit before the war interrupted this interest, he also owned his own radio station for a number of years. Dick studied electrical engineering at Pennsylvania State College and at the Capitol Radio Engineering Institute in Washington, D. C., and was a laboratory technician for two years. He did one year's research on industrial applications for crystals and holds four patents on crystal applications and holders, with one patent pending.

ELECTROLYTIC CAPACITOR BRIDGE

Laboratory requirements for a compact and accurate electrolytic capacitor testing device have been satisfied by construction of a special bridge.

By ALFRED W. BULKLEY
Receiver Engineering

In any engineering laboratory it occasionally becomes necessary to depart from the regular work of the department and construct special-purpose test equipment. Such a device is an electrolytic capacitor bridge which has given satisfactory service in the Receiver Engineering Laboratory for more than a year.

Testing paper capacitors, formerly the only type used in low-frequency filter systems, presents no problem. Paper capacitors, however, have been almost totally replaced by electrolytic capacitors in ground radio equipment, because the electrolytic type effects a worth-while saving in space and weight.

Affected by Temperature

The chief reason electrolytic capacitors have not been adopted for universal use by the aircraft radio industry is the variation in their electrical characteristics at extremes of high and low temperature. Variations result from the nature of the dielectric, which is a thin oxide film coated on the surface of the positive electrode. Certain properties of the dielectric vary not only with changes in temperature, but also with age. For this reason there is variation in the three important characteristics of this type of capacitor: capacity, leakage, and equivalent series resistance or power factor.

Manufacturers of electrolytic capacitors have made considerable progress in recent years in improving the design of their product. Nevertheless, it is still difficult to obtain a unit meeting the rigid specifications to which airborne equipment must be built.

Obviously, it is not the function of the Receiver Laboratory to design capacitors. However, in the interest of obtaining a satisfactory component, full cooperation is given to capacitor manufacturers. Detailed information on requirements is furnished. Complete equipment, such as temperature chamber, shake table, and vacuum chamber, is available for testing many hundreds of samples submitted. Comprehensive reports are made on the results of the tests.

For use in conducting these tests, commercially built bridges have not been found sufficiently exact, although probably satisfactory for the services for which they are intended. One type, for instance, designed for a service shop, is accurate to only about 25 or 30 per cent in measuring capacitors under extreme temperature variations, whereas usual aircraft radio specifications require accuracy to about 5 per cent. Another type, designed for laboratory use, has greater accuracy, but requires considerable auxiliary equipment, making the test procedure awkward and time-consuming.

Features Required

To effect the accuracy and compactness necessary for exact and convenient operation, a piece of test equipment has been designed exclusively for testing electrolytic capacitors. A bridge for this purpose must meet the following requirements:

1) A *single*, compact, portable unit sufficiently light-weight to be moved about the laboratory.

2) Very sharp null indication for accurately measuring capacity.

3) Equivalent series resistance measurements to 10,000 ohms.

4) A test frequency of 120 cycles, with provision for other frequencies applied externally.

5) Provision for wide variations in leakage current from a few microamperes to 50 milliamperes.

6) Variable polarizing voltages to 800 volts with indicating voltmeter.

7) Provisions for external null indication.

8) Measurement of capacitance in steps of .01 µfd between .1 µfd and 1000 µfd.

9) Provision for aural null indication.

10) Built-in power supply.

Practical Design

In the newly-designed tester these requirements are met as follows:

1) By proper design, the components necessary for all electrolytic tests have been included in one case. Handles are provided to aid in carrying (see figure 1).

2) A two-stage high-gain resistance-coupled amplifier is incorporated. The output of this amplifier is fed to a vacuum tube voltmeter which functions as a null indicator. Included in the amplifier are two filter circuits tuned to 120 cycles so that harmonics of the 120-cycle signal voltage cannot mask the exact null point.

3) One of the shortcomings of previously used commercial bridges is their inability to indicate the equivalent series resistance,

Figure 1—Front view of electrolytic capacitor bridge, with capacitor attached.

which rises to a high value when electrolytic capacitors are subjected to temperatures of the order of —40°C. These bridges do not provide a wide enough range, a defect which is overcome in the present design by the use of a special three-gang rheostat, the values being 100 ohms, 1000 ohms, and 10,000 ohms (see figure 2). The proper range is selected by switch S6. These resistances are connected in one leg of the bridge, in series with the standard condenser, to compensate for the equivalent series resistance of the sample under test. More accurate balance of the bridge as well as an indication of the power factor is thus provided.

4) Most specifications require a test frequency of 120 cycles. Many commercial bridges use 60 cycles because it is convenient to provide an additional winding on the power transformer for the test voltage. An interesting circuit is used in this case whereby the primary of a transformer T3 is inserted in the high voltage lead and shunted with a 1 μfd capacitor to resonate to the 120-cycle component appearing at the cathode of the full-wave rectifier. Since most electrolytic capacitors are used at 120 cycles, this test frequency is logical. A potentiometer across the secondary of the transformer T3 varies the voltage applied to the bridge. Binding posts are provided on the front panel for injecting test voltages of any other frequency required. A switch connects these binding posts into the circuit and simultaneously disconnects one of the 120-cycle filters.

5) To provide for wide variations in leakage current, a three-range d-c microammeter is in series with the polarizing voltage. In order to protect against the high initial surge current, a toggle switch shorts out the meter except when the handle is depressed.

6) The range of polarizing voltages is from 0 to 800 volts. A voltage divider across the output of the filter system consists of a center-tapped 15,000 ohm resistor in series with a 10,000 ohm potentiometer. A selector switch, S1, and the potentiometer P1 are the coarse and fine adjustments for polarizing voltage.

7) Binding posts for an external detector are available on the front panel and controlled by a toggle switch. Occasionally it may be desirable to use a different null detector, such as a cathode-ray tube device, to give independent indications for capacitive and resistive balance.

8) Four decade resistance boxes are used in the variable leg of the bridge to indicate capacity. These resistances are of the semi-precision type and are accurate to about 2 per cent. The four variable controls provide maximum readings of 10 μfd, 1 μfd, .1 μfd, and .01 μfd, thus permitting accurate measurements to .01 μfd. Two standards are used—one of 1 μfd, and the other of 10 μfd.

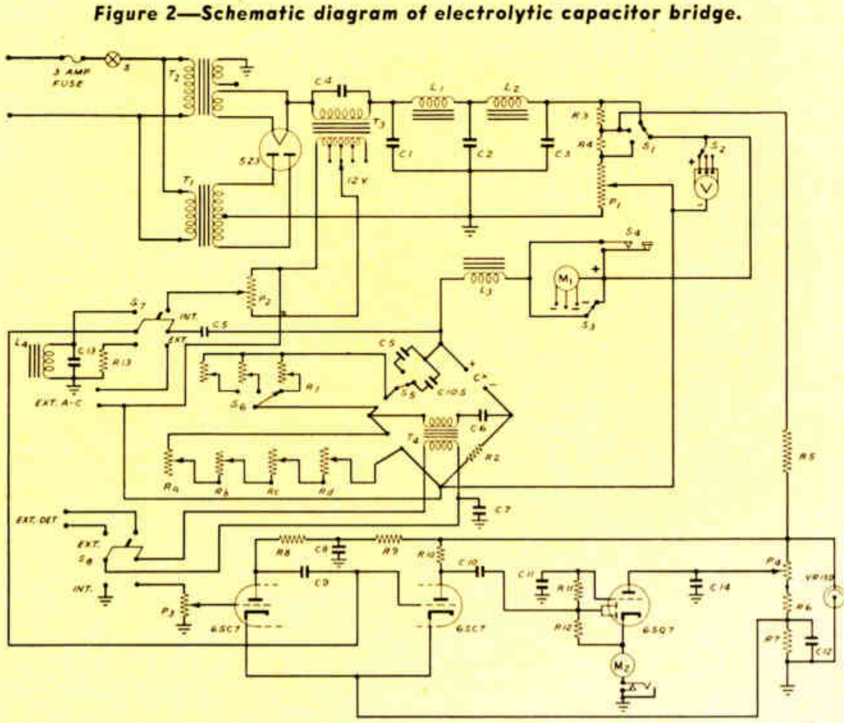
9) As an aid to finding a coarse null point, a phone jack is included at the rear of the bridge and connected to the output of the audio amplifier. Headphones inserted at this point are useful in obtaining the approximate initial balance when testing capacitors at very low temperatures, where the equivalent series resistance is high.

10) The self-contained power supply is conventional except for the insertion of the transformer T3 to furnish the bridge voltage and the use of a VR-150 voltage regulator tube to stabilize the voltage to the vacuum tube voltmeter and audio amplifier.

It has heretofore been possible to obtain from the charts and curves in reference books considerable information about the characteristics of electrolytic capacitors within a restricted temperature range. With this new instrument, however, extended tests have given valuable data about electrolytics at great extremes of temperature.

The compactness of the equipment has made it practical to test conveniently a wide variety of designs. Consequently a definite advance has been made toward obtaining a type of electrolytic capacitor which gives maximum performance both in Arctic regions and in the tropics.

Figure 2—Schematic diagram of electrolytic capacitor bridge.



A. W. Bulkley

ANY CONNECTION BETWEEN the magic of electricity and the magic of the black arts would be promptly disavowed. Still, there is A. W. Bulkley, who came to the Bendix Receiver Engineering Department two years ago from Hannibal, Missouri, after eight years in the radio parts jobbing business. Back in 1921 in physics class he built his first one-tube receiver. Later he became an active amateur operator. His diversified radio experience has taken him into the fields of engineering, repair work, instructing, radio correspondence and writer of radio magazine articles. He has constructed public address systems and electro-medical equipment such as the electrical stethoscope, and diathermy equipment. And now, since the war has restricted his outside radio activities, a new turn in his extra-curricular experiments has given him some success as an amateur magician warranting membership in the Demons Club of Baltimore and affiliation with the Society of American Magicians.

Radio Gets Its Wings

—*Official Photo, U. S. Army Air Forces*

Lieutenants Follett Bradley (now Major General, USAAF) as radio operator, and H. H. Arnold (now General in command of USAAF) as pilot, prepare to take off for first successful tests of radio in airplane reconnaissance and artillery control (1912).

IN JANUARY, 1910, radio signals transmitted from the ground were received by a plane in the air. Although the plane, built by Orville and Wilbur Wright, was suspended by cables from the roof of the Chicago Coliseum, and the signals originated in the annex of the building, the feat was enthusiastically acclaimed by the spectators. It also convinced the sponsors of the demonstration that radio was a practical adjunct to the airplane.

In retrospect the event only emphasizes the infancy of the two wonder children of the twentieth century. A 25-pound radio could still keep a light plane grounded; and the roar of the engine and propellers drowned the faint signals from the radios of the early days. Sustained performance by either airplane or radio made headlines.

Pioneering Attainments

Sustained flight at first meant twelve seconds, then eighteen minutes. Thirty-seven minutes from Calais to Dover was the record of Bleriot who landed abruptly after a wind-tossed flight on a July Sunday in 1909. In the same year, a Signal Corps plane furnished by the Wright brothers averaged 42½ miles an hour, carried two persons, and remained in the air over an hour. Even the best airplane had only an oil pressure gauge and a mediocre compass as instruments. Speed and endurance gradually increased, but flights were usually exhibitions for the next few years. To curb the daring young aviators, a member of the Missouri House of Representatives introduced an "Anti-Suicide Bill" forbidding pilots to fly above 1000 feet.

By HARRYETTE CREASY
Technical Publications

This article on the early history of aeronautical radio was prepared because it is an interesting chapter in the story of communications; and because the subject has received only casual treatment in publications on the airplane and radio. No attempt has been made to include every experiment at home and abroad, nor to describe in detail the use of radio in lighter-than-air craft. Emphasis has been directed, instead, to the milestones in the adaptation of wireless telegraphy to heavier-than-air ships.

During this period, radio telegraphy (wireless communication by code) was established commercially and ready for aeronautical development. The Marconi and subsequent systems of radio telegraphy had much in common. They all used some form of the Marconi grounded antenna with both the transmitter and receiver; and all of them coupled the transmitting antenna inductively to a tuned circuit. The main difference in these sets lay in their use of detectors. With such equipment, the Signal Corps sent messages twelve miles in 1899. The letter S was signaled across the ocean in 1901; and two years later, transatlantic service by radio telegraph was established.

Radio telephony or voice communication was yet to come at the turn of the century. About this time Fessenden transmitted speech a distance of one mile, but the reception was noisy and of poor quality. Though transmission of voice signals was considered for early aeronautical radio, Morse code was more practical.

Unlike ordinary transmitting and receiving stations, aeronautical radio sets had to operate in motion and at a height. Pioneer work under these conditions had been done with installations on balloons and on ships. Several of these developments deserve mention as part of the background of aeronautical radio.

After careful consideration, the Navy in 1903 purchased some Slaby-Arco radios—product of collaboration by a German professor and an Italian count. Their spark telegraphy system had had considerable success when, on the German ship *Deutschland*, it transmitted clearly to land from a distance of about 96 miles. A dozen of these Slaby-Arco sets were installed in the battleships of the North American fleet before a mock battle on Long Island Sound. The

Blues then beat the Reds in the battle because their radio message helped their forces rally in the dark.

By the end of 1904, the Navy had twenty shore stations in actual operation and 24 warships carrying wireless equipment. Twenty radio telephones were installed in some of the Navy vessels for the cruise around the world in 1907.

Civil War Precedent

More important to the development of radio for airplanes were the efforts to establish communication between balloons and ground stations. During the Civil War, the Signal Corps had first used balloons, equipped with telegraph wires and keys, in reconnaissance and artillery adjustment, and later for reports directly to the Capitol at Washington on the progress of the battle of Richmond. Perhaps because of the difficulty of handling the wires and transporting the balloons, their use was abandoned after the Civil War. Nevertheless, with the coming of wireless apparatus, there was precedent for adapting it to flight usage. The first radio message from air to ground was sent in England from a captive balloon in 1907; and a year later signals were received in a balloon from a distance of 20 miles.

The earliest recorded attempt in the United States to combine radio with aircraft was made by the Signal Corps, near Washington, D. C., on May 13, 1908. A small receiving set was installed in a balloon basket, from which dangled 300 feet of wire for an antenna. The basket was enclosed in chicken wire which acted as the counterpoise for the set. With this equipment Lieut. Col. F. L. Lahm, accompanied by Major Edgar Russel and Captain E. S. Wallace, received messages from altitudes between 300 and 3000 feet. Although they had considered carrying a transmitter, they were deterred by fear of fire from the spark which would have been directly beneath the gas bag of the balloon.

The enthusiasm for the performance of the equipment in this experiment and its continued acceptance during the following year elicited many contemporary accounts. The *Scientific American* [1] for February 6, 1909, carried this description:

> The whole apparatus is so compact that it occupies only a space as large as a small steamer trunk. To do away with the danger of the airship's catching fire from sparks, provision was made for confining the sparks in a wooden box and a glass case, so that there is absolutely no danger from that cause. The network of the wires which support the car of the airship, it was discovered, could be quite successfully used as the "ground" wires; and instead of the very tall poles necessary on ground stations to catch the radiations when messages are sent and received, the simple expedient was adopted of dropping a wire some 300 feet long from the airship, so that the waves instead of being caught above a station, are caught below.

Inherent in such a description of radio for lighter-than-air craft are some of the early problems which have cast their lengthening shadow into the present. For example, the problems of weight and antenna design are very real considerations to contemporary radio engineers. Not so easy to imagine, however, is the lack of alternatives known to the pioneers. Not only did they have little information from past experiments, but they sometimes duplicated each other's efforts because they were unaware of current experiments.

First Air Transmitter

The first successful radio equipment for a heavier-than-air machine was a transmitter built by Harry M. Horton in 1910. Typical of the difficulties encountered and ingenuity shown in overcoming them was the matter of an aerial for this first set. Horton recalled experiments in a Cleveland building where he could not project an aerial upward in the customary way. There he had hung wires on a window flagpole which was horizontal to the ground, and the makeshift aerial had worked. The dangling aerial used for his first airplane transmitter was an adaptation of this experiment.

Then there was the problem of grounding a set not in contact with the earth as the fixed stations were. Horton remembered that at an experimental station in Denmark, he and Valdemar Poulson had grounded a fixed station by using a counterpoise of bare wires strung through insulators on top of short posts set in the ground. Until he applied this principle, his aircraft transmitter seemed to generate enough energy but this energy would not radiate from the airplane. Horton has described his efforts to solve this problem:

> We realized that several hundred feet of wire is used in the construction of a plane. In putting more wire upon it we were multiplying our troubles rather than subtracting from them. Electrical interferences were set up between the wires we placed upon the plane and the wires that had been used in its construction. "Why not use these wires already upon the plane, even the plane itself?" we argued with ourselves. We did so and success was immediately ours.[2]

—Courtesy of Curtis

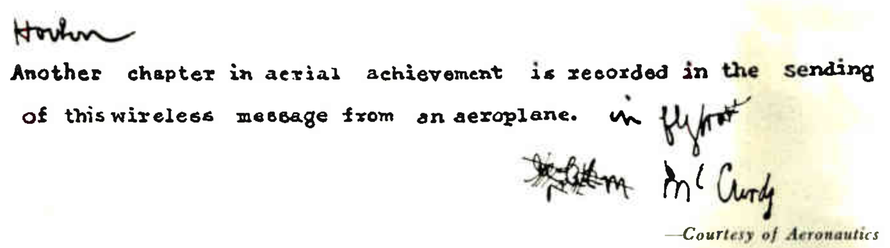
J. A. D. McCurdy was the pilot and radio operator for the first successful airplane transmission at Sheepshead Bay, and for the first distance transmission from a plane over Bridgeport to New York.

