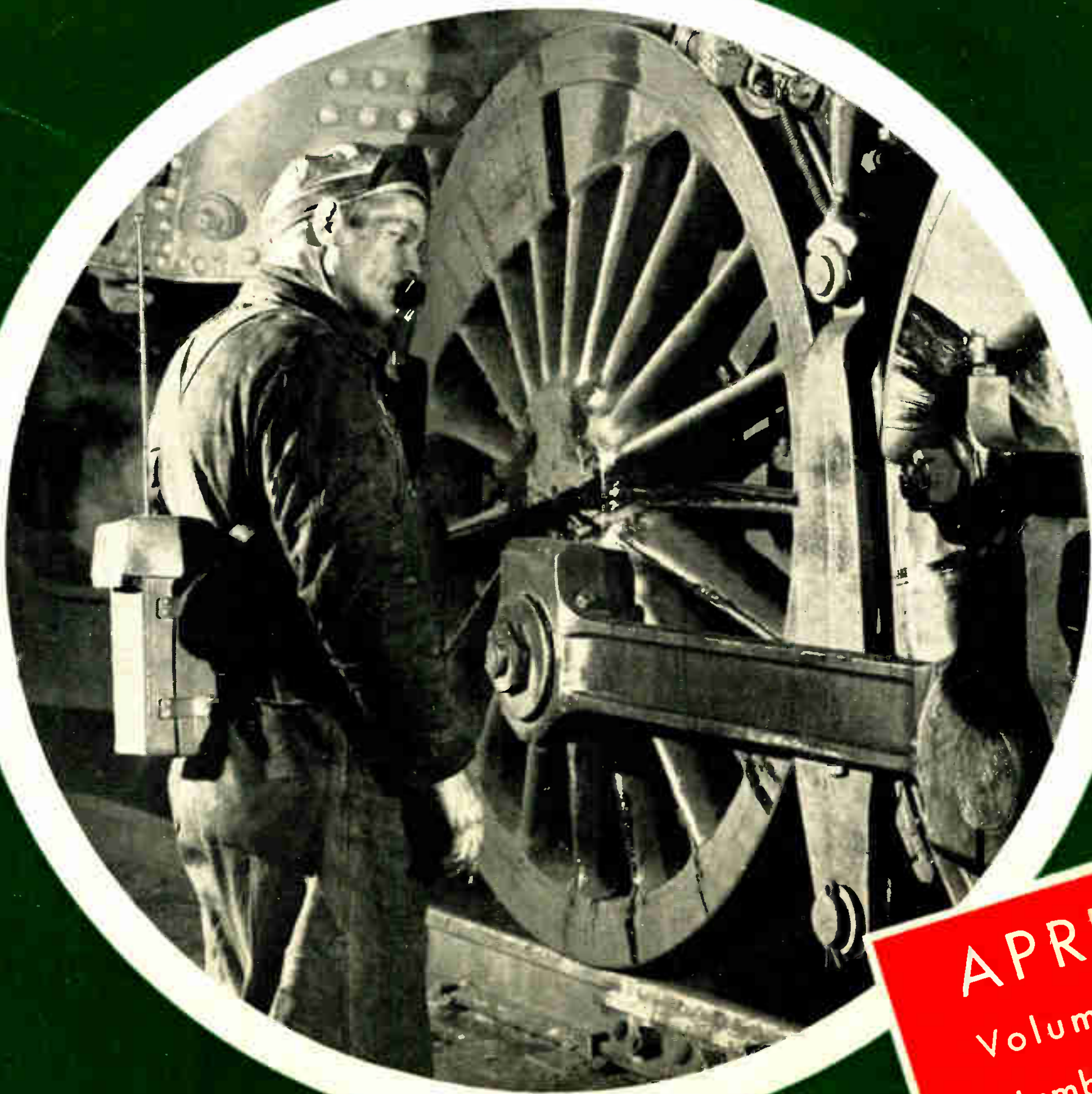
BENDIX RADIO ENGINEER



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IN THIS ISSUE

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The Cover

Among the Bendix units developed for radio communications on the railroads is the pack set held by William Bender, of the B & O. Pack set permits a member of the crew to maintain direct contact with conductor and engineer while some distance from the train. Other railroad radio developments are described in an article by Willis G. Jones on page 23 of this issue—*Photograph by P. K. Morris.*

BENDIX RADIO
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Notice

See important statement concerning the BENDIX RADIO ENGINEER by W. L. Webb, director of engineering and research, on inside back cover.

Editorial Staff

EARTH-MOON RADIO CIRCUITS

An explanation of how the moon may be used to complete transatlantic television and multi-channel communication circuits. The author worked with Lt. Col. John DeWitt in the early stages of his radar moon-reflection experiments.

By A. C. OMBERG
Chief Engineer
Research and Development

THE ANNOUNCEMENT OF THE reception of radar echoes from the moon has opened a new field for engineering speculation. The idea of using the moon as a link in a communication system is no longer mere conjecture. Although it still sounds fantastic, it is now subject to an engineering appraisal.

Calculations necessary to determine the performance of radio waves traveling to the moon and back are relatively simple. The derivation of the necessary equations and a detailed computation are given in an appendix to this article. Such calculations predict signal-to-noise ratio of the reflected signals with reasonable accuracy, and are adequate for the design or appraisal of practical radio systems.

Basis of Evaluation

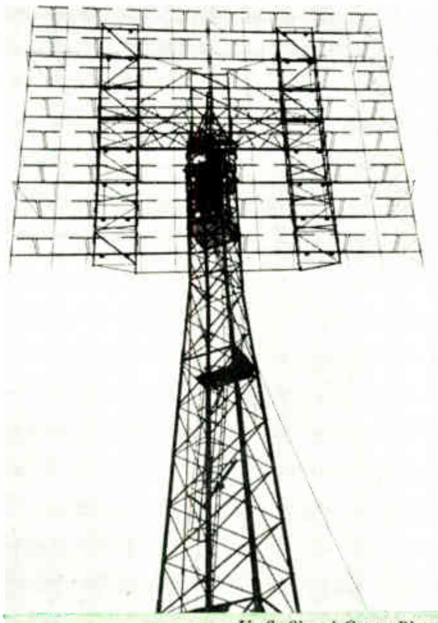
The value of any communication circuit is based on three main factors: (1) The availability of alternate facilities; (2) the percentage of time the circuit is available; and (3) the rate at which intelligence can be transmitted. The latter is a function of the bandwidth and signal-to-noise ratio.

For services, such as television, which require a very wide band of frequencies there are no existing long-distance facilities. A successful earth-moon link would fill this need and be of real value.

The percentage of the time an earth-moon circuit is available would depend on the location of the receiving and transmitting points, and on the effects of the atmosphere on the propogation factors involved. Communication would be limited approximately to the time during which the moon is above the horizon at both stations. A New York-Buenos Aires channel would be available approximately 50 per cent of the time, while a New York-London circuit would be open during a smaller percentage of the time.

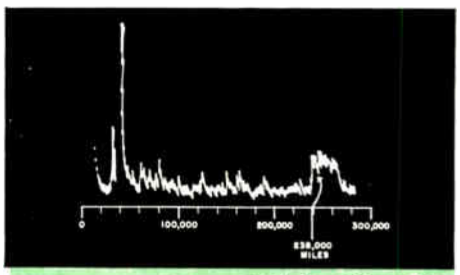
Effect of the atmosphere, including the ionosphere can only be ascertained by data collected over long periods. According to present information, anomalous propagation should not be a serious obstacle, but experimental data is necessary before this can be determined with certainty.

The bandwidths and signal-to-noise ratios which control the amount of information that may be transmitted can be estimated, and will be discussed in some detail. There are some uncertain factors, such as the effect of the relative motion of the earth and moon, and the large size of the reflecting area on the modulation. These considerations may well dictate the types of modulation that are practical. The matter of noise from space and the sun are also factors about which more information is needed.