—Photo from Knight

Harry M. Horton designed the first successful airplane transmitter in 1910, received a patent for it in 1915, and was on active duty as a captain in the Aviation Section of Signal Corps during World War 1. Post-war picture above shows him as Major, Air Service Reserve.

[1] "A Wireless Apparatus for Airships," p. 112.

[2] H. M. Horton, "Story of the First Communication by Radio from a Flying Plane to Earth," *U. S. Air Services*. Vol. II (March, 1926) p. 21-23.


Horton

Another chapter in aerial achievement is recorded in the sending of this wireless message from an aeroplane. in flight

[signature] McCurdy

—*Courtesy of Aeronautics*

This first message from an airplane to the ground was sent from McCurdy to Horton in 1910. "In flight" was added to the typed copy.

The success mentioned so casually was really a spectacular affair which took place on August 27, 1910, during a Sheepshead Bay meet, seven months after reception of the message in the stationary plane at the Chicago Coliseum. A receiving set built by Lieutenant C. C. Culver, was installed in the grandstand of the Sheepshead Bay race track; and Horton's transmitter, weighing about 25 pounds, was placed just behind the pilot's seat in a four-cylinder Curtiss biplane. Representatives from the Signal Corps, from the Navy, and from the press were assembled in the grandstand for this momentous occasion. J. A. D. McCurdy, whose interest contributed much to aeronautical radio in the next few years, flew the plane and operated the transmitter. Frank D. Caruthers of the New York *World*, who wrote the first message to be sent from a heavier-than-air craft, showed awareness of history in the making. Tapped out by McCurdy, it read:

> Another chapter in aerial achievement is recorded in the sending of this wireless message from an airplane in flight.[3]

McCurdy wrote an account of the event, giving more details about the flight itself, although suggesting that the antenna and ground hook-up was the reverse of that described by Horton:

> The telegraphic key was fastened to my steering wheel and was easily operated. For a ground wire from the machine, we used a wire about 50 feet long, which, after I got well into the air, was thrown overboard and allowed to dangle behind the machine, with one end fastened to the apparatus. The antenna consisted of the guy wiring of the machine so that the whole system was very simple. I made certain definite signals (certain letters) which were easily picked up by Mr. Horton from his position on the grandstand. I flew away for a distance of about two miles and circled at an elevation of about 700 feet and within this distance the instrument worked extremely well. So far as I know, this is the first time that such an experiment has been performed . . .[4]

McCurdy tactfully neglected to mention for publication that he received a severe shock every time he touched a metal part of the machine while he was keying. This uncomfortable effect was minimized later by adding more insulation, by using the metal in the plane as part of the oscillating system, and by having the operator grasp the uninsulated lever firmly.

Nevertheless, participants and observers at this tournament were impressed by the possibilities of airplanes and of aeronautical radio. Lieutenant Culver, Major Reber, and Lieutenant Foulois[5] perceived instantly the implications of successful communication from plane to ground, and anticipated the time when planes could talk to each other. Army and Navy men continued to make strenuous efforts to secure appropriations for airplanes. A favorite story, perhaps apocryphal, was that a member of Congress remarked impatiently, "Why all this fuss about airplanes for the Army—I thought we already had one."

Army and Air Radio

Until appropriations could be secured from Congress, another airplane was loaned to the Army. Early in 1911, this airplane made what was considered a cross-country, nonstop flight of 106 miles from Laredo to Eagle Pass, Texas. Before returning on this long trip, a fifty-pound transmitter was installed in the machine. Unfortunately, Lieutenant Foulois and the commercial pilot, P. O. Parmalee, crashed before the transmitter could be tried. They were gesturing about a flock of ducks that made a startled flight near their airplane; and one of the aviators accidentally tripped a control cord above their heads. The engine stopped, the plane crashed in a forced landing, the ducks flew on, and an observant cowboy rode to a bluff above the aviators and their wrecked plane to offer assistance.

But in the meantime, other Signal Corps experiments were more successful. In January, 1911, Lieutenant Paul W. Beck demonstrated a transmitter of his own design to a board of army officers at Selfridge Field, near Detroit. From a height of 500 feet, Beck communicated with a ground station 1½ miles away. He held the 32-pound transmitter in a box on his lap, and the aerial was the usual phosphor bronze stranded wire hanging from the tail of the plane. This spark-gap set included an ordinary telegraph key, a storage cell, and a shunt to prevent the coil from being overcharged.

During the same week, an unofficial report credited Charles F. Willard with having received a brief message aboard his Curtiss airplane. Willard was reported to have shown his understanding by obeying the message "Turn to the left and descend." Although this experiment took place at Selfridge Field also, Beck's reports obviously considered reception in airplanes as the next problem of aeronautical radio:

> We are now in a position to report positive results. We can build a sending apparatus that will weigh less than 25 pounds which will send for a distance of 25 miles . . . The question of receiving messages sent from the ground to an aeroplane is now reduced to a mere question of providing mechanical devices for deadening the sound of the propellers . . . [and of the] wind and providing some simple means for placing the received messages on written

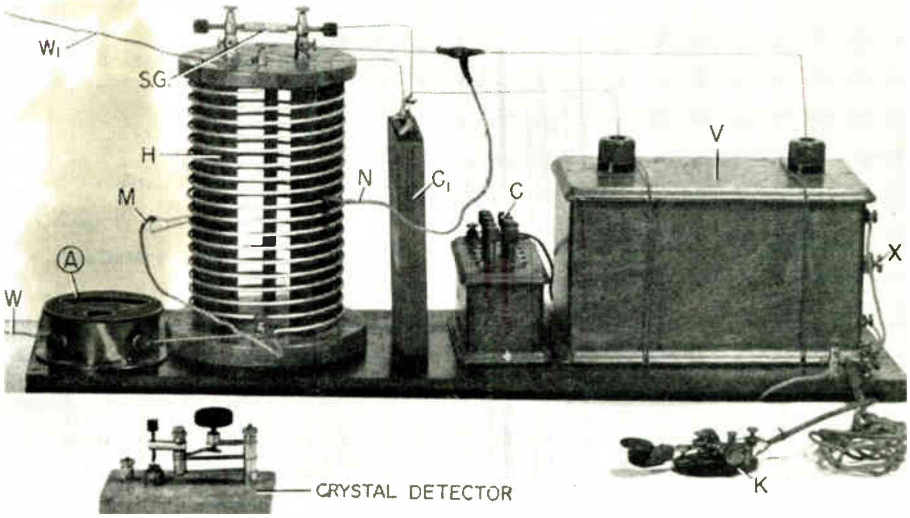
Oscar C. Roesen, now *president of the Wood Newspaper Machinery Company, designed the first airplane transmitter capable of sending signals over a distance of 55 miles.*

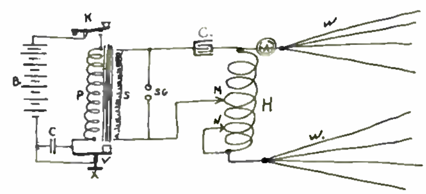
[3] *Ibid.*

[4] "Wireless Messages Sent from Airplane," *Aeronautics*, Vol. 6 and 7 (October, 1910), p. 129.

[5] Colonel Culver and Major General Foulois are now retired from the U. S. Army. Reber became a colonel, and retired some years before his death.

forms . . . all . . . comparatively simple problems.[6]





Roesen's transmitter (above) consisted of an ordinary telegraph key (K) with arm taped to prevent shocking the operator, and with a 7-foot lead between wheel and radio installation on lower wing; an induction coil and vibrator in wooden box with adjusting screw (X) to control vibrations; damping condenser (C) with regulating keys on top; a high frequency, high tension condenser (C1); helix or inductance (H) with movable contacts (M and N); spark gap (SG); Hickley high frequency meter (A); and aerial and counterpoise leads (W and W1). Batteries were beneath the wooden box holding the equipment. The crystal detector in left foreground was part of the receiver installed in the grandstand at Bridgeport.

Right—This schematic of the transmitter was found on the flyleaf of an old radio text belonging to Mr. Roesen.

Successful Reception

By early spring of 1911, the reception of messages by an airplane in flight was accomplished. At that time, McCurdy was working at Palm Beach with a group of civilians interested in aeronautical radio as an aid to military reconnaissance and courier service. In the group were P. G. B. Morriss, a Marconi engineer and radio operator, and G. W. Hoey, a veteran engineer of the Spanish-American War. Their first experiments concerned the transmission of Morse code from the aircraft without using the hanging antenna. For this purpose they substituted a "loop antenna of flexible insulated wire tightly stretched from strut to rudder supports." Then they turned their attention to an aircraft receiving set.

On March 6, 1911, McCurdy and Morriss took off on an eventful flight. For the first time, several series of signals from the ground were received in a plane. Morriss heard Key West Naval Station distinctly as soon as the plane left the ground at Palm Beach, and later signals from Havana, 300 miles distant, were clearly audible. Signals from ships at sea were detected but were not intelligible. Morriss wrote the following account of the experiment:

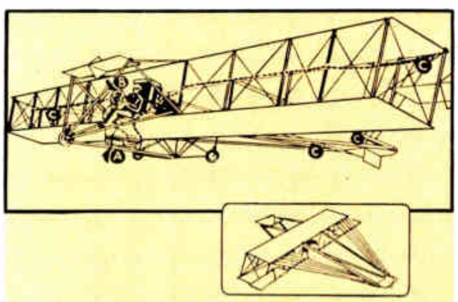
> A light seat was fastened on the bottom of the plane . . . close to the engine, and the writer . . . was successful in receiving readable signals. In these experiments a Marconi magnetic detector was used and connected on the "ground" side to the metal framework of the machine, which, used in series with a number of small plates of tinfoil, formed one side of a condenser of which the earth itself made the other. To the "aerial" side of the detector 150 feet of 25-No. 28 rubber-covered wire was wound from the end struts of the machine around the after rudder frame and back several times. In order to reduce any local interference that might be experienced from the unmuffled exhausts or from the intense rush of air, a temporary headdress was improvised of a towel, handkerchief, and cotton wadding, the whole being tightly bound around the head over the telephone receivers with tire tape. The detector and tuning apparatus was carried on the knees of the operator who experienced no difficulty in adjusting with one hand and in writing with the other.[7]

A Distance Record

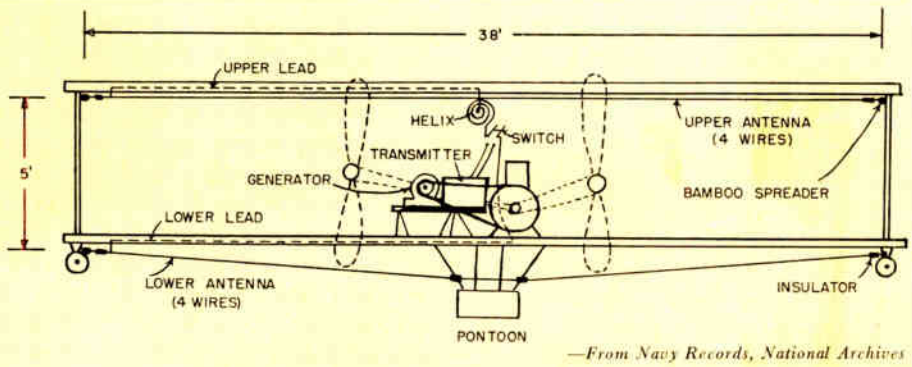
Though each set was acclaimed as being more efficient than its predecessor, the most enthusiastic headlines appeared about the middle of May, 1911, and concerned a transmitter constructed for the New York *World*. Ten days before a flying exhibition at Bridgeport, Conn., the aeronautics editor of the paper asked Oscar C. Roesen, an electrical engineering student at Stevens Institute, who was carrying on experiments atop the World Building, to design and build an airplane transmitter. Within a week, this remarkable young man had a transmitter ready to install in a Curtiss plane. For the aerial and ground, he used two sets of wires running from the wings of the plane and converging at the tail just in front of the rudders. One set provided counterpoise, since it was impossible to ground the set on the bamboo of which the plane was constructed. Two disappointments were in store for the young inventor before the successful trial of his equipment. In the first place, Glenn Curtiss used a hacksaw to cut away part of the fine hardwood box which contained the transmitter, so that some of the control and guy wires were not obstructed by it. Then, the plane had not enough power to lift a pilot, the transmitter, and Roesen who was over six feet tall and weighed 180 pounds. So that a pilot could transmit while flying, the sending key was removed from the set and mounted on the control wheel of the plane. With this arrangement of equipment, McCurdy—again

[6] San Francisco *Examiner*, January 22, 1911.

[7] P. G. B. Morriss, "Automatic Wireless Telegraphy," *Scientific American*, Vol. 104, No. 19 (May 13, 1911), p. 489 ff.



These diagrams of the installation of the Roesen set appeared in "Aeronautics," June, 1911.



—*From Navy Records, National Archives*

Sketch by Maddox shows installation of radio in the first seaplane of the U. S. Navy.

the operator and pilot—sent the signals RMD and WLD from an altitude of 2000 feet at Bridgeport to the dome of the World Building in New York, a distance of 55 miles. Although the signals were received more clearly in Bridgeport and New Haven, they were still distinguishable at the greater distance; and the New York *World* hailed the new distance mark which had been made in spite of wind and the atmospheric interference of city reception.

Roesen's successful equipment included a receiver installed in the grandstand as well as the airplane transmitter. The receiver consisted of a variable condenser, a variable inductance, headphones of 2000 ohms and a Clapp-Eastham perikon detector (zincite and iron pyrites). The transmitter was thus described in a contemporary account:

> The total weight is between 40 and 50 pounds. The whole outfit is neatly packed in a light box about the size of a dress suit case . . . The transmitter consisted of a four-inch heavy output induction coil with ordinary spring vibrator; 15 dry batteries, emf 1.5 and extra high amperage, connected in series; high tension condenser consisting of copper plates with special insulating compound as dielectric; helix consisting of wooden frame five inches in diameter, wound with 12 [actually 17] turns No. 6B and S gauge, and an ordinary telegraph key.[8]

After the flight, McCurdy praised the equipment and asked to make tests on a calm day. He was sure that he could have tapped out longer messages if control of the plane had not required *both* hands during most of the eight-minute flight! McCurdy's desire was fulfilled indirectly during the aeronautical meet at Sheepshead Bay in October of the same year. By that time Roesen had found an ex-Western Union telegrapher who weighed only 90 pounds. This telegrapher took aloft a sealed message from Claude Graham White, the famous English aviator who was skeptical of wireless tests at this meet. Though he was amazed and perhaps not entirely convinced even after the signals came through clearly, White had had the presence of mind to use the message "Bon Voyage to Nassau Boulevard" as a publicity stunt for selling property in Garden City, Long Island.

[8] "Successful Wireless from Aeroplane," *Aeronautics*, Vol. 8, No. 6 (June, 1911), p. 199.

Sky Anchors Aweigh

Under the not-too-enthusiastic direction of the Bureau of Steam Engineering, radio for airplanes was not even considered by the Navy during the first decade of this century. As long as land-based planes were received with great skepticism, only enthusiasts like Glenn Curtiss could imagine a flying boat or a catapult. When in 1910, a land plane flew from a 57-foot runway on the deck of the *U.S.S. Birmingham*, the bluejackets clinging to the superstructure whistled—as usual—to show their delight. But topside was still unimpressed. Though Captain W. I. Chambers, official naval observer, gave glowing accounts of the Horton experiments at Sheepshead, no appropriations were forthcoming. He was even asked to move his files to his home, so that the Navy Department could have his small basement office for more important activities.

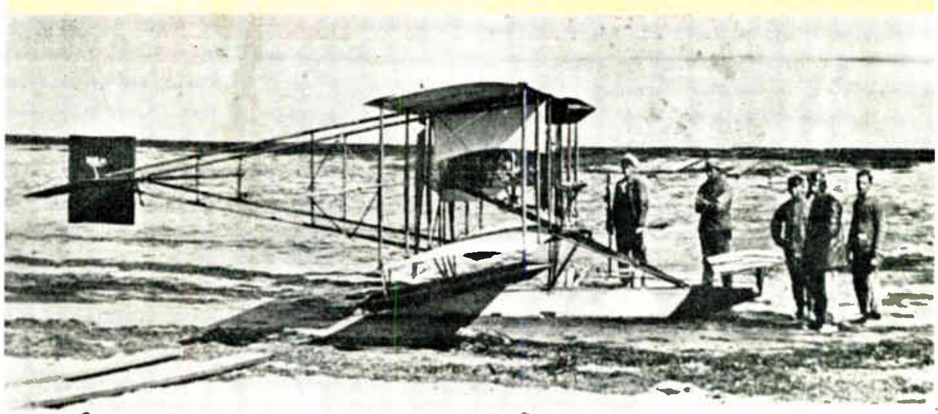
By 1912, after much prodding, the Navy was experimenting with two land planes, and one seaplane. Ensign Charles H. Maddox[9] built and operated a ¼ kw transmitter for the seaplane. In his design, Maddox used a fixed aerial and increased the spark frequency by using a high frequency generator and quenched gap. The sending key was mounted on a T-shaped baseboard, the vertical part of which was gripped by the operator's knees. The signals transmitted from this set were strong enough to be heard twelve miles.

The equipment also included a receiver suspended in front of the operator by a strap passing over his shoulders. In contrast to the towel-swathed helmet used at Miami in the preceding year, the helmet for this set was specially constructed to keep out noise and to hold the earphones. Within reach of the operator was a switch which changed the set from receiving to sending. In spite of this de luxe equipment, the performance of the receiver was limited to receiving signals from a ship while the airplane remained in a tent on shore. The disappointing fact was that the plane was too rickety to raise from the ground during the week of receiver tests.

But the transmitter made naval history. On July 26, 1912, Lieutenant John Rodgers made a short test flight during which the signal D was transmitted to the torpedo boat *U.S.S. Stringham*. Then, according to Ensign Maddox's reports to headquarters, he accompanied Rodgers on a longer flight. At a distance of 1½ miles and from a height of 300 feet, he sent messages to the *Stringham*. The event attracted no attention in contemporary publications; it was not mentioned in the log of the *Stringham*, nor in an article on aeronautical radio written by

[9] Captain Maddox is now Commander, Western Sea Frontier, in San Francisco.

First Navy seaplane equipped with radio by Ensign Charles H. Maddox in 1912.



—*Official Photo U. S. Navy*

—*Official Photo U. S. Air Forces*

Lieutenant J. O. Mauborgne (now Major General, retired) tests field set to be used in Fort Riley experiments in reconnaisance and artillery control while Lieutenant Arnold (left) looks on.

Maddox a year later. Yet these transmissions appear to have been the first from plane to ship while both were in motion.

First Practical Results

Military authorities both here and abroad were vaguely hopeful that radio reports from aircraft to ground would improve the accuracy of gunfire. By 1911, British dirigibles were regularly equipped with transmitters, and shortly thereafter sent messages during army maneuvers.

On November 2, 1912, the first recorded use of aircraft radio to control gunfire in our Army involved three young lieutenants now well known in a war-swept world. The pilot of the plane was Lieutenant H. H. Arnold, now General in command of the army Air Forces. Accompanying him as observer and radio operator was Lieutenant Follett Bradley, now Major General on active duty with the USAAF. The operator of the equipment on the ground was Lieutenant J. O. Mauborgne, now Major General and recently retired from the post of Chief Signal Officer of the Army.

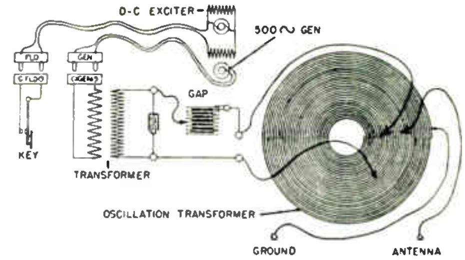
The equipment, built and installed by Ernest R. Cram, radio engineer in the Signal Corps Laboratory, was tested in a plane flown by Foulois at College Park, Md. Later it was sent to Fort Riley and re-installed by Mauborgne after he had tested various types of antennas. The transmitter was a quench-spark 500 cycle type, and was controlled by a key strapped to Bradley's leg. Both Bradley and Arnold were seated on the lower wing of a Wright-B pusher plane, while Mauborgne listened on the ground with a receiver adapted from a Signal Corps pack-set. The observation plane rose several hundred feet and made figure-eights between the battery, which was behind one hill, and the target just beyond a second hill. This target was a silhouette wagon train with a column of silhouette soldiers in the usual line of march. After two corrections for distance and direction, the third salvo hit the target so accurately that shrapnel damaged every wooden soldier and wagon.

Army radio enthusiasts were still unsatisfied because messages could not be received by their planes. As a makeshift means of reception during these Fort Riley tests, strips of cloth laid on the ground acknowledged the radio signals. But by 1914, Mauborgne was testing two-way radio communication for the Army while he was stationed in the Philippines.

With the help of Lieutenant Herbert Dargue, later a Major General in the Air Corps, Lieutenant Mauborgne built a receiver with a molybdenum detector which would not burn out or shake to pieces. The receiver was about 4 x 6½ x ¾ inches. For the transmitter, he used an old spark coil, a storage battery, a glass-plate condenser, a small inductance coil, and an open gap. Its 200-foot aerial was let down through a piece of circular loom, and was weighted with some large iron washers which Dargue found in a corner of the machine shop. This equipment was installed on a Burgess-Wright pusher—the entire air force in the Philippines at that time.

Thus equipped, this plane—even then recognized as an old crate—carried the two lieutenants on seven test flights before cracking up in Manila Bay. On all of these flights around the Bay, Mauborgne established two-way communication at distances up to 7½ miles from the 10 kw quenched-spark station at Corregidor.

And the immediate result of this achievement? Mauborgne's senior officers buried it in a laconic and unenthusiastic sentence of their next report to Washington headquarters. Like many others, they were unaware that aeronautical radio was to revolutionize warfare. As late as 1914, James Means was still urging the use of smoke signals, even though



—*From "Radiotelegraphy," U. S. Signal Corps*

Schematic of Signal Corps transmitter designed by E. R. Cram and used in Fort Riley experiments.

the Army found them unsuccessful when the black puffs of smoke vanished in a stiff wind.

Nevertheless, the groundwork for successful aeronautical radio was complete. The possibility of reliable performance seemed closer to reality than ever. The opening of World War I, by launching a race for the most effective use of a new weapon—the airplane—hastened concerted effort toward the establishment of aeronautical radio.

ACKNOWLEDGMENTS

For records of events concerning early aeronautical radio, the writer is indebted first to the now unknown reporters on contemporary magazines and newspapers, and later to the preliminary research among these publications by Dolores Snider and Cecilia Muth of the BENDIX RADIO ENGINEER staff. In the search for descriptions of equipments, Ernest L. Jones, formerly editor of *Aeronautics* and now Lieutenant Colonel in the Historical Section of the Army Air Forces, has been particularly helpful because of his experience and wide circle of friends in this field. Eye witness accounts, pictures, schematics, and further details have resulted from interviews or correspondence with: Frank P. Lahm, Brigadier General, Retired, United States Army; J. A. D. McCurdy, Department of Munitions and Supply, Ottawa, Canada; Oscar Roesen, President, Wood Newspaper Machinery Corporation, New York; George H. Clark, Historian, Radio Corporation of America, New York; Ernest R. Cram, Cardwell Manufacturing Company, Brooklyn; N. H. Randers-Pehrson, Division of Aeronautics, Library of Congress; and Fred C. Reed, Division of Engineering, U. S. National Museum, Washington, D. C. To all of these, the writer is especially grateful; but they are not responsible for the limitations of the article.

TAMING THE SCHEMATIC DIAGRAM

A carefully planned functional diagram simplifies study and servicing of aircraft radio sets.

STUART H. LARICK
Microwave Engineering

"QUICK, WATSON, THE SCHEMATIC!" This might have been Sherlock Holmes' cry if his sleuthing talents had encompassed radio. But if he were investigating an aircraft radio, he might have found the schematic as much a mystery as the set itself. He would have to weave all over the sheet, trace through many networks, dodge and cross lines, and in the end not be certain that he had followed the right circuit.

It is paradoxical that designers of communications equipment often fail to communicate clearly their own ideas. Too often schematics—the language of the design engineer—need interpreting.

New Technique Needed

Much of the difficulty is that the technique employed in making home receiver drawings is applied to the aeronautical radio. The home receiver schematic simply shows the parts and how they are connected, with no attempt at visually indicating electrical function. When several components are in one container, such as a two-section electrolytic capacitor, they are drawn in proximity. But components located near each other physically are often unrelated electrically, and when this home receiver system is used for the more complicated aeronautical radio, a confusing and cumbersome drawing results. The conventional schematic, nevertheless, bows to the physical presentation and sacrifices a clear electrical picture.

Actually the schematic should maintain continuity of electrical circuits, and a wiring diagram should indicate physical layout. If properly done, the wiring diagram will show the component as a unit and the circuit will be subordinated to the parts in it. The schematic diagram, on the other hand, will present the *circuit* as a unit, and when there is a conflict, the component will be subordinated to it.

Such a diagram is a powerful aid in analyzing the radio, whether the technician wants to locate trouble in the set, or simply study it. For, to understand how the radio works, he must know how its circuits work. And to understand that, he must first know what parts constitute a circuit. If he can see clearly *the entire circuit at a glance*, he will not laboriously have to construct a satisfying mental picture from a confusing drawing.

The diagram can be made even more helpful if the drawing of parts in the circuit suggests the function they perform. This functional presentation is another departure from the conventional schematic, since *a component is not drawn merely because it exists in the set, but because it performs a definite function there.*

For instance, a conventional presentation of a power supply having two output voltages is shown in figure 1*a*. An improvement is shown in figure 1*b*, and a functional picture in figure 1*c*. In figure 1*c*, R is presented not simply as a circuit component, but as a resistor dropping voltage from 500 volts (level A) to 300 volts (level B).

How confused a simple circuit can become is illustrated by the voltage divider in figure 2, which is taken from a schematic of a popular commercial set. No indication is given as to the function of R4, R5 and R6. When the circuit is portrayed as in figure 3, the action of the voltage divider is immediately evident.

Once we realize that each component should be shown in the light of the job it does in the circuit, planning a schematic is like building with blocks. Each circuit has a job to do in its stage; each stage performs a function in its section; while each section does its own job in the set. The radio, then, has a definite electrical structure.

Basic Planning

As an example of what can be done with functional schematics, the organization of the RTA has been chosen. This set is a transmitter and a receiver, with power supplies for both, all built into one compact box.

First, the over-all electrical structure of the radio must be transferred to paper. Since the RTA is composed electrically of several operating units, the diagram can be built like the rack and panel construction often used where units are physically on separate chassis but work together electrically. In the diagram the units will be represented so

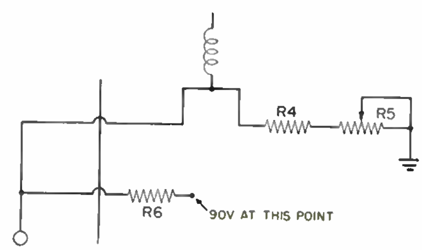


Figure 2—Conventional technique confuses a simple voltage divider circuit. Compare with figure 3.

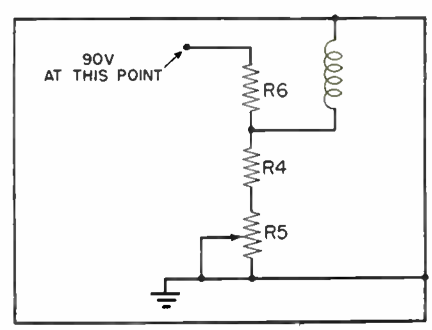


Figure 3—Voltage divider in figure 2 drawn to show the function of R4, R5 and R6.

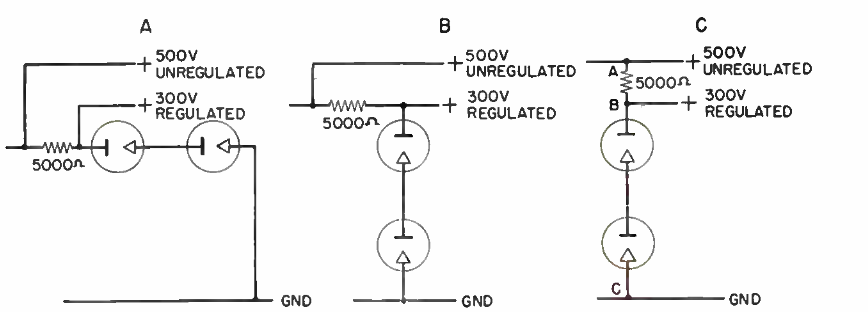


Figure 1—Comparison of conventional and functional presentation of a power supply. A. is poor; B. is an improvement; C. clearly shows the function of the dropping resistor.

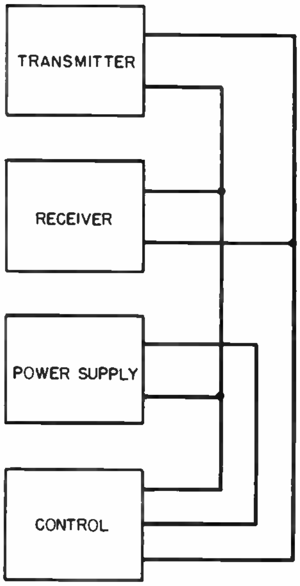


Figure 4—First step in re-drawing RTA-1 schematic was to lay out units in logical order, and draw power connections.

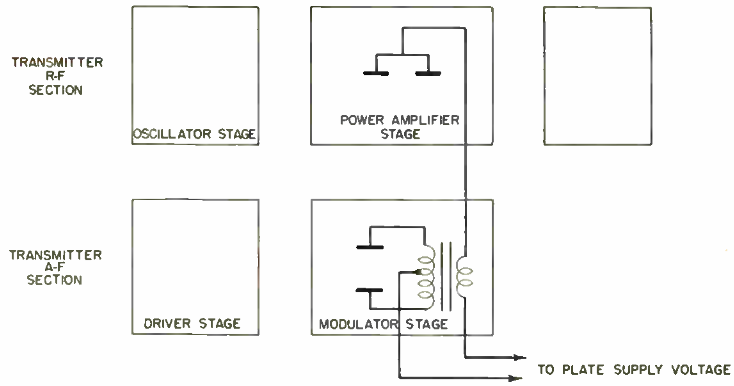


Figure 6—Sections broken down into stages. Alignment is maintained where one stage works into another.

that they suggest the jobs they do merely by the way they are drawn.

The power connections are cabled in as shown in figure 4, and this arrangement is used as a general layout for the schematic. There is a certain logic in placing the blocks in the order shown. The transmitter delivers high power at high frequency. The receiver, too, deals with high frequency, but at lower power. Both units are fed by the

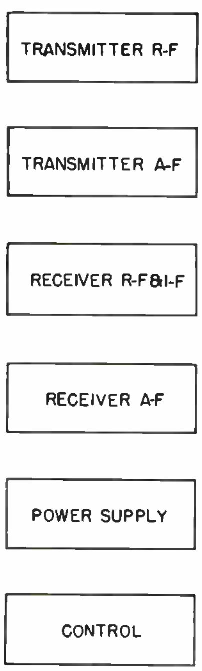


Figure 5—Break-down of units into sections. High-frequency sections are placed over those of lower frequency.

d-c power supplies, and the entire set is controlled by the switch and relay section.

The arrangement of the functional diagram is really an artistic problem of properly directing the eye and the imagination. A radio technician looks at such an arrangement and feels that the diagram is fundamentally correct and satisfying.

A breakdown of the units into sections follows the same logic. The transmitter and receiver both have audio frequency and radio frequency sections; therefore the complete block arrangement will be as shown in figure 5. The sections in turn are made up of stages, which are broken down as indicated in figure 6.

Sometimes a stage of one section works into a stage of another section, as in figure 6 where the secondary of the modulator plate transformer is in series with the power amplifier's plate supply. Then it is desirable to shift the power amplifier and modulator with respect to each other until a straight line connects the two. Where many such line-ups are involved, the same arrangement problems are encountered that a designer faces when he lays out a chassis. In general, they may be solved by the same method—by making the best possible arrangement on the first attempt and then constantly modifying. Since one arrangement suggests another, the designer finally arrives at the point where everything fits together in the best way possible.

Each stage of a section, taken as a unit itself, is usually centered about a vacuum tube, or a group of tubes such as a push-pull, or a parallel stage. The tube circuits (grid, cathode, plate and possibly screen) then become the units of which the stage is composed. The units are blocked out on the drawing board. For example, the layout of the oscillator unit in the transmitter r-f stage is given in figure 7.

Each unit follows the same general pattern, with its circuit blocks as nearly the same in size, shape, and position to that of the oscillator as possible.

Uniform Arrangement

With the spaces organized for the general structure of the sections, the stages, and the circuits, the components that make up the circuits are next laid out to complete the system down to the smallest element. A consistent pattern is followed even in the arrangement of parts.

The a-c voltage developing components are drawn at higher levels than the d-c developing components, as figure 8*a* shows. Observe that components which do similar jobs are drawn on the same level. Figure 8*b* shows a complete grid layout for the RTA receiver r-f and i-f sections.

Figure 9 is the complete functional schematic of the RTA receiver r-f and i-f sections, after the grid is filled in.

Notice that the tuned circuit components (parallel coil and condenser) are drawn in the same relative position. If the technician using the diagram identifies the tuned circuit in one stage, it is easy for him to locate it in any other stage because his eye travels in short horizontal lines. The habit developed in the first stage to understand this element is simply repeated in the exami-

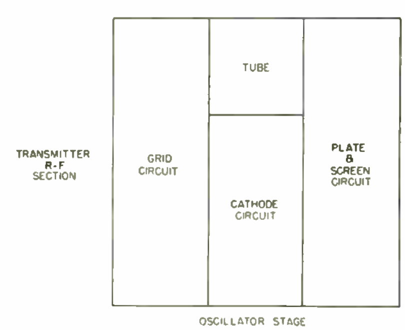
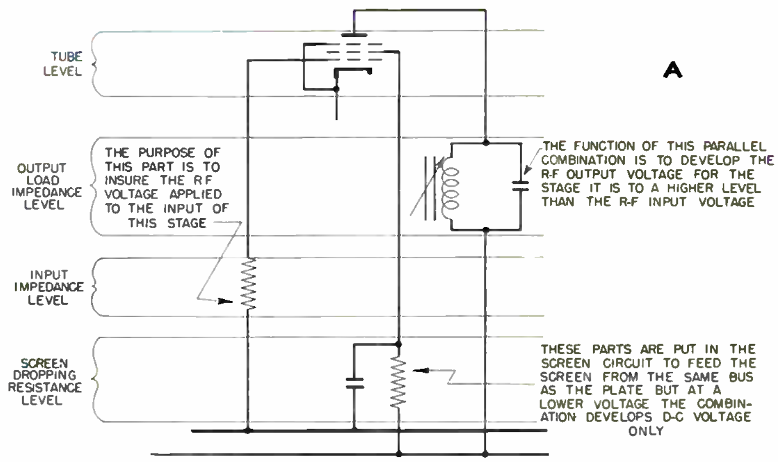


Figure 7—The various components making up a stage are laid out in this general pattern.

nation of the other stages. This technique has a sound psychological basis.