U. S. Signal Corps Photo

Antenna structure of Radio Set SCR-271 used to establish radar contact with the moon at the Evans Signal Laboratory, Belmar, N. J. Set was operated on 112 mc; pulses, transmitted at five-second intervals, had width extended as much as a half-second.



U. S. Signal Corps Photo

Oscilloscope trace photographed during one of the successful tests conducted at Belmar. Beginning of transmitted pulse can be seen faintly at the left of the superimposed range scale and reflected signal at the right.

The following considerations indicate that an earth-moon long distance, low grade television link is just within the limits of present day engineering practice. They also point out that hemisphere broadcasting via the moon is limited to rather narrow bandwidths, and that television broadcasting by this means is quite beyond the present state of the art.

Let us take the experimentally observed value of signal-to-noise and see what might be done to improve it to the point where it would be valuable as a means of communication. The factors which affect the signal-to-noise ratio are:

1) transmitter power,
2) receiver sensitivity or noise figure,
3) the transmitting antenna gain,
4) the receiving antenna area, and
5) bandwidth.

Each of these factors will now be considered in the light of what seems reasonable with our present knowledge and facilities.

Transmitter Power

The radio frequency power which can be employed is a function of the carrier frequency. For transmission via the moon, frequencies not reflected or absorbed by the ionosphere must be used. This indicates frequencies above 60 or 70 mc or perhaps higher. The amount of cw power which can be generated economically today is not easy to estimate (it is to a large extent a matter of profitable returns for a financial investment). However it would not be stretching things too far to say that a carrier power of 100 kw can be generated in the 100 mc region. This could be done by adding the power from several amplifiers, which are all driven from the same source. It may be possible for this power to be increased by 10 db, or to 1 megawatt, but such an increase becomes unreasonable when cost and return are considered. At frequencies from 300 to 600 mc the reasonable upper limit is probably nearer 25 kw. For the microwave range up to 3000 or 4000 mc, it is conceivable, without too great a stretch of the imagination or of a corporation's finances, that klystron amplifiers might be operated to produce 5 kw.

Receiver Sensitivity

The noise figure at 100 mc can be made about 3 db. This figure gradually increases to about 10 db at 1000 mc and above. There are no great improvements in sight (or probable) for the 3 db end; and certainly not more than 5 or 6 db improvement can be expected at the microwave end.

Transmitting Antenna Gain

The gain possible from an antenna is proportional to its area expressed in square wavelengths. Since the antenna to be used must follow the moon, its size will be limited by mechanical considerations.

A reflector 400 feet in diameter would produce a gain of 50 db at 250 mc, 57 db at 600 mc and 67 db at 1800 mc. Such a 400-foot reflector would have a beamwidth of ½ degree at 200 mc. This, incidentally, is the angle subtended by the moon. It might be thought that nothing could be gained by using a higher frequency with the consequent narrower beamwidth since the total transmitted power would be intercepted by the moon for all angles smaller than ½ degree. This, however, is not the case, as explained in the appendix. The received power will continue to increase as the transmitted beam is decreased to angles considerably less than ½ degree.

Let us consider just what is involved in constructing an antenna 400 feet in diameter. As radio engineers we might be a little staggered at this size, but a moment's reflection brings to mind movable bridges and expanding gas tanks that are large and a lot heavier than a wire mesh antenna reflector. A slowly moving reflecting surface 400 feet in diameter actually is neither extremely complicated nor expensive. The fact of the matter is that it would definitely be cheaper than three stratosphere airplanes equipped with television transmitters.

Another approach to the problem of a 50 or more db steerable antenna would be along the line of a MUSA, or multiple unit steerable antenna, used by the Bell Telephone Laboratories for transatlantic telephony. This system is composed of several diamond antennas in line connected through phase shifters. The phase is varied so as to control the vertical pattern of the entire array. By placing arrays side by side and connecting them through suitable phase shifters, the array conceivably could be steered in two dimensions.

A variety of large fixed antennas, the beams of which are shifted electronically as in the GCA, could be devised. However, all such designs would suffer from the disadvantage of being useful for only a small band of frequencies.

Receiving Antenna and Bandwidth

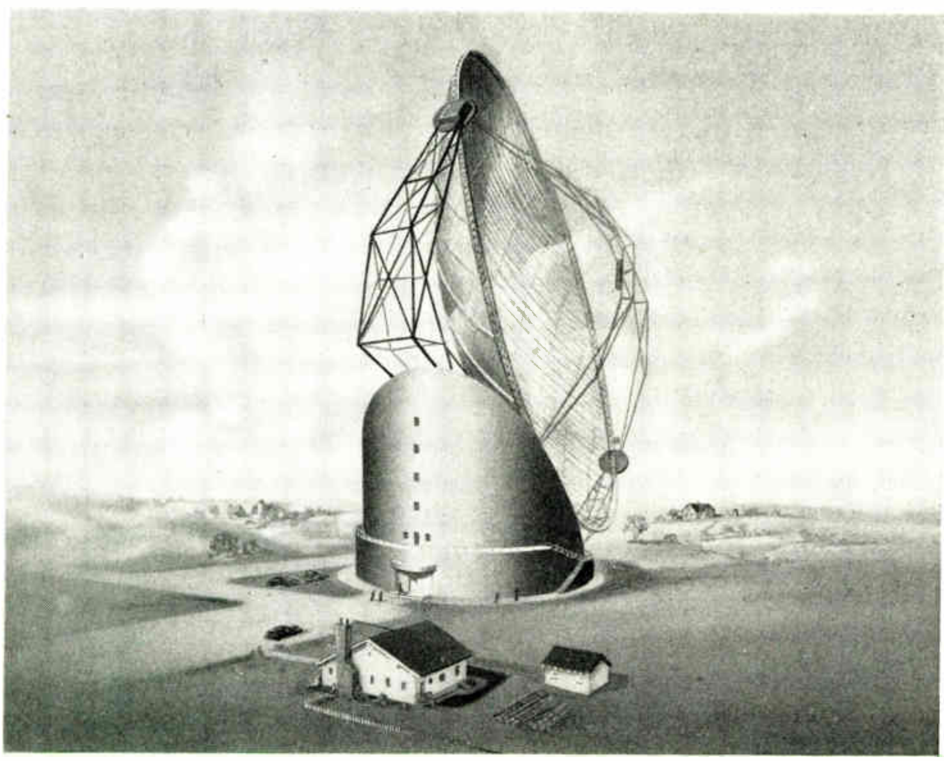
The benefit which can be obtained with the receiving antenna is limited only by its size and is independent of the frequency. A receiving antenna can be thought of as a funnel which scoops in energy. The practical limit is of course the size which can be positioned to follow the moon.

As the bandwidth of the receiver is increased the amount of noise power admitted is increased directly. A television system using 5 mc bandwidth would admit 50 db more noise than the 50 cycle band used by Lt. Col. DeWitt's radar.

Immediate Possibilities

On the basis of this review of equipment, let us see what would constitute a useful earth-moon circuit. First we shall take DeWitt's observed experimental signal-to-noise value, and modify it to obtain the best results that might be expected within the next few years.