There are other techniques which may be employed. Figure 10*a* shows the coil in direct line with the plate lead and the capacitor tacked to its side. Tracing through the circuit, the eye travels down the plate lead to the tuned circuit and tends to continue in the same straight line in which it is moving (momentum and inertia of a body having mass). The eye notes the coil first, and has to be diverted to see the capacitor. Hence, the coil occupies a more prominent place on the drawing than the capacitor. Figure 10*b* shows the capacitor in the more prominent position. Electrically, however, the coil and capacitor work together to perform a function common to both. In fact, they make up another small unit—the tank—and it is the tank which develops the plate voltage. Therefore, this unit should be drawn straight in line with the plate lead, as illustrated in figure 10*c*.

Compare this parallel combination with the commonly encountered cathode bias resistor and capacitor. The bias resistor develops a d-c voltage between cathode and ground. The capacitor helps the resistor to do its job more effectively by keeping the a-c components of cathode current from

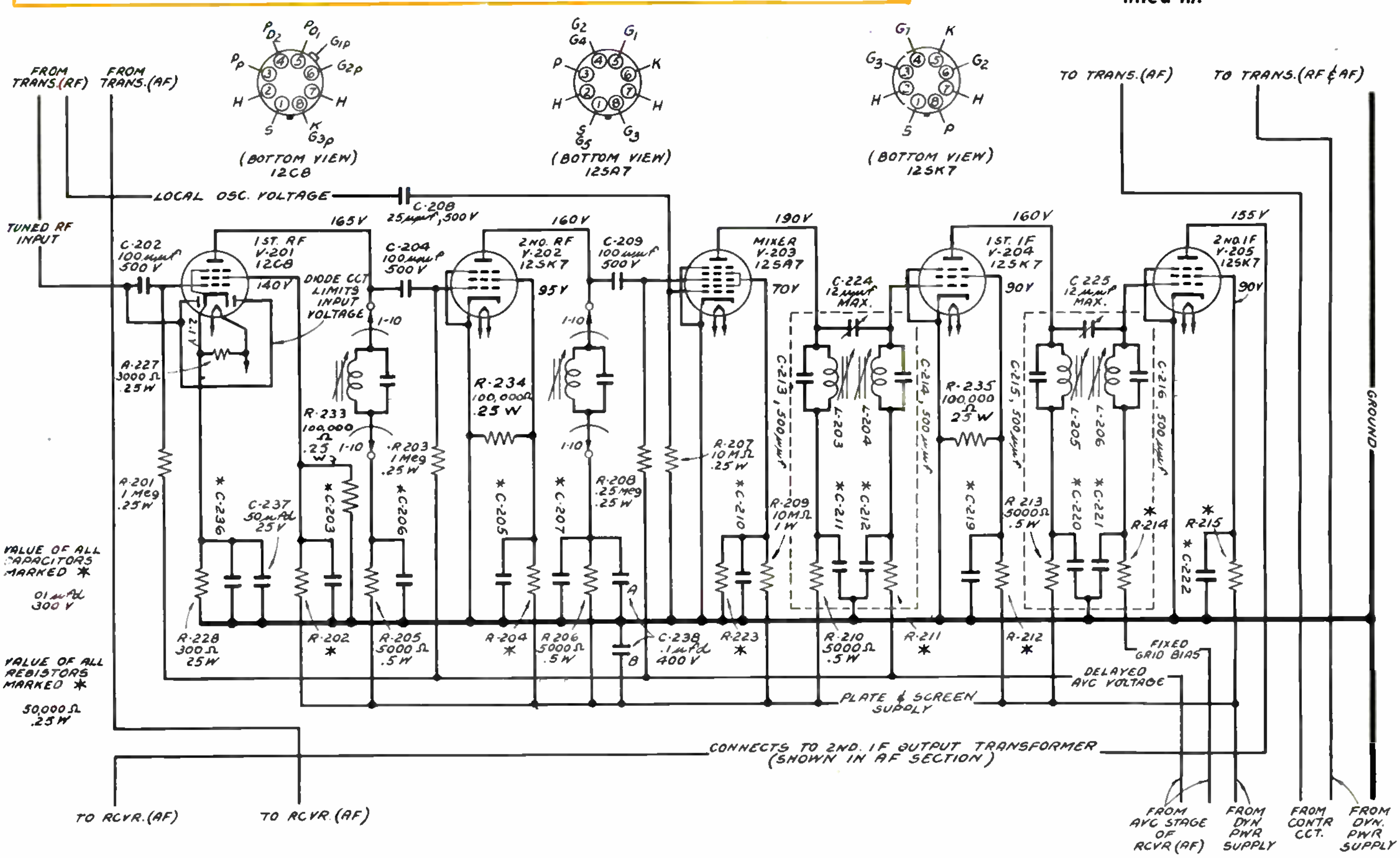


B

	1ST R-F	2nd R-F	MIXER	1ST I-F	2nd I-F
TUBE					
PLATE LOAD					
GRID LEAK					
SCREEN DROPPING RESISTOR & BYPASS CONDENSER					

Figure 8—Consistent arrangements are followed in laying out components. A. A-C components are drawn at higher level than d-c components. B. Complete grid layout for RTA receiver r-f and i-f sections.

Figure 9—Functional schematic of RTA receiver r-f and i-f sections with grid filled in.



flowing in the resistor. Electrically, then, the resistance is the main element of the combination, while the capacitance is the supporting element. Hence, the combination is drawn to express this relationship and again we use one of the artist's tools to direct the eye where we wish. (See figure 11).

These few examples show some of the subtle devices which serve to make a schematic diagram lucid. The most forceful method, however, is to keep the circuit completely within a small area. This method is best illustrated by the control circuits which, in conventional diagrams, are apt to ramble all over the drawing.

Function Clarified

Typical control circuit elements—relays, switches, motors, pilot lights, primaries of dynamotors—all are d-c components and are usually energized by the aircraft battery. A complete circuit starts at the plus terminal of the battery and ends at its minus side (ground). An aircraft radio has several such circuits all connected across the battery; therefore they are in parallel. To represent these parallel circuits on paper, two bus lines are drawn. Every complete control circuit will lie between the two horizontal lines.

The RTA control circuits follow the plan outlined in figure 12*a*, and are filled in on the drawing in figure 12*b*. Thus a person can tell at a glance exactly what circuit the controls are in, and what happens when a switch is closed.

Nearly all of the RTA is housed in one unit. But when this system of drawing is applied to sets composed of several units, it is easy to find which unit a part is in, even though the diagram does not place it in its proper physical box. Examine the switch contact in figure 13. The square symbols in this figure represent a particular plug and receptacle. Let us assume that the receptacle is in the pilot's control box. (This information would be in the legend printed on the diagram). The diagram shows that the circuit goes into the control box at number 2 and comes out again at number 4. (The numbers 2 and 4 refer to the pins on the plug and receptacle).

In general, the relay solenoids are in the control section, while the contacts they control are scattered throughout the set. At first glance, this arrangement looks like a serious drawback. It is turned to advantage, however, by making a separate drawing of the complete relay, and including a word description of what it does and how it works. Figure 14 shows how relay K-101 of the RTA is drawn.

The typical control circuit section is probably the most valuable part of the func-

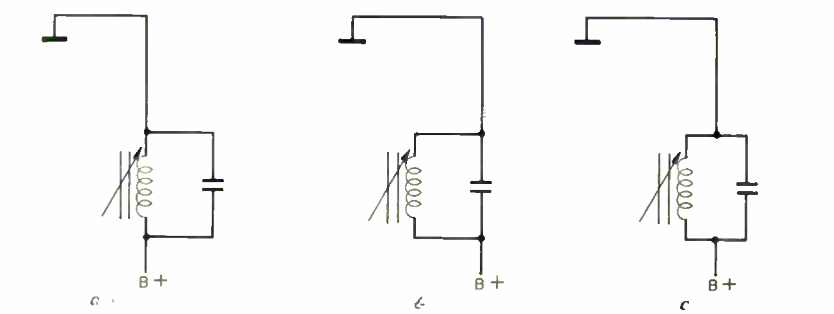


Figure 10—Comparison in presentations of tank circuit. A. Coil given undue prominence; B. capacitor given undue prominence; C. Coil and capacitor correctly shown as an electrical unit.

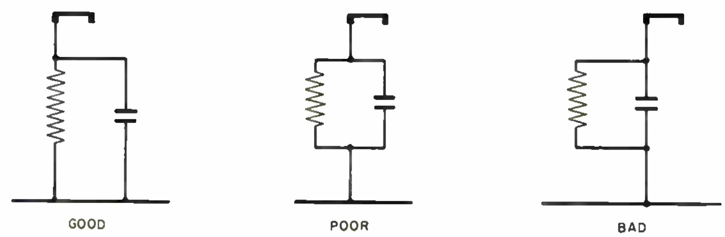


Figure 11—In the cathode-bias circuit, the resistor is the main element and the capacitor a supporting element. Resistor is therefore given prominence.

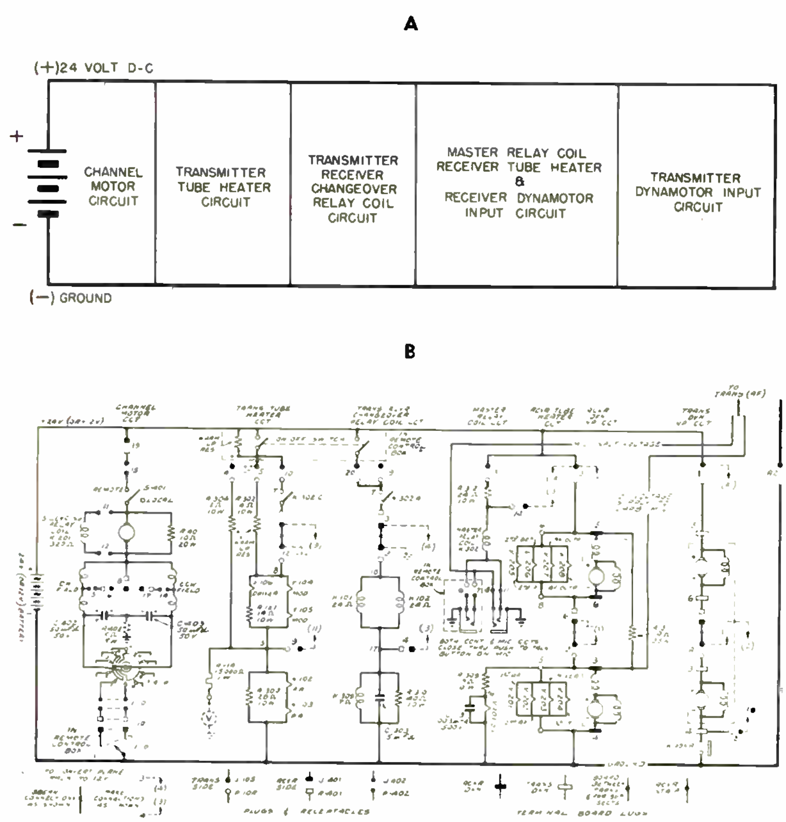


Figure 12—Typical control circuits are wired in parallel across a battery. A. Two horizontal bus lines are drawn, and the individual circuits lie between these lines. B. RTA control circuits filled in.

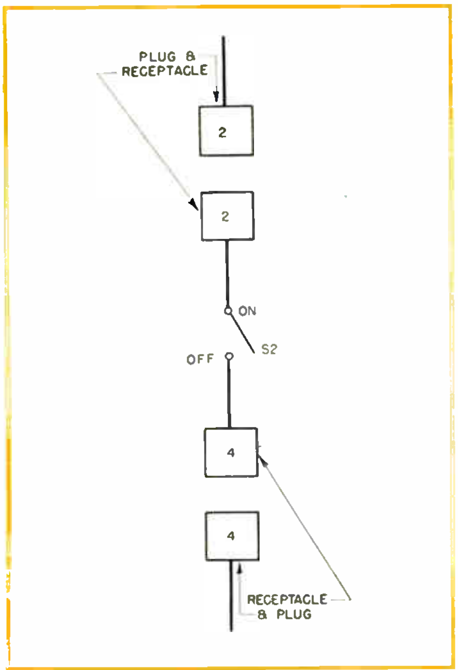


Figure 13—When several separate units are involved, parts may be identified with their correct units, though physically misplaced, as shown by this switch contact. Location of receptacle is indicated in a legend. Numbers indicate that circuit enters control box at pin 2 and comes out at pin 4.

tional diagram, because it is the weakest element in the conventional schematic presentation.

Strangely enough, the most obvious device for obtaining a clearer picture is usually overlooked—that of imparting as much information as possible in words and numbers. Some extremely helpful data are: 1) what each section is; 2) what each stage does; 3) typical voltages that may be measured at the tube sockets; 4) impedance values; 5) where long leads (when they must be used) come from and what they do; 6) labels of switch and relay positions. Drawing extra detail sketches, such as the relay details, often will make the schematic more understandable.

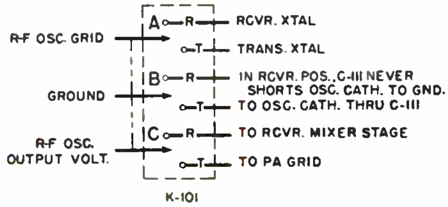


Figure 14—A separate drawing is made of a complete relay. Above is relay K-101 of the RTA.

Fresh Start Best

It is obviously much easier to lay out a functional schematic in the very beginning, than to analyze an old diagram in order to synthesize a new one. When starting fresh, the designer may have control over his symbol numbering system. Of course, the nature of the set or the desires of the customer may influence the rules he follows.

One system which has been found effective in quickly locating and identifying components is to proceed in accordance with the chart in figure 15.

The RTA is the first of our sets to be described by a functional schematic diagram. It was chosen because it had the reputation of being one of the toughest to trouble shoot. It frightened people. Well over fifty pages of rough sketches were required before the schematic could be brought near enough to its final form to be turned over to the draftsman for a good copy.

The circuits were traced, separated, reformed, and re-grouped after much trial and error. The functions of many components often were not apparent until a familiar arrangement was made. Simple sketches were drawn to isolate a particular circuit and cast it into a more standard, recognizable form.

After an individual circuit was drawn satisfactorily, it was put aside until the other circuits with which it worked could be presented clearly. The group of circuits was then coordinated to form a coherent picture. When enough groups were organized, a complete section was drawn. Sketches of each section were arranged on one sheet to build a clear-cut functional diagram of the complete RTA. The diagram has been printed in two forms. In the first, each section was separated, and printed on 8½ x 11 inch sheets. In the second, the entire schematic was reduced to a vest pocket 3 x 5½ inch accordion fold.

Stuart H. Larick

VERSATILE STU LARICK is practically a radio prodigy. Interested in radio at twelve, he had an amateur station at fourteen. While a student in the School of Engineering at the College of the City of New York, he worked as a radio engineer at station WNYC, and later commuted to Bayonne, New Jersey, as a tester of electric motors and generators at the Electric Boat Company. Within a week after his graduation in 1941 with a Bachelor of Science degree in Electrical Engineering, he was employed in the Transmitter Engineering Section at Bendix Radio. The first engineer to take the engineering training course which permits the trainee to work in many departments to understand better the structure and problems of the organization, Stu was then transferred to Microwave Engineering and, as a junior engineer, designed special test equipment. He is now at the Hazeltine Corporation in New York City as Bendix Radio's representative in a cooperative engineering program underway there.

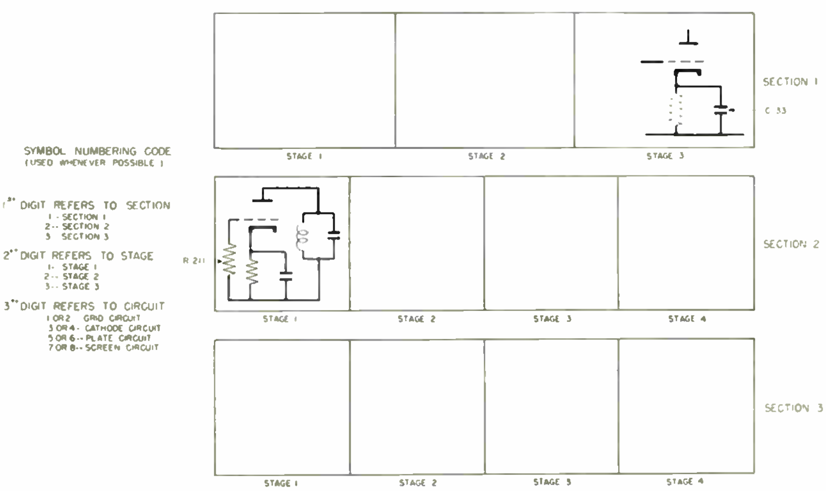
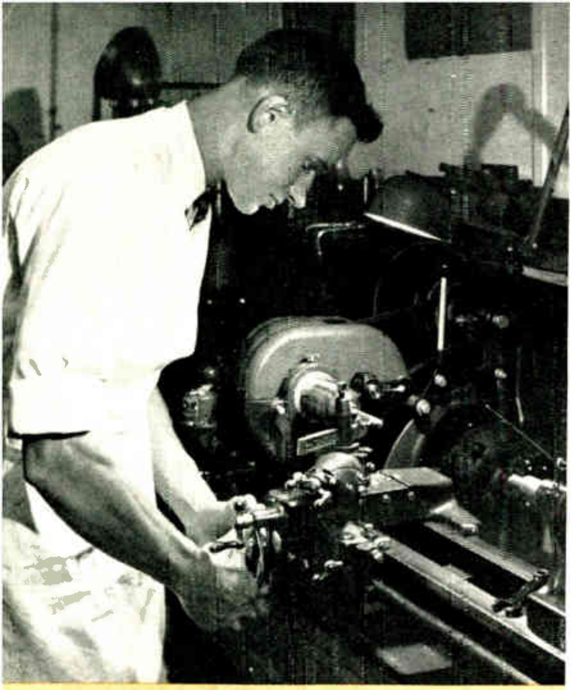


Figure 15—Chart helpful in locating and identifying components.



In the Instrument Engineering machine shop John O'Gorman operates a lathe for turning out a precision engineering part.

INSTRUMENT ENGINEERING

The Instrument Section of the Engineering Department has been closed. Work ceased as a result of the decision to abandon the manufacture of quartz crystals and associated equipment by the Radio Division, since such manufacture is somewhat alien to the principal field of Bendix production, and because of the great expansion of the crystal industry in the United States. During its existence, Instrument Engineering performed many valuable services. This article is intended as a record of its activities.—The Editor.

Some section designations in the Engineering Department are more informative than others. Receiver Engineering, for instance, needs no explanation. Transmitter Engineering is perfectly obvious. Microwave Engineering, though a newcomer in the ranks, is self-explanatory. The designation Instrument Engineering, however, requires some interpreting

Instrument Engineering, with W. J. Holey as section chief, had two distinct divisions, each demanding personnel with entirely different qualifications: 1) development work on quartz crystals, formerly a part of Transmitter Engineering, requiring a force of crystal experts; and 2) development work, formerly conducted independently in all engineering laboratories, on equipment whose accuracy is determined by quartz crystals. This work calls for skilled engineers.

Research Activities

In the light of further disclosures, the term "development work" is found to err on the side of understatement. As applied to crystals, it meant making new crystals to specified tolerances, or increasing the efficiency of existing types, for equipment requiring precise frequency control. It involved the study of the fundamental piezoelectric properties of quartz, the processing of raw quartz, and the ultimate development of practical forms of crystals for use as components of Bendix equipment or for distribution in the competitive market as Bendix Radio products.

The measuring equipment developed in the Instrument Engineering Section has a closer relation to crystals than appears on the surface. In general, it is equipment which uses the properties of quartz crystals for some function other than that of frequency control. One device, the frequency standard, has the primary frequency based on a quartz crystal. Another product, the frequency meter, uses quartz crystals as calibrators of a secondary nature. Still other devices use crystals for filters as well as for the generation of supersonic sound waves. In all of this equipment the crystal may be said to be the heart of the mechanism, without which it could not function. So crystal development and instrument development in Instrument Engineering were clearly allied.

New designs, or improvements in existing designs, in both crystals and instruments, originated either with the Bendix management or in the Section itself, as the outcome of familiarity with available equipment and knowledge of the need for certain apparatus not now obtainable. If, for example, a certain government agency indicated a desire for a frequency meter to cover a specified range, a development contract was drawn up and preliminary experiments conducted at the agency's expense. If the Bendix management decided to carry on the development at its own expense, an appropriation for the project was made. Then Instrument Engineering set to work and carried the job to completion and delivery of the first model. Or, if one of the engineering laboratories required a special crystal whose characteristics are different from available standard crystals, the long and tedious process of developing a new crystal was initiated.

Inspection of the crystal laboratory yielded much information. A crystal, in the very nature of things, even as a fully developed unit, is inevitably insignificant in appearance. It may, for instance, be tube-shaped, quite small, encased in an aluminum cap, unimpressive. And yet, it is an intricate mechanism involving a long series of experiments and tests, as highly scientific in its own right as the transmitter or receiver of which it is to become an integral part. When incorporated in such designs, as it invariably is without further study on the part of the project engineer, only in its efficient performance does the crystal give evidence of the specialized knowledge and superior facilities which produced it.

Among these facilities which enabled the Instrument Engineering Section to carry the raw quartz through to the production of a highly precise finished unit, are the conoscope, polariscope, X ray, sodium light, ultraviolet light, Bausch and Lomb petrographical microscope, quartz saws, lapping machines, stooging wheels, edging wheels, and vacuum plating system. Finishing positions complete with measuring equipment for handworking the rough quartz blank to final dimensions and frequency, and temperature ovens with automatic recorders for making temperature runs on completed crystals or on crystals at any stage of the finishing process, are other pieces of equipment used by the Section. In fact, every possible aid for the pro-

Making a final adjustment in the assembly of a variable condenser, Margaret Schnorrenberg is about to determine its temperature coefficient in a chamber where the temperature is varied from +75 to −70 degrees centigrade.

duction of a reliable crystal plate for specific applications was available.

Development Procedures

The routine procedure in crystal manufacture developed on the pilot line at Towson and duplicated in production at the Charles Street plant, is as follows: a piece of raw quartz is immersed in oil and inspected through a conoscope to determine by optical means the proper angle for cutting. Then it is placed on a plate under a diamond-embedded saw so that the marked angle indicated in the preceding inspection is in line with the saw blade. It is cut first into slabs, then into bars approximately three inches in length. The bar is cemented on a glass mounting plate and the crystal cut into blanks like minute slices of bread. After cutting the first blank, however, it is customary before cutting the entire bar, to examine this blank under an X-ray machine made especially for this purpose, in order to determine definitely whether it is the proper cut for piezoelectric use. If not, it is rejected and the preliminary process repeated. If, however, it is satisfactory, the entire bar is cut into uniform blanks, which are then ground in a lapping machine to a thickness very close to the final thickness.

From this point the process of finishing the blanks to frequency is accomplished by hand, one blank at a time. The rough blank is rubbed on a piece of glass using a mixture of fine abrasive to polish it to the desired thickness, which determines frequency. It takes an experienced hand to know just how often to draw the blank over the glass surface to get this result. When the operator thinks he has achieved his purpose, the blank is connected to an oscillator in order to check the radio frequency output. If it passes this test, it is mounted in a permanent holder and the frequency again checked. The final test is for frequency over a given temperature range, the frequency being recorded automatically over the specified range. This completed, the crystal is ready for use.

In the process of manufacture, all crystals were continuously followed by development engineers to maintain quality in production. If destined for the open market, the finished article carried a price tag varying between $7.00 and $20.00.

Developments in progress in crystal engineering at the time of its discontinuance were: crystals for generation of strong supersonic sound waves; harmonic crystals to permit control of vhf oscillators without using extremely fragile crystals; continual investigation directed toward the elimination of the use of large crystals with a view to replacing them with the small plated type.

Instrument Design

If the stature of measuring instrument development in Instrument Engineering seems dwarfed by comparison with developmental work on crystals, it is only an accident of circumstance. The serious handicap of a shortage of engineering personnel placed definite limitations on the number of projects undertaken.

G. R. White, engineer in charge of the development of the wide-band phase-meter, tests the inherent phase shift appearing in the radio frequency converter section.

After grinding the quartz blank on glass and abrasive, Leo Servary measures its thickness on a precision micrometer.

Development work on instruments grows out of a known need for testing equipment not available, or a decision to reproduce a piece of equipment available only in limited quantity, or possibly, a demand for a modification of equipment in use. It is not unlikely that a year or more be spent on the completion of such projects as, for example, those on which engineers in the Instrument Section were working—a vhf frequency meter with a fundamental range of 100 mc to 156 mc, a phase meter for a wide band of frequencies, apparatus designed to make possible the production of small plated crystals with contact wires soldered to the face of the crystal.

Here again the facilities provided were the best the market affords. General Radio, Leeds and Northrup, RCA and other manufacturers' test instruments constituted the laboratory equipment of vacuum tube bridge, capacitance and inductance bridges, precise Wheatstone resistance bridge, Type K2 potentiometer, distortion meter, single range potentiometer, r-f bridge, audio oscillators, field intensity meter, vacuum tube voltmeters, signal generators, "Q" meters, oscilloscopes, decade boxes, galvanometers and a series of receivers covering the entire range from 50 kc to 300 mc.

The Instrument Engineering Section had jurisdiction over all crystal frequency meters in production, and did all development engineering on this equipment. Whenever substitute parts were required, they were developed, their use approved, and all necessary supplementary tests made to determine performance. Complete files were kept of CFI drawings and change orders. In all this, Instrument Engineering did its job well.

PATENT DIGEST

Means for Reproducing Motion, Paul F. Bechberger (Bendix Aviation Corporation), Pat. No. 2,342,637.—Eclipse-Pioneer Division's "Magnesyn" permits remote control or indication of remote angular displacement by a system wherein brushes, slip rings and commutators are eliminated; and regular polyphase and single phase windings on the stator of the transmitter and receiver are replaced by a single coil having a number of taps.

As shown in the accompanying sketch, the coil of the transmitter stator is electrically connected to the coil of the receiver stator. The coils are also tapped and interconnected at points E, F, G and H, dividing them into sections of 1200 along the circumference of the magnetically permeable core. Both coils are energized by single-phase alternating or pulsating direct current.

The tapped points (E, F, G and H) in effect constitute polyphase connections, while the ends of the coils (A, B, C and D) constitute single-phase connections. In other words, the entire length of the coil is single phase, while the tapped sections correspond to polyphase windings. Thus the coils function as autotransformers, having input terminals at A, B, C and D, and output terminals at E, F, G and H.

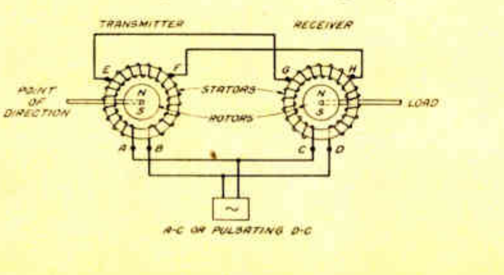
Frequency Divider Network, Murray G. Crosby, Pat. No. 2,344,678.—The effectiveness of the usual frequency divider network in some applications is limited because it produces oscillations even in the absence of controlling input waves. The network devised by Crosby provides means for preventing output oscillations at the divided frequency when no alternating input voltage is present.

The system is particularly adapted to phase or frequency modulation receivers where frequency dividing networks are desirable.

The present patent provides several advantageous features of which the following are of special interest:

(1) A dividing system which is more stable than circuits using the relaxation or multi-vibrator principle.

Electrical diagram of the "Magnesyn."



(2) A method of reducing the center frequency by a predetermined factor, so that the frequency modulation detector may be adjusted for a reduced band width, with a consequent improvement in signal-to-noise ratio at the input.

(3) Network constants may be so adjusted as to provide the characteristics of a limiter stage.

(4) Interfering signals not of the same order as the center frequency are rejected because the resonant frequencies of the circuits employed in the regenerative circuit have selective action.

(5) The threshold action of the circuit can be utilized to reduce noise in the absence of received signals, or between stations.

The circuit illustrated in the accompanying diagram comprises the usual intermediate transformer coupled to the plate of the preceding tube. Both the primary and secondary of this transformer are tuned to the center frequency, F, which is deviated at the transmitter. The transformer secondary is coupled to the input grid of a converter tube, A, such as the type 6SA7. The plate of the converter is connected to a positive direct-current source through a parallel resonant circuit, A, consisting of a coil and capacitor. This resonant circuit is tuned to a frequency of $\frac{F}{N}$; where N is any factor which is an integer.

The modulated carrier voltage developed across this circuit may be transferred to any utilizing means through a capacitor, C1, which offers low impedance.

The effective band width of B is reduced N times. For instance, if the band width at the input transformer is 200 kc and N is equal to 4, then the pass band width at the tuned circuit, B, will be 50 kc.

The frequency multiplier tube, D, may be an r-f pentode such as 6SK7. The signal grid is coupled to the high side of B through capacitor C2. The plate is coupled to the grid of the converter through capacitor C3 and also to the top of a resonant circuit, E, which is tuned to a frequency equal to

$$(N + 1)\ \frac{F}{N}$$

In the present example, the resonant frequency of circuit E is 5 mc. Bias resistor R1 is given a value such that in the absence of an input signal on the grid of the multiplier, the tube is operated close to plate current cut-off. It can be seen that the voltage across circuit E is impressed upon the injector grid of the converter simultaneously with the arrival of the frequency modulated carrier of center frequency F upon the input grid.

The frequency modulated carrier voltages impressed upon the two grids are heterodyned by electron coupling and produce a beat voltage whose center frequency is $\frac{F}{N}$.

Hence, in circuit B the output of the converter is tuned to the desired subharmonic and fed to the input electrode of a frequency multiplier tube, D. The subharmonic is then multiplied by a factor of $N \pm 1$, and the output is fed to the grid of tube A. Accordingly, the output of the converter consists of the heterodyne beat between the center frequency (F) and the frequency of the voltage across circuit E. Under such circumstances, oscillation will exist in circuit B when the gain of the converter and multiplier exceeds unity.

Since the converter gain is dependent upon the signal strength applied from the input transformer, in the absence of such a signal, there will be no voltage across B since no oscillation is produced through the multiplier tube. Tubes A and D with their associated circuits provide a re-entrant or regenerative modulation circuit.

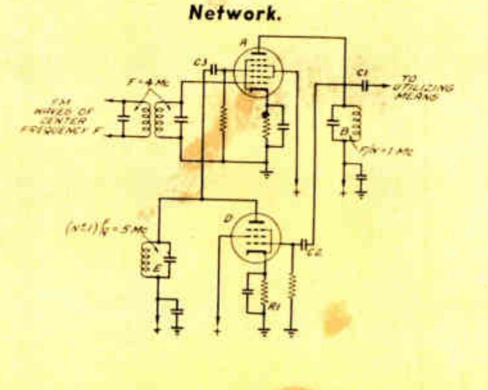
Patents to Bendix Engineers

The following patents have been issued to employees of Bendix Radio Division since July 1, 1944:

Richard S. Bailey, Etched Crystalline Hone. Patented 8/29/44, Pat. No. 2,356,910.—Use of piezoelectric quartz as a honing material.

George V. Eltgroth, Direction Finding Apparatus. Patented 8/29/44, Pat. No. 2,356,922. — Improvement of direction finder sensitivity by the use of a variable phase angle element responsive to voltage changes in the switching frequency amplifier.

Circuit diagram of Frequency-Divider Network.



Cross Sections

Tuning Unnecessary In 8-Channel Unit

Construction is under way in both Transmitter and Receiver Engineering Sections on a complete aircraft communication system which will provide more channels than have heretofore been available and will be simpler to operate than present equipment.

The new system will have eight channels in contrast with the four now available. It will require no tuning of any kind, thus satisfying the requirement of simpler operation. The frequency range will compare favorably with previously developed vhf radio.

Designed by Colonial Radio and undertaken as a subcontract by Bendix Radio, the project has been assigned to C. B. Lau of Receiver Engineering and R. C. MacArthur and R. V. Lindner of Transmitter Engineering.

The transmitter will have eight available channels, which require no manual tuning. With the proper crystals plugged in and the desired crystal selected, the transmitter will operate on the correct frequency. This is accomplished by the ganging of all tuning capacitors, the gang being driven by a motor. The operation of the motor is indirectly controlled by the presence or lack of grid drive to the final amplifier. In other words, if a new channel is selected there will be no grid drive on the final stage. Therefore the motor will begin to turn the gang and will continue turning until grid drive becomes available to the final amplifier, which, in turn, will shut off the motor.

Receiver tuning is essentially the same as in the transmitter, but in addition each channel on the receiver has a dial which determines the harmonic of the crystal to be used. The accuracy of the dial setting does not affect the tuning accuracy as long as it is fixed at a point within one per cent of the signal frequency.

The power supply and junction box consist of two dynamotors, one of which is used for the receiver alone and runs continuously, while the other for the transmitter is used only when the transmitter is operated. Provision is made for quick removal of the dynamotors merely by unfastening snap slides. This facilitates easy servicing of the machine.

The control box contains the channel selector buttons which operate the equipment. With selection of a channel the system is turned on and the channel which has been selected is automatically tuned. In addition to the buttons there are three jacks, one for microphone and two for headphones. An "off" button with an interlock makes it necessary to push two buttons to turn off the equipment.

Although the control box is painted, the metal surfaces of the receiver and power supply are unfinished.

Iron Core Loops Being Investigated

In an attempt to get greater loop sensitivity without increasing air-drag, G. O. Essex of Receiver Engineering has been investigating the use of iron core loops as directional antennas on airplanes.

It is known that the air-drag of a loop antenna mounted on the outside surface of an aircraft, together with other parasitic air resistances, increases in proportion to the square of the speed.

The ratio of lift to drag in modern aircraft is in the order of eight or ten to one. This means that for every pound reduction in parasitic air-drag for a given aircraft at a given speed, approximately ten pounds additional pay load may be carried without sacrificing aircraft performance.

Design of the air-core loop, now generally in use, is considered to have reached a point where little improvement may be made along the desired lines, inasmuch as the effective height of an air-core loop at a given frequency is a function of the diameter of the loop and the number of turns in the loop winding.

The use of a suitable powdered iron core, however, will cause an increase in effective height of the loop and provide greater sensitivity without increasing physical size.