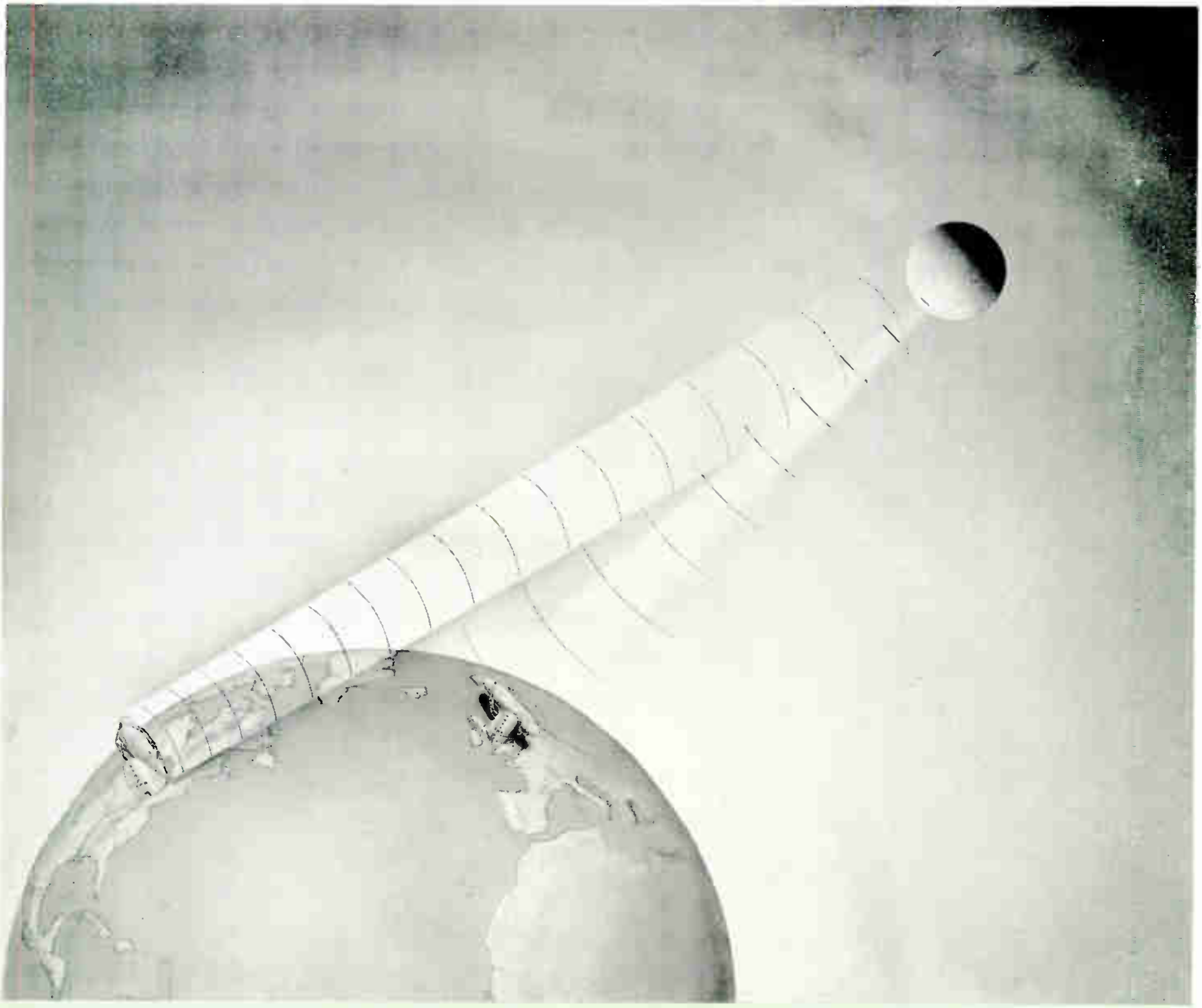
The Belmar experiments showed signal-to-noise ratios between 10 and 20 db. These signals were reinforced by ground reflections possibly as much as 12 db. Such ground rein-



Drawing of antenna and 400-foot reflector that might be used to establish a transatlantic communications and television link via the moon. One axis of the spherically oriented array would be parallel to that of the earth's rotation.

A. C. Omberg

ALTHOUGH HE is head of the Bendix Radio Research and Development Section, A. C. Omberg is not exclusively a theorist. Recently he renewed the first class commercial radio operator's license which he has held since 1927. The intervening years have been packed with practical radio experience, which on occasion, as ship radio operator, has taken him all around the world. During the war, his theoretical work in Washington, as assistant director of the Signal Corps Operational Research Group, was interspersed with journeys to Air Force bases in the Pacific to help make radio equipment work when it was giving trouble. His interest in the subject matter of the accompanying article stems from his ten-year association with Col. DeWitt at Radio Station WSM, where he assisted in the original moon reflection experiments in 1939. There he made use of many techniques which subsequently have become popular in radar. Later studies were undertaken in collaboration with K. A. Norton, to determine the maximum range of radar.



Visualization of a transmission from New York to London by moon reflection.

forcement will not be present with large antennas producing narrow beams. We shall assume 8 db as the approximate free space signal-to-noise ratio.

If the transmitter power is increased from 4 kw to 40 kw, an increase of 10 db is obtained. Likewise, at 250 mc the 400-foot antenna will provide a gain of 50 db; that is, an increase in gain from 23 to 50, or 27 db. This antenna would give an increase in receiving gain of 19 db (ratio of areas). The noise figure could be reduced from 8 db to 5 db, or an increase of 3 db. A high quality television circuit would require a bandwidth of 5 mc, which would represent a loss of 50 db over the 50 cycle bandwidth employed in the Belmar experiments. The net change would thus be $10+27+19+3-50=+9$ db. Adding this to the experimental value of 8 db, we have only 17 db—a signal not sufficient for television.

By pushing the power to 100 kw and reducing the bandwidth to 2 mc, we could gain 8 db and get a signal-to-noise of 25 db, which would provide a low quality television service.

The corresponding figures for 600 mc with a 25 kw transmitter give 23 db, and for 1800 mc and a 5 kw transmitter, a 24 db signal-to-noise ratio.

For communication circuits the signal-to-noise would be quite adequate for an extremely large number of channels. It should be pointed out that one large moon-following reflector would serve for an almost infinite number of simultaneous channels. Low powered narrow band telephone and teletype channels on separate r-f frequencies could illuminate this reflector independently. It also could be used for both transmitting and receiving simultaneously by frequency separation.

Conclusions

To summarize, two 400 foot moon-tracking antennas, one located in New York and one in London, would, with a high degree of probability, afford many simultaneous low quality television channels and an extremely large number of communication point-to-point channels. These channels would be available for several hours a day, and the operating time could be predicted accurately long in advance.

Since large following antennas are out of all reason for private home reception, television broadcasting via the moon must await new inventions that are fairly basic. For communications, however, a moon link seems quite practical.

The derivation of the equations and the detailed computations on which this article is based are contained in an appendix on page 22.

DIRECT READING PHASEMETER

A laboratory model of a wide band instrument designed to provide unambiguous measurements of phase difference and frequency.

By DR. HAROLD GOLDBERG
Research and Development

At Bendix, a laboratory model of a phasemeter has been developed to satisfy a need for a wide band, direct reading instrument for use in the laboratory, in the field, and for monitoring. It gives the lead of one channel over another, and provides unambiguous readings of phase difference directly on a meter. In its present form (see figure 1), it measures phase difference over two frequency ranges. One of these, the audio range 20 to 5000 cps, uses a high impedance input to the meter. For the other frequency range of 0.2 to 10 mcs, the input to the meter may be either by high impedance probes or terminated transmission lines. As an adjunct to its use in the high-frequency range, a changeover switch converts the instrument to a direct reading audio frequency meter with a range of 0 to 3600 cps.

Figure 1—Direct reading, wide band phase and frequency meter.

Method

It is a well-known fact that the phase difference between two sine waves of the same frequency is preserved if their frequency is changed to some new value by heterodyning. If the new frequency is obtained as a difference between the original frequency and the heterodyning oscillator frequency, the phase difference is preserved only if the heterodyning frequency is less than the frequency of the original signals whose phase difference is under consideration. If the heterodyning frequency is greater, the phase difference between the resulting difference frequency products is the negative of the original.