Amplifier Designed For Huge JRM-1's

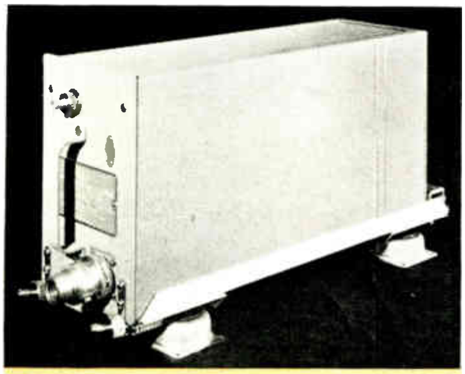
When the Glenn L. Martin Company was seeking a loud speaker system for use on the JRM-1 Aircraft—a system that would successfully override the noises when the craft was flying at full speed and yet would not boom out with a deafening roar under less noisy conditions—Bendix Radio was given the contract.

A system based on calculations made by Dr. S. B. Littauer determining the power output necessary from the speech amplifier is being designed in Receiver Engineering. The length, height and width of each compartment, the noise level at various frequencies experienced in the Mars (inasmuch as the JRM-1 is a flying boat very similar to the Mars), the sound level above this noise level necessary for the amplifier and loud speaker system to convey intelligible messages, the efficiency, location and number of speakers, are considerations which these calculations had to take into account.

The proposed system is so arranged that the pilot can give orders to personnel on the upper and two lower decks of the boat.

Design Is Completed On Marker Receiver

Although a marker beacon receiver was developed at the Bendix Radio Chicago plant six years ago, it was not put into production. This left one important gap in the Bendix line of radio aircraft equipment. Now, however, in the Receiver Engineering Laboratory, with Vernon Moore as project engineer, design has been completed on a single-channel, fixed-frequency receiver which will soon be available on the market. Both government and commercial airlines are prospective purchasers.



Front view of marker receiver

This equipment is designed for the reception of 75 mc marker signals. It is a crystal-controlled superheterodyne, having both aural and visual output. Aural output is provided by means of headphones, and the visual indication is given by small panel lamps with suitably colored jewels. When a 75 mc signal, modulated at 400, 1300 or 3000 cycles, is received from a marker beacon, the location of which is known to the pilot, one of the three indicator lamps on the instrument board lights and a definite tone is heard, telling the pilot how far along the given course he has progressed.

Provision is made for operation from either 14 or 28 volts.

VHF Tube Developed In Transmitter Lab

A tube capable of delivering one kilowatt output at frequencies between 100 and 156 mc has been developed in Transmitter Engineering. H. M. Huckleberry and his associates, in designing a vhf amplifier, found that a pair of type 8014A tubes would produce one kilowatt at frequencies no higher than 125 mc.

Believing that if the filament could be center-tapped, thereby eliminating excessive inductance, the tube would operate satisfactorily at higher frequencies, they sought the aid of the manufacturer, but were unable to get the modification made.

They decided to do the job themselves. At the Eclipse-Pioneer Laboratory in Teterboro, N. J., where the necessary facilities are available, a connection was welded to the center support of the filament and brought out the side of the glass envelope. A pair of these tubes was tested in the same circuit as the type 8014A tubes and an output of 1100 watts obtained, with a circuit efficiency of from 68 to 72 per cent over the entire band. The manufacturer of the 8014A tube, RCA, then agreed to modify additional tubes under the experimental number A2255.

Multi-Purpose Control Box In Final Stages

A receiver selector circuit designed to hold cross-talk to approximately 40 db, and having a power output sufficient for satisfactory headset operation with no auxiliary plate voltage supply, is the distinctive feature of a control box originally developed by J. W. Hammond and S. J. Holland, and now in the final engineering stage in the Transmitter Laboratory under the direction of E. L. Weigel. Facilities are also provided for interphone, for transmitter control, and for feeding the output signal of either the automatic or manual compass through a radio range filter. The unit weighs only 3.87 pounds, and measures 8¾ x 5¾ x 3 3/16 inches. inches.

From two to five control boxes may be used in a complete installation. Each unit makes available, through the use of toggle switches, the output of any one of eight receivers. The control box contains a one-tube amplifier system which matches the output impedances of as many as nine receivers to the impedance of standard headphones, eliminating the need for dual audio output circuits in the receivers themselves. Filament and plate voltage for a type 28D7 tube is obtained from a 28-volt d-c source.

Cross-talk discrimination between channels is held to approximately 40 db by use of series resistors in each of the eight input circuits of the control box. The low-impedance 600-ohm receiver outputs are loaded with a resistor of approximately 600 ohms.

The volume control has a range of approximately 10 db and the circuit is so designed that the output cannot be reduced lower than 8 to 10 mw with the 600-ohm load. The maximum output of the control box, with volume control set to maximum gain position, is approximately 200 mw into a 600-ohm resistive load, when any receiver selector toggle switch is positioned so that an input circuit of the control box is connected to a receiver output of 6 volts.

All the transformers are hermetically sealed by the use of Kovar-glass terminals. Connections to the box are made through a 27-conductor plug. Cable clamps used are the type for open wiring.

A unique feature of the control box is the tube shelf, which weighs one pound, and is attached to the chassis by two shockmounts, which runs through the center of gravity. This method of mounting reduces torque when the unit is vibrating and allows for operation of the unit in any position. The shelf can be withdrawn from the case for easy servicing by the removal of four screws fastened to the two shockmounts.

The interphone circuits of the box provide facilities for any station to call all other stations regardless of switch positions, and means for maintaining contact only with the stations desiring intercommunication.

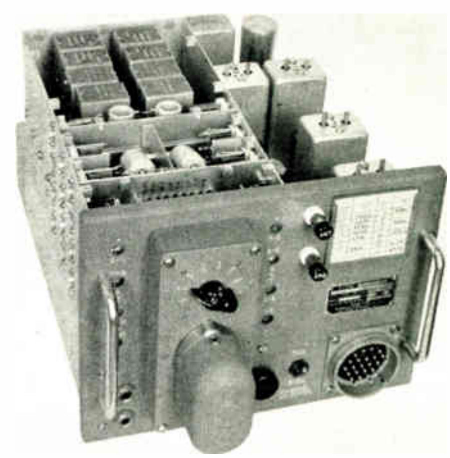
There is a separate junction box designed for the interconnection of the control boxes. It contains eight 4000/600 ohm autotransformers which can be used to match the high impedance (4000-ohm) receiver outputs.

Limited control of three transmitters, available at all stations, is provided by operating the usual press-to-talk microphone button. An auxiliary radio range filter can be placed in either the automatic compass or the manual compass receiver output by means of a filter switch on the control box.

All selector switches are mounted on a panel removable from the front to facilitate replacing toggle switches.

Fixed Frequencies Doubled On RA-2C

The RA-2B Series Aircraft Receiver, companion unit to the TA-2 Transmitter, has been re-designed to double the number of fixed frequencies, and to incorporate several other desirable refinements. A. T. Parker, Service and Parts, did the engineering work on the unit, which has been approved by the CAA and assigned type number RA-2C. It is



RA-2C Receiver, top removed

already being used by PANAGRA, TACA Airlines and British West Indies Airlines.

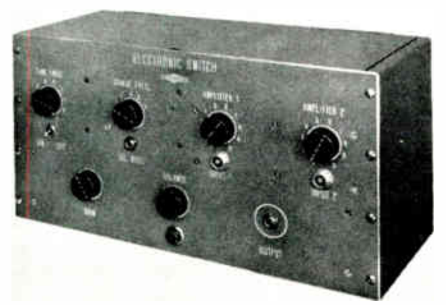
In addition to increasing the available fixed frequencies from eight to sixteen, the new model includes a beat oscillator for cw reception. Power supplies for operation on 12/14 volts and 24/28 volts input have been devised, and designated Type MP-12B and Type MP-12B-24, respectively.

Considerable thought was given to the problems of maintenance and availability of replacement parts for the RA-2C. Components widely used in other equipment were selected because their value has been proved through long periods of service, and because they are readily available.

Electronic Switch Gives Double Sweep

An electronic switch designed by James F. Gordon, Special Development Group of General Engineering, alternately places two amplifying channels into operation so that the output of first one channel, and then the output of the other, may be applied to the plates of a cathode-ray tube at a rate rapid enough to cause both signals to appear to be on the screen simultaneously.

Such a device has a number of laboratory uses, among which are visual examination of phase shift across a network, of phase shift in an amplifier circuit, or of relative gain or loss across a channel or network. It also affords a direct comparison of amplitude-modulated envelopes with modulating fre-



Electronic switch

quencies, and visual observation of over-all distortion between any input and any output of a continuous circuit.

Paint Specifications To Be Clarified

In order to make certain that specifications on paints used by all Bendix plants and sub-contractors are clear and precise, and to insure uniform procedure, the Mechanical Engineering Section has undertaken a comprehensive study of the subject. R. J. Streb, section chief, explains that the paints are submitted to a series of rigorous tests through which they can be evaluated.

At the conclusion of these tests an exact description of the paint will be possible. Present specifications for organic finishes will then be revised to include this data.

Flux Gate Compass On Agenda Of IRE

The Baltimore section of the IRE will open the new season on October 24. D. H. Smith, of Eclipse-Pioneer, project engineer on the Bendix Flux Gate Compass, will deliver a paper on this subject.

The question of modernizing college engineering education will be discussed at the meeting on November 28. Dr. William L. Everitt, professor of electrical engineering at Ohio State University, now on leave with the Signal Corps, who as chairman of education for the IRE is advocating a revision of present procedures, will address the group.

The need has long been apparent for a modification of facilities which provide only electrical or mechanical engineering courses and subsequent individual application of this basic engineering knowledge to radio.

As part of the same program, J. W. Hammond, sales manager, will read a short paper on the application of radio in train communications based on the recent test made by Bendix engineers.

Control Console In Use At La Guardia

A ground station control console, designed by W. D. Price, Jr., Sales Engineering, has been installed at the National Airlines offices at La Guardia Airport, New York, where it is used to facilitate transmission of modifications in flight plans, weather reports, and other company flight information. Arranged to permit ready accessibility to any controls or equipment the customer may specify, the low construction of the console can be installed to afford the operator an unobstructed view of the airport.

Each of three standard nineteen-inch control panels is built in sections, any one of which can be removed from the front for rapid servicing. The cabinet is also easily serviced from the rear, and is equipped with a fan to cool the unit and eliminate dust.

Two line-amplifiers for amplifying signals coming over telephone lines from the remote receiver are located in the left panel receiver section, with two controls for adjusting receiver sensitivity, and two receptacles for the headset jacks. The transmitter section in the center has a multi-toggle switch mixer panel and a telephone-dial transmitter channel selector. The right panel contains a "stand-

Control console installed by National Airlines at La Guardia Field.

by" receiver for emergency use in the event of remote receiver or telephone line failure.

A Bendix Expander-Compressor Amplifier,* for improving intelligibility of received and transmitted speech, is installed in the lower left drawer compartment. A desk-top section, with typewriter space, filing shelves, and a lower right desk drawer compartment remain for regulation office use. A foot "press-to-talk" switch is located below and to the right of the typewriter section, freeing the operator's hands for control duties or typing.

Suggestions of Donal G. Erskine, Engineering Department artist, and Robert E. Bingman, industrial artist, were incorporated in the final design. The accompanying photograph shows the National Airlines model which was built in the Experimental Engineering and Sales Service sections.

Make Radiographs With Regular Film

The Photographic Unit of Technical Publications has found that the use of ordinary photographic film and developer for radiographing small parts gives a much longer range of densities than is obtainable by the use of regular X-ray film. Fine detail can be obtained in the representation of the various thicknesses of the object being radiographed.

A pen point, for example, is a very difficult subject to photograph by the lens method. By the X-ray method, using single emulsion film, it can be reproduced faithfully even showing in delicate detail the slight indentations of lettering on the curved surface.

* See "Expander-Compressor Amplifier," by L. R. Yates, BENDIX RADIO ENGINEER, Volume I, Number 1 (July) 1944, p. 10.

Aircraft Approach Project Under Way

WORK ON A FIXED INSTALLATION for ground control approach for aircraft is well under way in the Microwave Engineering Laboratory.

A. E. Abel, section chief, also reports a cooperative engineering effort with the Hazeltine Corporation on a new project.

Another project, initiated under a development contract with Wright Field, is for pulse navigation equipment.

Special tubes designed by Microwave Engineers will be built by the Eclipse-Pioneer Division, Teterboro, N. J.

With this division also, development work is in progress on an Autosyn data take-off system for microwave antennas.

Expressor Amplifier Used In PA System

THE EFFECTIVE MUSIC programs, heard periodically in the Towson plant, are an outgrowth of months of investigation and planning on the part of D. C. Hierath and H. L. Spencer of General Engineering. A system combining plant music and paging facilities, was designed to meet the specific needs of this plant. The Muzak service provides musical programs via telephone wires.

Of particular interest to Bendix Radio will be the absence of feedback howls, volume variation and extraneous racket formerly picked up by the paging microphone. With the new system, regardless of the type of paging voice or the level at which the microphone is addressed, the signal on the floor will never exceed a predetermined volume level. This ideal condition is accomplished through the use of Bendix Radio's new Expander-Compressor Amplifier.

Omni-Directional Beacon Investigated

COMMERCIAL AIRCRAFT ON cross-country flights are guided along any one of four courses by the standard four-course low-frequency radio ranges. A system of radio navigation capable of guilding aircraft along a great number of courses, is a current project on which Paul Kreager of the Receiver Engineering Laboratory is working.

This system has several advantages over the present range, chief among them being that course indications are visual, thus relieving the pilot of obtaining his course indications by aural methods. A further advantage is that the pilot at all times knows his position in relation to the station to which his receiver is tuned without executing the complex orientation procedures required in the four-course range.

An example will serve to illustrate its operation. In the accompanying sketch, an aircraft at point A wishes to proceed to point B. The pilot, having obtained the true bearing of A with respect to B from his aeronautical charts, needs only to orient his plane after attaining altitude until the indicator mounted on his instrument panel reads the same as the true bearing. A glance at the magnetic compass will tell him whether he

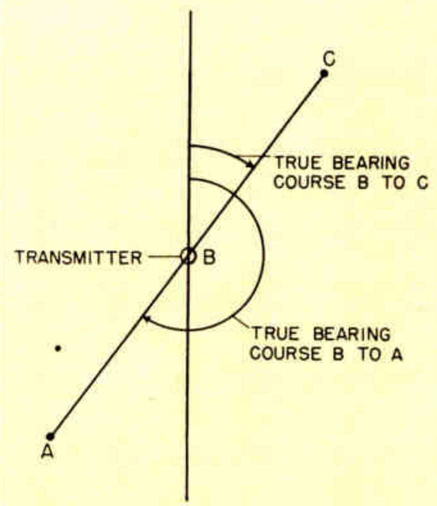


Diagram showing operation of omni-directional beacon.

is flying "to" or "away from" point B. The course flown will be the great circle course between A and B, regardless of the direction and strength of the wind, provided the pilot's indicator reads the true bearing of that course at all times.

The indicator executes a 180° turn on passing over the transmitting station located at point B, thus advising the pilot that he has reached that point. If, after reaching point B, the pilot wishes to proceed to point C, the same procedure is followed except that the true bearing for the great circle course B to C will be maintained. In flying away from B, the pilot always knows that he is on the great circle course when his indicator reading corresponds to the true bearing.

The system is not restricted to use in any portion of the radio frequency spectrum. Indeed, some uses may show that best operation is obtained at low frequencies, while other services may best be accomplished at very high frequencies.

New Specifications For Transformers

BECAUSE OF GOVERNMENT requirements forcing the entire transformer industry into 100 per cent hermetically sealed equipment, the Transformer Section is making new designs, and converting many old ones to new specifications. This applies even to a 250-pound transformer, the largest yet built by the Section.

H. J. Oosterling, section chief, states that a completely satisfactory molded bakelite head soldered into either a copper or steel can is now in use and meets all requirements of hermetic sealing. However, striving for a solution that may be still more acceptable, glass terminals supplied by different manufacturers are being investigated. Kovar leads and collars in combination with pyrex glass beads have been found advantageous because the Kovar and the glass have the same coefficient of expansion. If heat is applied to the metal, the glass and the metal will expand to the same degree. This characteristic is particularly desirable in the tropics.

Engineering Library Increasingly Popular

THE ENGINEERING LIBRARY, little more than two years old, is nearing a monthly average of a thousand books charged out. Special requests through the public and university library loan service total more than a hundred a month. Of inestimable value in research is the unusual card file of subject indices for all books, magazines and catalogues, set up by Mrs. Downey, librarian. The vhf literature being acquired is one of the finest collections in the country.

Phase-Meter Under Development Here

TO SUPPLY THE NEED for apparatus capable of measuring accurately and readily the phase-angle between two radio-frequency voltages or currents encountered in laboratory practice, a wide range phase-meter capable of many applications is under development.

According to G. R. White, engineer on the project, the meter consists of two high-impedance probes, a variable-frequency local oscillator and two separate mixer or modulator circuits. By heterodyning, the radio-frequency voltages are converted into a suitable audio-frequency voltage of the same relative phase-angle.

By **WILLIS G. JONES**

SHORT-WAVE RADIO *(Third edition), by J. H. Reyner. Published by Sir Isaac Pitman & Sons, Ltd., London. 183 pages. Price $3.25.*

When an author sets himself the task of covering Short-Wave Radio in 183 pages, it is a foregone conclusion that he can only hit the "high spots." That is exactly what Mr. Reyner has done. This little book is a non-mathematical discussion of short waves written at what would be the amateur level in the United States. A brief introductory chapter titled "What Are Short Waves," is followed by a rather interesting one on "The Propagation of Wireless Waves." Antennas and feeders, aerial arrays, and receiving aerials are then taken up.