The instrument under discussion uses the combination of this principle and a wide band, direct reading, audio phasemeter. Since the term "wide band" is applied to the audio range of the instrument, and to the heterodyne range as well, the meaning of the term is twofold. In the first place, "wide band" means that the measurement of phase in the audio band is independent of frequency. This characteristic makes for quick measurement of phase difference without concern as to frequency stability or frequency. In the range covered by the heterodyning principle, "wide band" means that the phase difference measurement is limited only by the range of the local oscillator and converter, and that for a given setting, the frequency stability of either the input signal or the local oscillator is delimited only by the band width of the audio phase reading system. Frequency stability of either input signal or local oscillator thus becomes a minor problem.

The frequency meter is used in the heterodyne range. It allows the local oscillator to be set for a beat frequency lying within the audio acceptance band and allows the operator to determine when the local oscillator frequency is below the signal frequency. The latter is determined by first setting the local oscillator to zero beat and then decreasing its frequency until the desired difference frequency is obtained. The direction of decreasing frequency is obtained from the calibration.

Phase difference is measured by generating a series of rectangular current pulses of constant amplitude and variable width which occur at the frequency of the signals whose phase difference is to be measured. The width is made to vary linearly with the phase difference. The average current is then a measure of the phase difference.[1] As an illustration, consider the circuit in figure 2.

Let A and B represent the two sine waves whose phase difference is to be determined. Arrange matters so that S is closed at each positive peak of A and opened at each positive peak of B. If the frequency of A and B is f, and the phase difference is P degrees, rectangular current pulses are generated of amplitude E/R and duration P/360f seconds. The average value of the current in the meter M, which is an average reading meter, is EPf/360Rf which is EP/360R. The meter therefore gives a reading directly proportional to the phase difference and independent of frequency. The reading is the lead of A over B. Obviously, a phase difference of 360° corresponds to switch S closed at all times. Calibration of the circuit is accomplished, therefore, by closing S, and by causing M to read 360°. The correct meter reading may be obtained by properly setting the value of E, R, or the meter sensitivity.

Frequency is measured by application of a similar principle. The positive peaks of either A or B are now made to close S only for a fixed length of time. The average value of the current is ELf/R, where L is the closure time. The output is now proportional to frequency. The only precaution to be taken is that Lf should always be less than unity for the range of frequency to be measured. As soon as Lf is equal to or greater than unity, the switch S never opens and the frequency meter does not function properly.

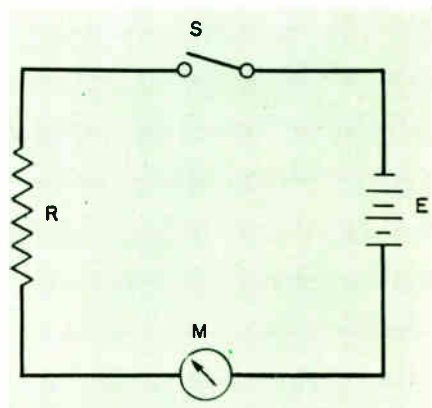


Figure 2—Simple circuit illustrating method of measuring phase difference and frequency of two sine waves.

Phase Measuring Circuit

The actual circuit used is not, of course, the simple one given in the illustration (see figure 3 for block diagram of phase-frequency circuits). The functions of switch, resistor, and battery, are provided by a hard tube circuit, based on the Eccles-Jordan[2,3] trigger circuit.

[1] Basic system contained in U. S. Patent No. 2,370,692, *Phase Angle Indicator* by J. E. Shepherd.

[2] W. H. Eccles & F. W. Jordan, *Radio Review*, Vol. 1 (1919), p. 143.

[3] H. J. Reich, "New Vacuum Tube Counting Circuits," *Review of Scientific Instruments*, Vol. 9 (July, 1938), p. 222.

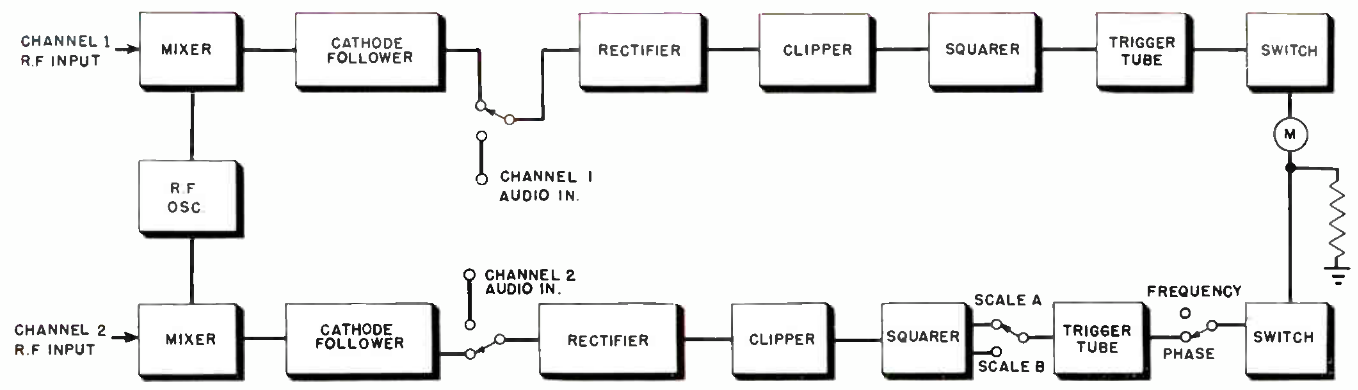


Figure 3—Block diagram of phase-frequency meter.

The switch is figuratively closed and opened by means of pulses derived from the input signals on channels 1 and 2. These pulses bear a constant relation in time to their respective sine waveforms. This circuit is shown in figure 4.

The circuit shown involves two functions: Tubes T_A and T_B function as trigger tubes; tubes T_a and T_b and their coupling circuit make up the switch. The meter M, of suitable sensitivity, is calibrated directly in degrees and reads the lead of channel 2 over channel 1.

The switch is a modified Eccles-Jordan circuit. The usual fixed bias arrangement has been replaced by self bias and the feedback capacitors have been omitted. The circuit is not used as a counting (scale of two) circuit, but each half is triggered separately; hence tubes T_a and T_b never conduct simultaneously. The circuit has two stable states—T_a conducting and T_b cut off, or T_a cut off and T_b conducting. If the circuit is in either state, it will remain so as long as the circuit is not disturbed. It may be put in the former state (T_a conducting) by momentarily grounding grid b, or in the latter state (T_b conducting) by momentarily grounding grid a. Tubes T_A and T_B, the trigger tubes, momentarily ground grids a and b if their own grids are driven positive by a short pulse. The changes in state take place very quickly.

These switch properties cause the circuit to behave exactly like that of figure 2. Assume a state in which T_b is cut off (Channel 1 has just pulsed T_B). No current flows in M. The next pulse from Channel 2 causes T_b to conduct. A constant current now flows in M but only until the next pulse arrives from Channel 1. This again cuts T_b off and current flow ceases in M. Rectangular current pulses of constant amplitude are generated whose duration is P/360f. M reads the average current. With the circuit arranged as shown in figure 4, the phase angle indicated is the lead of Channel 2 signal over Channel 1 signal. The insertion of M into the cathode of T_a would cause the circuit to read the lead of Channel 1 signal over that of Channel 2. There is no ambiguity in the system. To calibrate, the circuit is disconnected from the trigger system

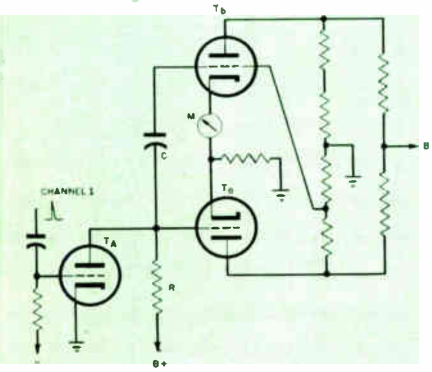


Figure 5—Modification of circuit of figure 4 to provide frequency measurement.

and put into the condition of T_b conducting. The meter sensitivity is adjusted to read full scale, or 360°. The upper limit of frequency in the use of this circuit is determined by its speed of triggering.

Frequency Measuring Circuit

The modification of the circuit shown in figure 5 converts it to a frequency measuring device. The changes provide a flip-flop effect.[1] In the normal state of this circuit, T_a is conducting and T_b is cut off. Triggering of the circuit causes T_a to cut off and T_b to conduct. This state does not remain indefinitely as it did for the switch circuit, however, since the circuit automatically regains its normal state after a fixed interval following the triggering. The duration of the triggered state is a function, primarily, of the quantity RC. The circuit thus generates current pulses of fixed amplitude and duration regardless of frequency. The average current, read by M, is ILf where

[1] Puckle, *Time Bases*, p. 44.

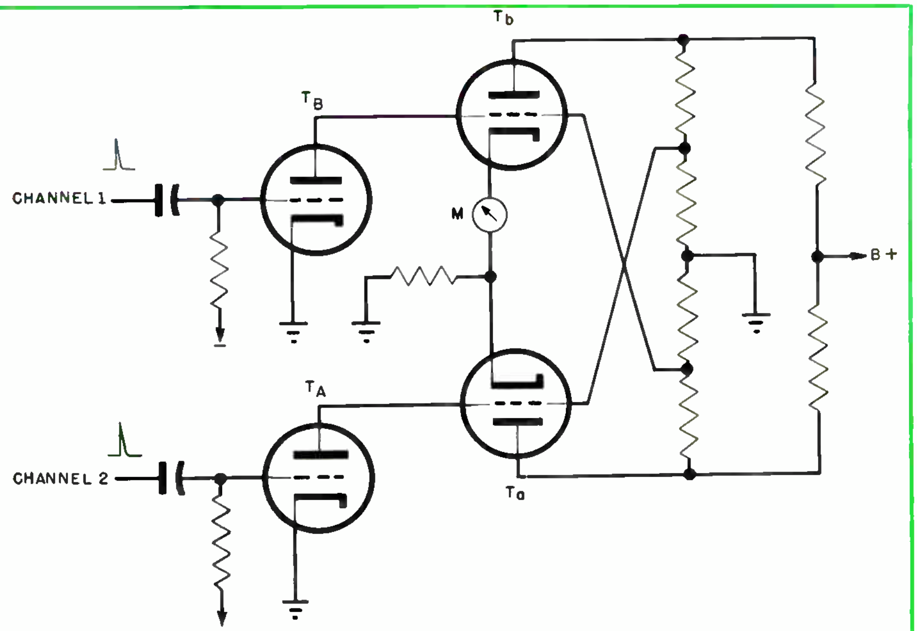


Figure 4—Simplified schematic diagram of switch and meter circuit for phase measurement.

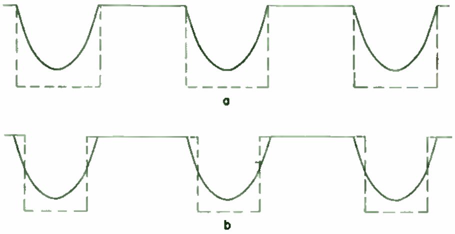


Figure 6—Phase meter accuracy largely depends on generation of rectangular pulse coincident with alternate zero points (most easily identified) of input sine wave. a. Correct relationship between pulse and half-wave form; b. Incorrect relationship in which proportions of pulse are determined by amplitude of rectified wave.

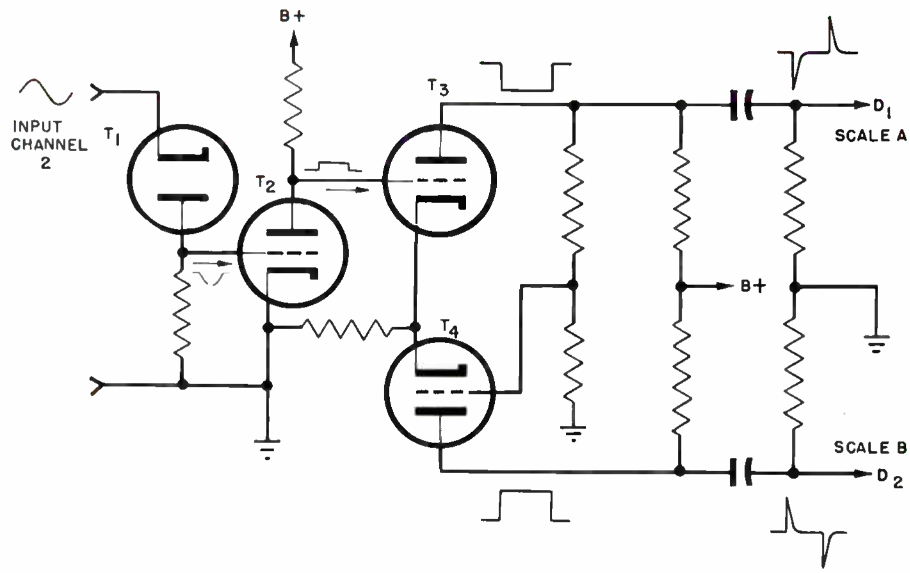


Figure 7—Rectifier and trigger circuit. Output from rectifier controls trigger generation. Two differentiated outputs on Channel 2 are of opposite polarity and permit use of two scales on meter to avoid ambiguity when reading phase in the neighborhood of 0 or 360 degrees.

L is the length of pulse. The current is a linear function of frequency. The upper limit of frequency determined by this circuit is a function of L, hence the upper limit is $f_{max} \leq 0.75/L$. It is evident that the shorter the pulse, the higher the frequency that may be measured by this circuit.

Pulse Generation

Nothing has been said thus far of the method of obtaining the Channel 1 and Channel 2 pulses used in the phase and frequency measuring circuits of figures 4 and 5. The circuits already discussed will trigger if the input pulse is greater than some minimum value. Equal amplitudes for Channel 1 and Channel 2 pulses are not necessary if each exceeds the minimum. To measure phase correctly and independently of input amplitudes, it is necessary only to generate these pulses so that their amplitudes exceed the required minimum, and so that the interval between the Channel 1 and Channel 2 pulses is precisely related to the phase difference between the input sine waves. To insure this, the derived pulses for Channel 1 and Channel 2 must always bear a constant time relationship to their respective input sine waves. Furthermore, it is desirable that this time relationship be independent of amplitude as long as the amplitudes of the sine waves exceed a certain minimum value.

The method chosen is the generation of a pulse at given alternate zeros of each input sine wave. A short pulse is generated at the zero preceding each negative half cycle of both inputs. This is done by passing the sine waves through half-wave rectifiers, clipping and squaring the results, and differentiating the outputs to obtain the trigger pulses. Care must be exercised in this process to avoid error. The major problem in the development was to make the pulse identification of the zeros foolproof, independent of amplitude in excess of a given minimum, and independent of frequency down to zero cps.