Transmitters and modulation theory, short-wave receivers, and ultra-short waves are discussed in succeeding chapters. The author concludes with chapters on frequency modulation and microwaves, each chapter consisting of about ten pages. It is this reviewer's opinion that *Short-Wave Radio* is neither fish nor fowl. It is not detailed enough for the beginner, not comprehensive enough for the amateur and not definite enough for the engineer. The reviewer recommends the more specialized works in Reyner's bibliography.

FIELDS AND WAVES IN MODERN RADIO, *by Ramo and Whinnery. Published by John Wiley & Sons, Inc., New York, N. Y. Price $5.00.*

This volume is the latest of an impressive series prepared by the General Electric Company for use in their advanced training program, which is aimed to provide adequate mathematical and scientific discussions of fundamental engineering topics. First principles have been emphasized in the program, and gaps in the engineer's training are thereby corrected. This ideal is followed closely throughout the book. The authors devote the first three chapters to basic circuits, transmission lines and static electric and magnetic phenomena. Ideas most apt to carry over into radio are given mathematical treatment. Thus the necessary mathematics is illustrated with the better known engineering and physical principles. While considerable material on vectors, partial differential equations and allied topics is neatly introduced, the treatment is probably much too brief. Chapter IV considers Maxwell's equations and discusses the systems of units in common use. Chapters V and VI return to transmission lines as an application of Chapter IV, and a preparation for coaxial lines and wave guides. Chapter VII deals with propagation and reflection problems in general. Chapters VIII and IX return to Maxwell's equations and apply them to wave guides. Chapters X deals with cavities and XI closes the book with antennas. A short bibliography and nomenclature tables are appended. The transmission line is carried along and its basic concepts stressed again and again both to illustrate new theory and re-explain such older notions as impedance, matching, resonance, etc. The book contains frequent summaries but lacks numerical problems. It is felt the gap between power engineering and modern radio is bridged successfully with mutual benefits to both fields. This makes it valuable both as a text and reference. However, the mathematics will be found difficult for one studying alone. All such treatments in this field lack the more recent developments. Only when presently restricted material is released, will a really practical book be possible. The subject book is as complete as any now available.

JOHN W. HURST, Ph.D.

RADIO DIRECTION FINDERS, *by Donald S. Bond. Published by McGraw-Hill Book Company, Inc., New York, N. Y. 274 pages. Price $4.00.*

The technique of radio direction finder design and theory is quite different from that of ordinary receiving sets and the author has attempted to sort out the theory and practices peculiar to his subject. His aim is to produce a textbook and reference work suitable for electrical engineers desiring to specialize in the design and theory of direction finders for aircraft, marine or fixed-station use. Detailed mathematical derivations have been placed in an appendix to facilitate study of the text by those with limited technical training. General considerations of direction finders including their functions, classes, two types of test procedures with charts, units of transmission, voltage and current ratios and measurements are first dealt with. Included is the theory of wave propagation as related to radio direction finders. Directive antennas, including loops, vertical wires, dipoles, etc., with a discussion of polarization errors and Adcock antennas used to reduce such errors are then treated. Bilateral and unilateral bearings are touched upon. Further information about loops is in a later chapter on "Performance Characteristics" wherein the author is principally concerned with the various types of noise effect. The two types of aural-null direction finders are described and various coupling methods are discussed. There is also a section on phase-shift characteristics with examples of both marine and aircraft circuits. His chapter on "Visual Direction Finders" includes a description of the Bendix Type MN-31 Automatic Compass as well as the Mark I (RCA-Sperry) equipment. Most of this information was published in a previous article by the same author in *Electronics Magazine*. One item which he has failed to describe is the Bendix dual automatic compass which permits two simultaneous bearings to be taken from a single azimuth indicator. Since this system is a definite advantage in certain navigational systems, it would seem to deserve a place here. The final chapter, "Radio Navigation Aids," describes several charts such as Mercator projections, Lambert Conformal Conic projections and gnomonic projection planes. The text is well illustrated with examples of each projection type from an article in *Life* Magazine (Aug. 3, 1942). The remainder of the last chapter is devoted to calibration of automatic direction finders in which a brief outline of accepted systems is described. The book should prove interesting and useful to engineering students as well as others connected with the aircraft and marine industries.

EQUIPMENT AND METHOD FOR MEASUREMENT OF POWER FACTOR OF MICA, by E. L. Hall, *Proceedings of I. R. E.*, July. Since power factor is the best single electrical property indicative of the suitability of mica for radio uses, the author describes method and equipment for r-f measurements.

FREQUENCY MODULATION OF RESISTANCE-CAPACITANCE OSCILLATOR, by Maurice Artz, *Proceedings of I. R. E.*, July. A method of frequency modulating an r-c oscillator said to be simpler and more stable than the beat oscillator.

GROUNDED-GRID RADIO-FREQUENCY VOLTAGE AMPLIFIERS, by M. C. Jones, *Proceedings of I. R. E.*, July. An analysis of the performance of several types of grounded-grid radio-frequency amplifiers.

THE DEVELOPMENT OF A NEW STATION LOCATION OR Z-MARKER ANTENNA SYSTEM, by J. C. Hromada, *Proceedings of I. R. E.*, August. Description and flight test information relating to a new Z-marker antenna system.

WAVE GUIDE JUNCTIONS AND TERMINATIONS, by V. J. Young, *Radio*, July. A discussion of wave guide junctions and terminations with some methods of attacking design problems.

FREQUENCY DETERMINATION, by John D. Goodell, *Radio News*, July. Discussion of frequency standards, multiplication, division and measurement.

DENSITOMETRY, by Albert A. Shurkus, *Radio News*, August. Methods and equipment for measurement of optical density.

SOUND ON VIDEO, by James E. Robinson, *Radio News*, September. An interesting new method of television transmission combining sound and picture modulation.

CARBON-BRUSH CONTACT FILMS (Part I), by C. Van Brunt and R. H. Savage, *General Electric Review*, July. Collector films largely determine performance critically affected by high altitudes.

EFFECTS OF ELECTRIC SHOCK, by H. A. Poehler, *Electronics*, July. Some timely data on the danger of being electrocuted.

28-VOLT OPERATION OF RECEIVING TUBES, by C. Hammond, E. Kohler and W. Lattin, *Electronics*, August. Triodes and pentodes operated directly from aircraft battery. Includes performance charts and tables.

PI NETWORKS AS COUPLED TANK CIRCUITS, by Frederic D. Schottland, *Electronics*, August. Design procedure to simplify matching the final amplifier to a transmission line or antenna without using an output transformer.

BRIDGE-CONTROLLED OSCILLATOR DESIGN, by William H. Bussey, *Electronic Industries*, August. Phase shift control based on a frequency-selective a-c potentiometer circuit.

STANDARDS ACTIVITIES

Two Bendix Radio Standards committees have been reorganized and are now functioning as Engineering Department Committees. The former "Bendix Engineering Standards Committee" is now known as the "Bendix Electrical Standards Committee." The former "Advisory Group on Mechanical Standards" has been reorganized on a full Engineering Department committee level and is known as the "Bendix Mechanical Standards Committee." Both function under the chairmanship of H. L. Spencer, Quality Engineer of General Engineering Department.

The Materials Committee of the Eastern Engineering Conference of Bendix Aviation Corporation is preparing Standard Specifications covering special materials used by two or more Divisions for which adequate standard or commercial specifications do not exist. Specifications covering Silicon Aluminum Dye Casting Material, Beryllium Copper Diaphragm Material, and Beryllium Copper Spring Material are scheduled for early release.

One purpose in issuing Bendix Aviation specifications is to encourage consistency among divisions now purchasing materials to similar but slightly varying specifications. By using standard Aviation specifications, mills and vendors can be encouraged to supply to our closer tolerances since increased volume will attract more sources. This is particularly true in the case of Beryllium Copper suppliers.

H. L. Spencer, General Engineering, and W. A. Willis, Chief Mechanical Engineer of the Receiver Section, Bendix Radio members of the Materials Committee of Bendix Aviation, were appointed Chairman and member, respectively, of the Sub-committee on Standards. The first release will be a Tolerance Brochure dealing with the standard tolerances involved in supplying ferrous and nonferrous materials to all divisions.

BROAD BAND ANTENNAS

(Continued from page 5)

APPENDIX

The mathematics for determining proper L and C constants to use in corrector circuits is as follows (see figure 4):

Find the range of frequency over which a given dipole can be made to operate with less than a given SWR. For example, feed this dipole with a 50-ohm line and set the SWR limit at 2 to 1. The band edge impedance can be set at 100 ohms, causing a 2 to 1 SWR in a 50-ohm line. To find the frequency limits beyond which the dipole cannot be corrected to less than 100 ohms resistive impedance:

$$Y_a = \frac{R_a}{Z_a^2} - j\frac{X_a}{Z_a^2}$$

where Y_a = dipole admittance,

R_a = radiation resistance from figure 3, and

X_a = reactance from figure 3.

$Z_a = \sqrt{R_a^2 + X_a^2}$ (Z_a is complex impedance)

$$Y_p = o - j\frac{X_p}{Z_p^2} = -j\frac{1}{X_p}$$

when Y_p = corrector circuit admittance,

X_p = corrector circuit reactance, and

$Y = Y_a + Y_p$ = combined admittance of dipole and corrector.

$$Y = \frac{R_a}{Z_a^2} - j\left(\frac{X_a}{Z_a^2} + \frac{1}{X_p}\right).$$

At resonance, $\frac{X_a}{Z_a^2} = -\frac{1}{X_p}$.

When resonance exists, $Y = \frac{R_a}{Z_a^2}$ and

$Z = \frac{1}{Y} = \frac{Z_a^2}{R_a}$ combined impedance of dipole and corrector.

At f_1, Z must $= 100 \pm jo$.

Inspection of the curves of figure 3 shows that at

$$f_1 = f_0 - 13.3\% f_0,$$

$$Z_a = 41 - j49 \text{ and } Z_a = 63.8.$$

$$Z = \frac{(63.8)^2}{41} = 99.5.$$

Also at $f_2 = f_0 + 12.5\% f_0$,

$$Z_a = 60 + j49.5 \text{ and } Z_a = 77.7$$

$$\left(\text{and } Z = \frac{(77.7)^2}{60} = 100.8\right).$$

The dipole of figure 4 may then be made to cover 13.3% + 12.5% or 25.8% frequency range.

The constants for the L/C circuits must now be determined. If the dipole were a lumped constant series resonant circuit it would resonate at the algebraic mean of f_1 and f_2. This is not exactly true of the broad band dipole.

At f_1 and f_2 $\frac{X_a}{Z_a^2} = \frac{1}{X_p}$

or $X_p = \frac{Z_a^2}{X_a}$.

At f_1, $X_p = \frac{(63.8)^2}{49} = +83.3$ ohms.

At f_2, $X_p = -\frac{(77.7)^2}{49.9} = -122.2$ ohms.

$$\text{At } f_1,\ X_p = -\frac{\omega_1 L \cdot \frac{1}{\omega_1 C}}{\omega_1 L - \frac{1}{\omega_1 C}} = -\frac{L/C}{\omega_1 L - \frac{1}{\omega_1 C}} = -\frac{\omega_1 L}{\omega_1^2 LC - 1}.$$

At f_2, $X_p = -\frac{\omega_2 L}{\omega_2^2 LC - 1}$,

where: $\omega_1 = 2\pi f_1$, $\omega_2 = 2\pi f_2$,

$f_1 = f_0 - 13.3\% f_0 = 0.867 f_0$,

$f_2 = f_0 + 12.5\% f_0 = 1.125 f_0$,

$$\frac{f_2}{f_1} = \frac{1.125}{0.867} = 1.3,$$

$$\frac{\omega_2}{\omega_1} = \frac{2\pi f_2}{2\pi f_1} = 1.3, \text{ and}$$

$$\omega_2 = 1.3\,\omega_1.$$

$$\text{At } f_2,\ X_p = -\frac{1.3\,\omega_1 L}{1.68\,\omega_1^2 LC - 1} = -122.2.$$

$$\text{At } f_1,\ X_p = -\frac{\omega_1 L}{\omega_1^2 LC - 1} = +83.3,$$

$$\frac{-\frac{1.3\,\omega_1 L}{1.68\,\omega_1^2 LC - 1}}{-\frac{\omega_1 L}{\omega_1^2 LC - 1}} = -\frac{122.2}{83.3},$$

and $\omega_1^2 LC = .734$.

At f_0 (of L/C circuit), $\omega_0 L = \frac{1}{\omega_0 C}$,

$$LC = \frac{1}{\omega_0^2},$$

$$\frac{\omega_1^2}{\omega_0^2} = .734,$$

$$\frac{\omega_1}{\omega_0} = .857,$$

$$\omega_0 = 1.167\omega_1, \text{ or}$$

f_0 (of L/C circuit) $= 1.167 f_1$.

$$\text{At } f_1,\ X_p = -\frac{\omega_1 L}{\omega_1^2 LC - 1} = -\frac{.857\,\omega_0 L}{.734\,\omega_0^2 LC - 1} = 83.3,$$

$$\omega_0 L = \frac{1}{\omega_0 C}, \text{ and}$$

$$\omega_0^2 LC = 1.$$

$$\text{At } f_1,\ X_p = \frac{.857\omega_0 L}{.266} = 83.3,$$

$$\omega_0 L = 25.85 \text{ ohms},$$

$$\omega_0 C = \frac{1}{\omega_0 L} = \frac{1}{25.5} = .0387, \text{ and}$$

$$\frac{L}{C} = \frac{\omega_0 L}{\omega_0 C} = \frac{25.85}{.0387} = 720,$$

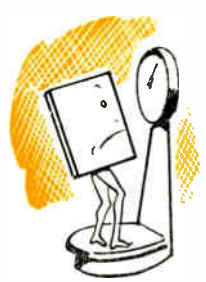
Z_0 of "bazooka" in figure 6 =

$$\sqrt{\frac{L}{C}} = 25.85 \text{ ohms}.$$

In order to obtain this low impedance it is necessary either to capacity load the antenna end of the "bazooka" or to build the "bazooka" as a shielded balanced line since an open line of 25.85 ohms Z_0 is impractical to build.

On Bathing Crystals

While the Fifth Army pushed north of Rome last June, J. W. Colvin was investigating the inactivity of some of the DC-11 crystals in that theatre. He discovered that most of their inactivity results from the scaling of the crystal surface. With the aging of a crystal which has not been finished by the etching process, a thin coating of very fine particles may form on the surface. Activity can be restored by cleaning with soap and water or carbon tetrachloride, but the frequency invariably increases from one to three kilocycles. After this shift in frequency, the crystals must be put back in stock to be ground to a higher frequency. The other chief causes of inactivity are dirt and oil; cleaning these crystals always raises their frequency by three to five kilocycles.



ENGINEERS on the GO

MANY PROJECTS are underway in the various engineering sections necessitating numerous out-of-town trips by engineering personnel.

W. L. WEBB and D. C. HIERATH called at the home office at Detroit to demonstrate a special high-fidelity sound reproducing system developed by Bendix Radio, and later joined W. P. HILLIARD in New York to conduct further business relating to the same equipment.

O. L. PETERSON visited the Chicago office to interview prospective employees for the Engineering Department.

J. P. SHANKLIN discussed an antenna development at the Naval Research Laboratory in Washington, D. C.

H. J. OOSTERLING and H. W. MERRIAM were in New York City at Insl-X Company to discuss a waterproof coating for transformers, then went to Millville, New Jersey, to confer with officials of the Wheaton Glass Company concerning prospective glass-type terminals for hermetically sealed transformers.

N. RAYMOND visited Colonial Radio Corporation at Buffalo in connection with liaison work between Colonial and Bendix Radio engineers; called at the Sparks-Withington Company at Jackson, Michigan; went to the Aircraft Radio Laboratories at Dayton; and conferred with Zenith Radio engineers in Chicago.

W. A. WILLIS participated in the Materials Committee conference at Radio City; visited the Polaroid Products Company in New York City to discuss the use of polarized glass on new instruments; and met with the Bendix Materials Committee at Red Bank, New Jersey.

W. H. SIMS, JR., went to the Naval Research Laboratory in Washington, D. C., to observe recently developed radio equipments.

A. A. HEMPHILL flew to the Azores to install a radio compass for the Portuguese Navy.

W. J. HOLEY and R. G. KORNMANN attended a crystal conference called by the Signal Corps Inspection Agency in Chicago.

R. V. LINDNER and C. B. LAU were in Buffalo attending a meeting at Colonial Radio Corporation.

A. R. PERONG reviewed vacuum tubes at the Electronics Section of the Eclipse-Pioneer Division at Teterboro, New Jersey, and attended the Radio Technical Planning Board meeting in New York City.

H. L. SPENCER went to Colonial Radio Corporation at Buffalo; attended an I. R. E. conference in New York City; and was in Red Bank, New Jersey, for a Materials Committee meeting.

R. J. STREB visited the Tubular Rivet and Stud Company, Wollaston, Massachusetts, concerning standardization of dimensions and tolerances of rivets. He also conferred with officials at the Charles E. Crofoot Gear Company at South Easton, Massachusetts, concerning the gearing of a special radio equipment; flew to Gear Specialties at Chicago to discuss standardization of methods of checking gears; then called at General Mills Corporation at Minneapolis concerning gears.

D. C. HIERATH and R. F. SMELTZER visited the F. W. Sickles Company at Springfield, Massachusetts, to discuss new equipment.

T. G. ARNOLD, JR., went to the Aircraft Radio Laboratories at Dayton to deliver, and to observe tests on, one of five preliminary models of a modified King George equipment now in production.

W. L. WEBB called at the General Instrument Corporation at Elizabeth, New Jersey; attended a Bell Telephone Laboratories meeting in New York City.