Fundamentally, the accuracy of the phasemeter depends on the accuracy with which the pulses are generated relative to the chosen aspect of the sine waves. The accuracy also, of course, is dependent on other factors, but these are more easily taken care of than the problem of proper pulse generation. Pulse

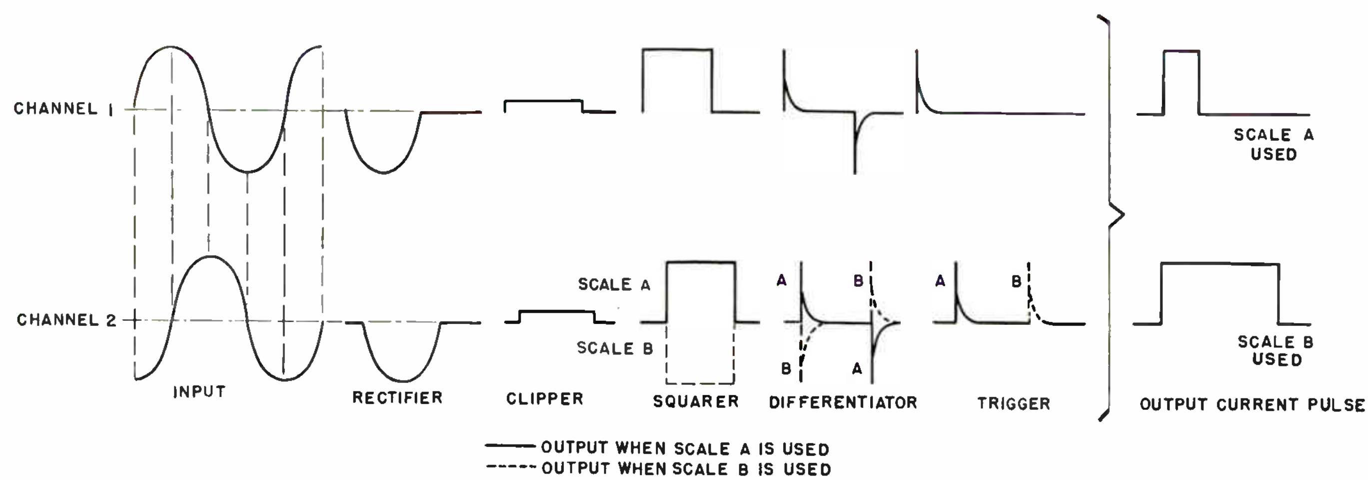


Figure 8—Waveforms showing phase relationship between Channel 1 and Channel 2 signals through the various stages of the instrument.

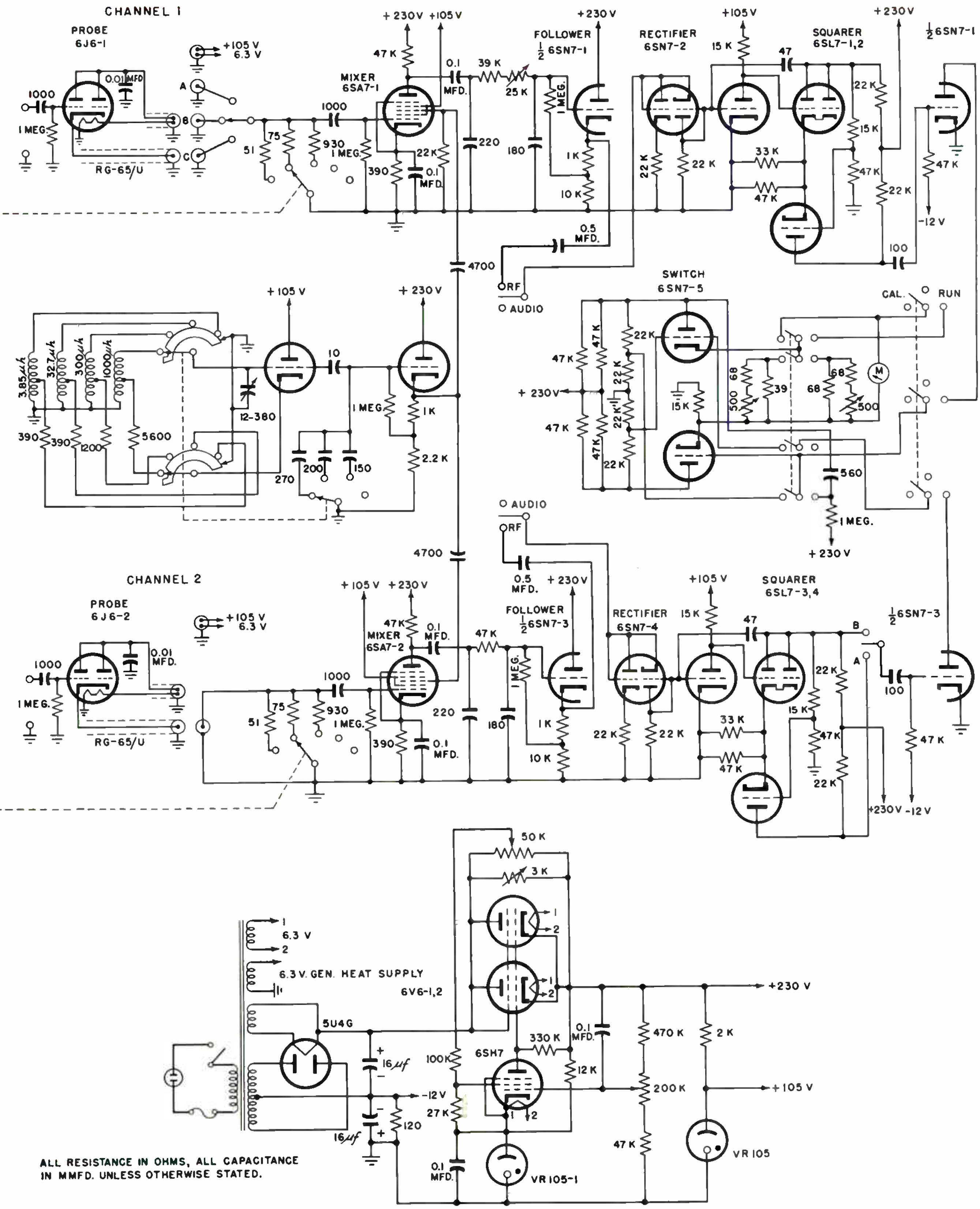


Figure 9—Over-all schematic diagram of phase-frequency meter.

Figure 10—Front panel view of meter.

generation at alternate zeros was chosen since the zero is the simplest part of the waveform to identify with accuracy. The first portion of the identification is accomplished by half-wave rectification. The next step is to convert the half-wave form into a rectangular wave. The correct result is shown in figure *6a*. The result shown in figure *6b*, which may be obtained if care is not taken, may lead to errors in phase measurement.

The error that may result from the behavior shown in figure *6b* is due to the fact that the proportions of the rectangular wave generated may depend on the amplitude of the rectified wave. If Channel 1 and Channel 2 sine waves are of different amplitudes, and they generally will be, the generated pulses for this type of behavior may not bear a unique time relation to the input wave forms, and an error will result in the phase measurement. That is, the relation of the pulse, in time, to the wave will be a function of amplitude and the reading given by the instrument will likewise depend on amplitude. If the pulses always occur at the zeros, the relative amplitudes will have no effect.

The circuit in figure 7 accomplishes this identification to a high degree of precision as long as either the input amplitude of Channel 1 sine wave or Channel 2 sine wave exceeds a given minimum. The accuracy increases with increasing amplitude and is least at the minimum amplitude.