E. O. GAGUSKI was at Derry, Pennsylvania, for a consultation with the ceramic division at Westinghouse.

P. G. CLICE demonstrated a model of a vhf meter to the Bureau of Ships, Washington, D. C., then demonstrated the same model at the Aircraft Radio Laboratories, Dayton, Ohio.

G. O. ESSEX, S. R. FUND, and H. WALKER went to the Aircraft Radio Laboratories at Dayton to discuss new specifications and developments on a Bendix Radio compass.

A. L. BOHN was in Chicago concerning tests of train radio equipment, and called at the Aircraft Radio Laboratories at Dayton.

E. S. OAKES and W. YATES discussed the construction of i-f transformers for radio compasses with F. W. Sickles Company engineers at Springfield, Massachusetts. MR. YATES also spent some two weeks at the Aircraft Radio Laboratories at Dayton concerning a new compass development on which he is project engineer.

R. F. HOOVER, M. FERNBACH and A. L. BOHN were in Richmond, Virginia, testing train radio equipment.

E. O. SWANSON, and W. H. SIMS, JR., discussed various phases of new equipment with Colonial Radio Corporation engineers.

J. H. TAYLOR, M. TAYLOR and R. J. DAVIS conferred with officials at Camp Evans Signal Corps Laboratory at Belmar, New Jersey.

H. A. VARLEY, of the West Coast Branch, visited Consolidated-Vultee and Tannart Field in Fort Worth; and Beech, Boeing, and Wichita Signal Repair Shop at Wichita, Kansas. MR. RIOTELLI, project engineer on the B-29, reported to MR. VARLEY that Boeing was having no difficulties with Bendix Radio installations on the Superfortresses.

E. J. KING spent several days at the Fort Monmouth Signal Corps Laboratory investigating wire tests.

DR. S. B. LITTAUER attended a meeting of the National Defense Research Council in Washington, D. C., and visited Eclipse-Pioneer at Teterboro, New Jersey, concerning the development of a new indicating instrument.

P. H. KREAGER conferred with officials of Sparks-Withington Company at Jackson, Michigan, concerning the production of a Bendix compass.

D. W. MARTIN, H. WALKER, W. H. SIMS, JR., and A. R. PERONG participated in a conference with officials of the Bureau of Ships in Washington, D. C.

C. B. LAU called at the Aircraft Radio Laboratories at Wright Field concerning a modified receiver development.

I-F TRANSFORMER ALIGNMENT

Test and Inspection finds signal generator using modulated oscillator is cause of faulty i-f transformer alignment.

INVESTIGATION OF DIFFICULTIES experienced by Receiver Test in accurately aligning i-f stages of compass receivers revealed that an r-f signal generator in which modulation was applied to the oscillator was the source of trouble. As a result of the investigation, Test and Inspection has offered these solutions to the problem: cathode-ray alignment making use of a mechanical, or an electronic sweep method.

I-f response curves obtained from receivers aligned with the modulated oscillator signal generator were found to be unsymmetrical. In one typical case, peaks of substantially equal magnitude were separated by 3.70 kc. The region between peaks contained a fairly flat section approximately 1.5 kc wide. The minimum in the response curve occurred within 300 cycles of the midpoint of the peaks, and the output at the minimum response was only 37.2 per cent of maximum output. When the same receiver was aligned with a signal generator in which the modulation was not applied directly to the oscillator, the response curve was found to be symmetrical. Peaks of equal magnitude were separated by 3.07 kc. The region between the peaks curved smoothly to a minimum which occurred within 125 cycles of the midpoint of the peaks, and the output at this minimum was 63 per cent of the maximum output.

It was believed that poor response was caused by frequency modulation occurring in this type of signal generator with the audio modulation applied directly to the oscillator stage.

Figure 1—Response curve of an over-all i-f system checked on a cathode-ray oscilloscope shows inaccuracy despite careful alignment by a signal generator with a modulated oscillator.

It is well known that the variation of the plate voltage of an oscillator produces changes in the oscillator output frequency; thus audio modulation applied directly to an r-f oscillator will produce a frequency modulated signal. When a frequency modulated signal is applied to a circuit with a characteristic typical of over-coupled i-f transformers, the steep sloping sides of the response curve cause detection of the frequency modulated signal, thus contributing audio components which add to the output due to pure amplitude modulation. The result is a fallacious response picture.

To verify this, results were compared of alignment obtained with a generator in which the modulation was applied to an amplifier stage, and a generator using no modulation. Agreement between the two sets of data was remarkable.

Twelve receivers were then aligned with an unmodulated signal generator. The dip of the over-all intermediate frequency response curve did not deviate more than 240 cycles from 112.5 kc, and only two sets were off by that amount. The average deviation was 122 cycles.

Although the results obtained with the unmodulated generator and the amplifier modulated generator were satisfactory, it was decided to investigate further and to study cathode-ray tube aligning methods for production work.

A motor-driven capacitor was used, with excellent results, to frequency modulate an r-f signal of 112.5 kc. An oscilloscope using a double trace of the i-f curve was necessary to assure accurate centering and equality of peaks. The sweep circuit of the oscilloscope was synchronized with the motor-driven capacitor at twice its rate of frequency sweep. This arrangement produced the double trace on the cathode-ray tube screen.

Figure 1 shows the over-all i-f response curve of a receiver carefully aligned by the original method, using a signal generator with modulated oscillator. Figure 2 shows the over-all response curve of an i-f system aligned with the mechanical sweep. Except for the disadvantage of continuous use of the motor-driven capacitor, the latter method is completely practical.

An electronic sweep, however, overcomes the disadvantages of the mechanically rotated capacitor, while giving equally satisfactory results. In the electronic method, a triangular wave generator is used to produce pulses at about 40 cycles per second. A reactance control tube varies the oscillator frequency linearly about a center frequency of 900 kc at a width of about 17 kc. The output is mixed with that of a fixed frequency oscillator of 1012.5 kc, producing a frequency modulated signal of 112.5 kc. The signal is applied, through an attenuator, to either the first or the second i-f amplifier grids. Receiver output is brought out from the plate of the detector-amplifier tube to the vertical deflection plates of the oscilloscope. Connection is made from the triangular wave generator to the external synchronizing terminals, and the sweep rate is set to twice the frequency of the triangular wave fundamental.

Of the two cathode-ray tube methods investigated, electronic alignment is preferable. In equipments with two i-f channels, a simple operation of a switch makes either i-f frequency available for use. The initial expense involved in installing equipment for production use probably can be offset by economies effected through the rapidity and accuracy of the alignment process.

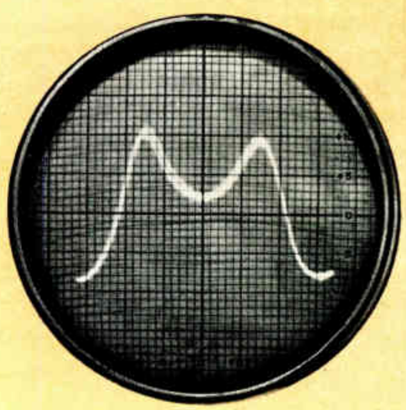


Figure 2—Response curve of an over-all i-f system properly aligned by the cathode-ray oscilloscope method.

INTEGRAL WAVEMETER

Accurate tuning of TA-12 transmitter facilitated by addition of easily operated wavemeter.

By H. K. BRADFORD
Transmitter Engineering

TUNING AND LOADING of a transmitter to the second harmonic of the desired frequency is so similar to tuning and loading to the fundamental frequency that even the technician or engineer of considerable experience often finds the two indistinguishable. The problem is greatly complicated through the use of 1) multichannel transmitters with wide band coverage, 2) both variable inductive and capacitive elements, 3) modified pi networks, and 4) a large range of antennas of widely varied characteristics. In the presence of these factors, merely noting the amount of capacitance or inductance used in the loading or coupling network is not sufficient to distinguish a fundamental from a second harmonic.

A Handy Solution

An excellent aid in making tuning or loading adjustments, the absorption wavemeter is not always used chiefly because the apparatus is not available, or because its value is not understood.

In making some recent improvements in our TA-12G and H equipment, we built an absorption wavemeter into the transmitter to increase its loading usefulness. The wavemeter is thus at hand always and there is no reason for improper tuning, if the simple instructions for its use are followed.

To adjust the circuits for each band, we decided to use a simple tuned circuit with variable capacitance, and a tapped inductance shorting out the undesired turns. A neon tube is used as an indicator of voltage across this tuned circuit. The point in the circuit at which the r-f voltage is most constant for all conditions is at the P.A. plate.

As shown by the circuit diagram in figure 1, the wavemeter is coupled through a .25 megohm resistor to the r-f side of the plate circuit. The wavemeter, as designed, is applicable only to channels 2, 3, and 4. A switch section, S-102-G, already used in the channel selector multiswitch, is employed on channel 1 only, for connecting direct current to the antenna loading unit relay. The connection is open for the other channels, since the low frequency loading unit is not used. The switch arm of S-102-G is bypassed to ground through C4, and another condenser, C3, isolates the A+ from ground.

In each of channels 2, 3, and 4, the ratio of maximum-to-minimum oscillator capacitance is the same. The oscillator condenser dials have 30 main divisions; circular rotor plates are used. C3 being negligible in determining frequency, C2 is adjusted so that

$$\frac{C_1 \text{ max.} \quad + C_2}{C_1 \text{ min.} \quad + C_2} = \frac{C \text{ max. osc. total}}{C \text{ min. osc. total}}$$

The distributed capacitance of the wavemeter coil L_1 is so small, relatively, that a change of taps has a negligible effect. A dial attached to C1 is graduated in 30 units, and its rotor plates also are circular. Thus, for each channel, the reading on the oscillator corresponds to the reading on the wavemeter dial within ± 1/2 division.

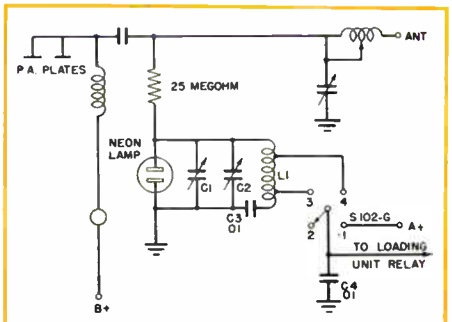


Figure 1—Circuit diagram of wavemeter for TA-12G and H transmitters.

Tunes Sharply

When properly loaded, the wavemeter tunes so sharply that the neon lamp is illuminated over an arc of less than one division. Since the maximum-to-minimum capacitance ratio of the oscillator circuits is less than four, none of the channels may produce double its lowest fundamental frequency. For this reason, the wavemeter has only one possible reading for a properly tuned and loaded circuit.

After tuning and loading, the wavemeter dial connected to C1 is tuned so that its reading corresponds to the oscillator dial reading. If the neon lamp is illuminated when the wavemeter dial reading corresponds with the oscillator dial reading, it indicates that the output circuits are correctly tuned. The brilliance of its illumination is an index of the transmitter loading.

Since the channels are automatically switched, there is no possibility of selecting the incorrect tap for the wavemeter coil. The correct inductance is selected for each channel with the channel switch of which S-102-G is a part. A very small fraction of one watt is utilized to drive the wavemeter.

Vest-Pocket Meter

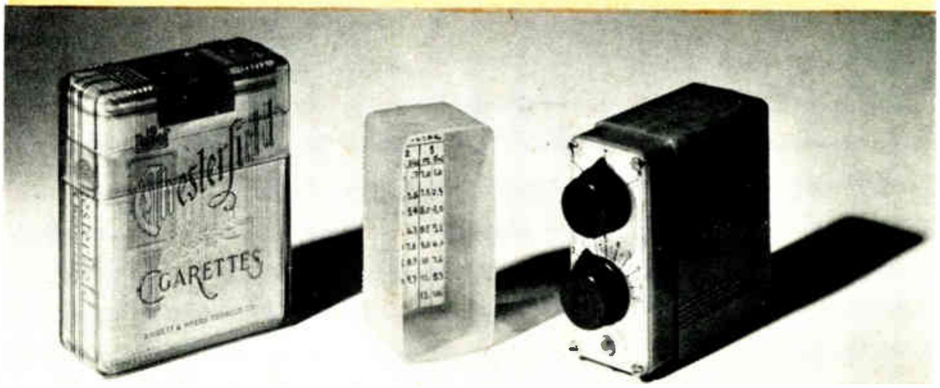
THE NEED FOR A HANDY WAVEMETER for tuning transmitters in the field has been neatly taken care of by A. T. Parker, Service and Parts engineer.

Since convenience is always a major consideration in field service, Al designed a unit of vest-pocket size. He took an ordinary plastic cigarette case and built into it a simple absorption type wavemeter covering a frequency range of 2.5 to 12 mc.

Calibration data is placed inside the plastic cover. Even a spare parts compartment is provided in the bottom of the case, and contains three extra bulbs.

Service and Parts is building twenty of the wavemeters for use by field representatives.

Photograph of vest-pocket absorption type wavemeter built into an ordinary plastic cigarette case.



FIELD ITEMS

Towboat 'Round the Bend!

Mark Twain's successors among river pilots will soon have all the conveniences of aircraft pilots. An experimental installation of the RTA-1B on the river towboat *Stark D. Whiteman* has operated satisfactorily for the past two months on frequencies above 2700 kc. As soon as a top-loaded bamboo antenna can be substituted for the vessel's 24-foot vertical antenna, four channels between 2100 kc and 2700 kc will be placed

in operation. The Bendix equipment has the advantages of requiring small space, and of being dependable with little servicing. With ship-to-shore communication, the towboat can report damage or delays directly to the office. Changed orders, special directions about dropping off or picking up barges, and warnings about low water can be received all along the line.

One of a fleet of river boats operating on the Illinois Waterway and the Mississippi, the *Stark D. Whiteman* has the second oldest steel hull in the United States. Seventy years ago when it came from Boston, its owners were proud of its hand-hammered Swedish steel. Now its Diesel engine provides the power for pushing strings of barges.

L. B. Gilmer found river life eventful. During his voyage, one man was lost overboard at night and not recovered; another lost a finger; a bridge collision damaged the tow; and Gilmer had a chance to cook three meals for the crew while the cook was confined to his berth with an unidentified complaint.

Life In the Azores

From the airliner, A. A. Hemphill's first view of the Azores was beautiful. Rising eight thousand feet above brightly painted villages was Mt. Pico with a collar of clouds around its peak. On an island beyond, cliffs four hundred feet high rose from the coast near the harbor, where the pastel-colored buildings were in strange contrast to a black bathing beach. The beach turned out to be a clean volcanic ash which did not glare in the sun.

Living on the islands, however, dispelled some of the illusions of distance. A strong, old-world odor was pervasive, and seemed to lessen only as Hemphill's sense of smell dulled with familiarity. Learning to eat the garlic-flavored, oil-drenched food required adjustments in both appetite and etiquette. Each meal was a leisurely, five- or six-course affair with two or three glasses of wine. The trick of eating a bite of food followed by a drink of this weak and pleasant wine, improved the flavor of the food, and had no ill effects. According to custom, the fork is held in the left hand for the second course, in the right hand for the third and so on. The local Emily Post also requires that bananas be skinned and eaten with a knife and fork.

The climate is consistently warm and humid. Temperature does not change with scattered rains and there is scarcely any wind. Clothes remain damp and, after a few days in a closet, one can almost wring water out of them. Perhaps because of the warm weather, the inhabitants are lackadaisical and slow—so slow that it took five days to install radio equipment in a plane.

Pilots flying near the Azores have just barely enough stations to use the automatic direction finder. A beacon station at the air base and a 200-watt Marconi station on 410 kc are about seventy miles apart and give cross bearings for positioning. Although there are no high power stations in Portugal which is about 900 miles away, bearings could be obtained within about 20 degrees on Portuguese stations. On fairly long ocean flights, bearing accuracy increases nearer Portugal.

On test flights, Mr. Hemphill reported some fairly decent blind approaches made by using the two stations on the islands and a 25-watt station at the seaplane base. In extremely bad weather, he was less enthusiastic about blind approaches than the local pilots. Even when fog closed in on the harbor and obscured the cliffs beyond, they were enthusiastic navigators with great confidence in their equipment.

Mr. Hemphill discussed with local officials the proposed radio network for inter-island communication which they need very much. Even by cable, it takes two days to receive a reply from an island sixty miles away. Reply by letter takes from two weeks to a month.

Afflictions—Chinese Style

I. E. Morrison, who has been commuting across the Hump, hardly expects the comforts of life in the China-Burma-India theatre. But he had the foresight to get an oxygen tank for a recent flight to China; and he blamed his wakefulness not on apprehension about Jap attacks, but rather on the clattering bombardment of the fuselage by ice cracking from the props. Once across the mountains, he was less philosophical

about such afflictions as prickly heat, spider bites, and ant stings.

During his travels in China he noticed that testing radio compasses by a range station often called down the wrath of any cruising Japs. To avoid this danger, he helped a Signal Corps unit build a portable oscillator with a range of six to eight hundred feet. It is so simple and works so well that any radio repair group in this area would find it handy for checking radio compass operation in planes.

King George on a Tricycle

Gus Treuke reports that an operational training unit in South Africa has a novel way of teaching pilots to navigate while relying on instructions received by radio. A King George equipment, a magnetic compass, and an "Airspeed" indicator are mounted on a self-propelled tricycle. The pedals are highly geared to reduce its speed, and the speed indicator is coupled to the wheels. With his vision of all but his instruments obscured, the trainee pedals around the parade ground, and responds to signals received, by changing his course or his speed.

BENDIX RADIO

DIVISION OF BENDIX AVIATION CORPORATION

BALTIMORE, MARYLAND