In this circuit, T_1 is a half-wave rectifier. T_2 is an amplifier directly coupled to the output of T_1. T_3 and T_4 form a modified Schmitt[5] trigger circuit which is directly coupled to the output of T_2. D_1 and D_2 are the outputs of a differentiating networks coupled to T_3 and T_4, respectively. (This choice of outputs on Channel 2 permits use of two ranges on the output meter.) The Schmitt circuit is another type of d-c trigger circuit. In this circuit, there exist two critical voltages for the grid of T_3. Let us call these E_u and E_d. E_u is always somewhat greater than E_d. Suppose the grid voltage on T_3 is less than E_d. In this condition, T_3 is nonconducting and T_4 is saturated. As the voltage on this grid is raised, nothing occurs until the voltage becomes greater than E_u. As soon as this happens, T_3 abruptly begins to conduct in the saturated condition and T_4 is cut off. Subsequent raising of the grid voltage does not alter this state. If the grid voltage is now lowered, nothing occurs until it drops below E_d. The circuit now abruptly reverts to its former state. The exchange of current takes place with great rapidity and is independent, essentially, of the rate at which the critical voltage is crossed. As soon as it is crossed, the circuit triggers on its own. The difference between E_u and E_d is essentially a hysteresis phenomenon and may be made small by proper design of the circuit.

Pulse Chain Operation

The operation of the pulse generating chain is as follows. T_2 and T_3 are adjusted so that the T_3 grid is just below E_d with no voltage applied to the input of the circuit. During a positive half cycle of input voltage, there is no output from T_1. As soon as the input goes negative, there is output from T_1 and the plate of T_2 rises and fires the trigger circuit. As the input reaches zero again, the plate of T_2 falls below E_d, and the trigger circuit fires back to its original state. With critical adjustment, the presence of output at T_1 and firing of the trigger circuit occur almost simultaneously. Actually, the adjustment is made so that a little margin is allowed. If one considers this margin, and the further fact that the rectifier does not immediately conduct when the cathode goes negative relative to ground (contact potential and other factors play a role), it is evident that good accuracy is achieved only when the input amplitude exceeds some minimum figure, this minimum being based on the minimum accuracy desired. The accuracy is increased as the amplitude is increased.

Because of the fact that the chain is directly coupled, it will operate down to zero frequency. The fact that operation of the Schmitt circuit is independent of the triggering rate makes the waveform of the differentiated output independent of frequency. Two such outputs are shown in figure 7 (D_1 and D_2). By choosing either one of these for Channel 2, for instance, and a fixed one for Channel 1, it is possible to have two ranges or scales on the output meter. If both Channels 1 and 2 use similar differentiated outputs (see figure 8), the output meter reads 0 to 360°. If opposite differentiated outputs are used, the output meter will read 180 to 180°. The reason for this is that the choice of opposite outputs essentially shifts one channel 180° with respect to the other. This characteristic is useful for reading phase angles in the neighborhood of 360° or 0°. In the normal use of the meter, the output will be unstable in this region since the phasemeter cannot decide whether to read 360° or 0°. These represent the same phase angle, essentially, but correspond to opposite ends of the scale on the indicating meter. A shift of 180° puts the uncertainty 180° away and allows the smooth reading of angles in the neighborhood of 0°.

[5] O. H. Schmitt, "A Thermionic Trigger," *Journal of Scientific Instruments*, Vol. 15 (January, 1938), p. 24.

General Design Features

If the over-all circuit, figure 9, is referred to, it will be seen that the half-wave rectifier is not as previously explained, but actually consists of two rectifiers of opposite polarity, with only one in use. The other rectifier is required with capacitor input. The use of this other rectifier makes the load into which the capacitor works a linear one. Thus, a d-c shift in the zero of the input wave is prevented. That is, the capacitor input system is prevented from operating as a d-c restorer and serves, truly, only to isolate the rectifiers from any direct current appearing in the input. Direct current on the half-wave rectifier would cause error in the zero identification since the output of the half-wave rectifier would no longer be truly half-wave.

The remaining parts of the circuit are more or less conventional and the rest of this discussion will follow the circuit schematic (figure 9) and cover the operating features of the phasemeter. Input to the r-f portion

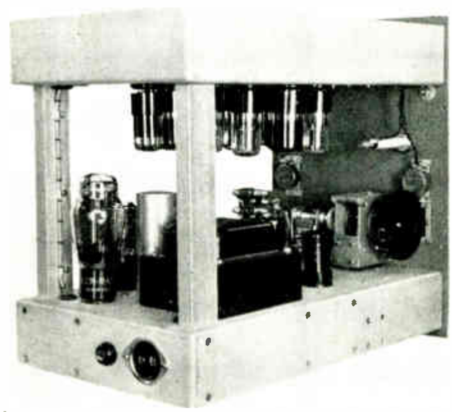


Figure 11—Construction of meter permits ready access to components. Upper chassis contains audio circuits; lower chassis holds power supply, converters, and local oscillator.

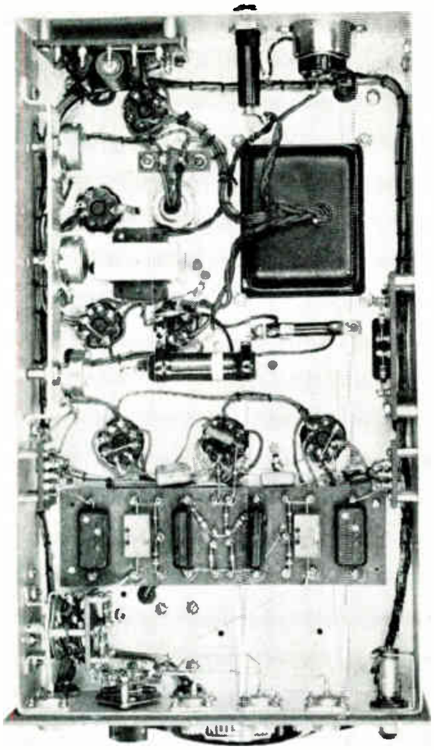


Figure 12—Bottom view of meter showing simplicity of wiring.

of the instrument is by means of terminated coaxial lines or high-impedance probes. Switches allow the selection of various input connectors and terminating resistors. The probes, which are cathode-followers driving 6-foot lengths of terminated coaxial line, use 6J6 tubes. The coaxial line is 930 ohm, RG-65/U spiral delay line terminated in 930 ohms. The high impedance is required by the voltage level needed to operate the instrument. The input voltages must exceed 2 volts rms to properly operate the instrument. A 6J6 cannot supply this voltage to a 50 or 75 ohm load without exceeding its plate dissipation ratings, but can supply it to a 930-ohm load. Terminations of 51 and 75 ohms are provided for coaxial line input but other values can be supplied.

The frequency changing portion of the instrument uses two 6SA7 mixers. The local oscillator-buffer system is provided by a 6SN7 tube (twin triode), one half of which acts as a Hartley oscillator, and the other half as a cathode-follower buffer. A capacity divider couples the two sections and attenuates the input to the follower. Since the output of the converter must be a good sine wave regardless of input amplitude (the phase measurement is incorrect if this is not true), the same care must be taken in the design of the converter as in the design of a beat frequency oscillator. Good output waveform is maintained by employing good oscillator waveform and keeping the injection amplitude below a given maximum value. The Hartley oscillator uses degenerative amplitude control instead of grid leak control and operates approximately class A. The oscillator input amplitude is kept at a figure which is a compromise between good converter output waveform and conversion gain. The minimum input figure of 2 volts rms is required to give a converter output of at least 10 volts rms under the operating conditions. This latter figure is the minimum voltage required for the operation of the audio-phase metering circuits. The filters for the output of the converters are pi section, R-C filters. The series leg of the filter in one channel is adjustable. By this means, the inequality in phase shifts caused by filters, and circuit strays in the two channels, may be equalized. Once the filter leg is adjusted, the outputs from the two channels have equal phase shift, independent of frequency, in the operating band. Cathode followers are used to effect an impedance transfer between converter and half-wave rectifier. The pulse generating chain which follows has already been discussed. Provision for shifting the indication by 180° is shown in the output of the Schmitt circuit in Channel 2. The final phase and frequency determining circuit is shown complete with calibration adjustments. The entire unit is supplied with an electronically regulated power supply.

Operation

The arrangement of controls and connectors on the front panel is shown in figure 10. The switches in the upper right and left hand corners select R.F. and Audio for their respective channels. The Phase-Frequency knob switches the instrument between the two functions. The Run-Calibrate switch is used only for phase. Calibration for frequency requires the run position and an external oscillator. The two sets of binding posts are input connectors for the audio channels. The meter is a one per cent meter and is calibrated both in phase and frequency. Directly beneath the meter arc the calibration controls for phase and frequency. The band switch and R.F. Tuning Control allow the local oscillator to cover the range 0.2 to 10 mc R.F. Channel 1 is provided with three alternative coaxial inputs and a selector switch. Channel 2 has only one coaxial input. This allows the successive comparing of phase of Channel 2 with each of three inputs to Channel 1. When probes are used, their plate power and heater power are obtained from the connectors labeled Probe. The correct termination is selected by means of a switch at the side of the instrument.

For audio-frequency measurements, it is necessary only to connect the instrument and to provide sufficient input. On R.F., it is necessary to tune the local oscillator to the proper frequency by means of the frequency meter. Zero beat is first obtained. The oscillator frequency is then lowered until the difference frequency is somewhere between 700 and 1500 cps. The instrument is switched to phase and the phase difference read. The presence of amplitude modulation has little effect on the reading if the input voltage is kept below 7.5 volts rms. Only on high-modulation peaks does the meter needle swing off from its proper reading. In tests on its use as a broadcast antenna phase monitor it has proved to be entirely satisfactory for use while program material is on the air.

The construction used, as shown in figures 11 and 12, was chosen because of the accessibility provided. While the number of tubes used is large, the circuit is relatively simple. The lower chassis houses the power supply, converters, and local oscillator. The upper chassis holds the audio portion of the system. As can be seen, the chassis wiring is relatively simple.

Dr. Harold Goldberg

APPEARING FOR THE first time as a contributor to the ENGINEER, genial Dr. Harold Goldberg is, nevertheless, an experienced hand at this type of writing, having previously had papers published in the *Journal of Physical Chemistry*, *American Journal of Physiology*, *Electrical Engineering*, *Science*, *Electronics*, and *Proceedings of the IRE*. He received his B.S. in Electrical Engineering at the University of his native state of Wisconsin in 1935, and was an engineering Fellow for two years while preparing for his Master's degree in 1936, and for his Doctorate the following year. In 1941, he received a Ph.D. in Bio-Physics at the same university under a postgraduate research scholarship. He came to Bendix in 1945 from Stromberg-Carlson where he was in charge of microwave research activities. As a member of the Research and Development staff at Bendix Radio, Dr. Goldberg has been engaged in development work in microwave communication. He is a member of the AIEE, the American Association for the Advancement of Science, holds Senior Membership in the IRE, and belongs to the honorary fraternities Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

TUBES IN THE MAKING

By HARRYETTE CREASY
Technical Publications

If you want to manufacture radio tubes, you may set up a highly skilled group of craftsmen to produce custom-built jobs, or you may buy intricate, electronically controlled machinery that produces tubes by the carload. Both types of production, in fact, often go on side by side, though the special tubes are manufactured by methods as old as the earliest electric light bulbs, while mass production of others was stepped up tremendously during the war. To be sure, the big machines ground to a halt during reconversion because of the mountainous stockpiles of war; but the glass blowers and spot welders continued their highly skilled work on experimental and special tubes ordered in small quantities.

Many parts of the manufacturing process are similar, however, regardless of quantity, design, or application. First step is made by deft-fingered girls who bend grid wires in the way they should go, attach the anode to the proper channels, thread two to sixteen fine wires into the cathode assembly, and put together the other fragile parts, such as tungsten leads and supports, found inside the glass envelope.

Cleaning Small Parts

Though many of these small parts appear gleaming and shiny, they are really in dire need of cleaning, sometimes both before and after assembly. To remove greases, they are dipped in steaming solvent and then held aloft in the vapor. Other cleaning agents are acids; and hot phosphates which have some special characteristics are also used to remove organic and inorganic materials and oxides. But gases still cling to each metal part until it goes through a hydrogen furnace. Across a strip of flame the metal parts are fed into the hydrogen oven where the gases trapped inside the metals are replaced by hydrogen through a process of diffusion. In this way more harmful gases are replaced by a gas which, although also undesirable, is the lesser evil. The parts are gradually cooled in a hydrogen atmosphere inside a water jacket, and brought out through a flame. When even hydrogen is unwanted, the metal parts are fired in a vacuum oven.

Application of the cathode spray takes place in hooded stations where jigs and spray guns gleam against the white backdrop and sides. An operator lifts the cathodes from an acetone solution, and after they are dry, sets them up in a jig. In some plants, every tenth cathode is weighed first, then sprayed for a measured time interval, and weighed again on glass enclosed scales to determine the thickness of the spray. If the coating is heavier or lighter than, say, 7.5 milligrams, the amount of spray is adjusted on the nozzle of the gun.

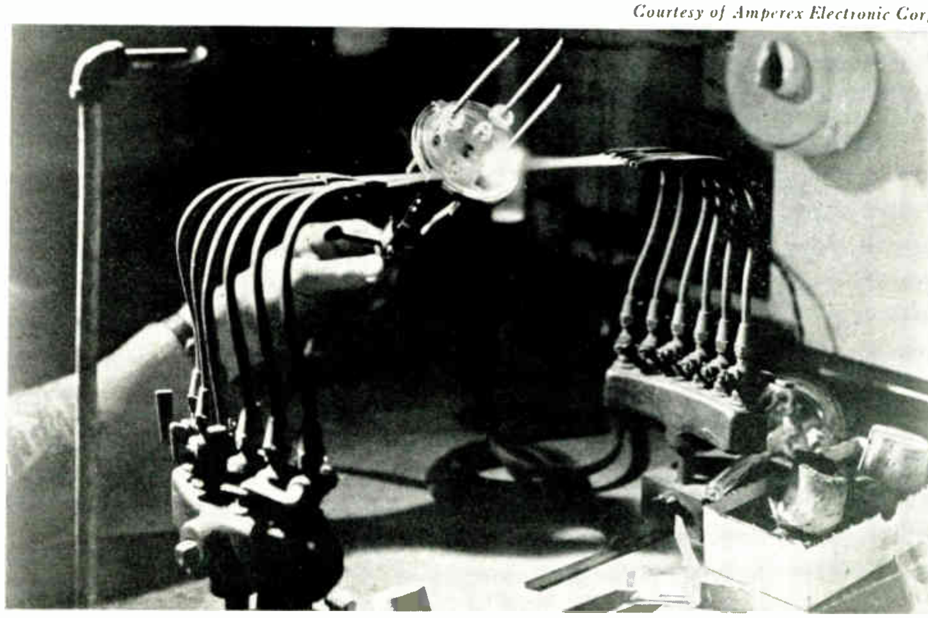
Glass Working

In the meantime, the carefully inspected and cleaned leads have gone to the glass room where they are made into stems. A short length of glass tubing encircling the leads is held on a jig and heated to the melting point; a pair of jaws rises automatically and clamps the glass into a wedge with the leads securely embedded; and the resulting stem is cooled and annealed before other structures are added.

Then the parts—inelegantly called the "guts"—are sealed into each tube with a quiet flourish by a glassblower or sealing lathe operator, or more prosaically by a machine. Essentially, the process is similar to any other glass shaping: preheat, heat, shape, cool, and anneal. A simple way of checking this seal is provided by a high frequency "spark" coil when the tube is hooked up to a vacuum pump. As the air pressure decreases, the color of ionization changes. A perfect tube is colorless when sparked; a slight leak is made

Operotor fuses tungsten lead-in connection into o VT90 transmitting tube base. Glass beads, previously fused to the wire, are sealed into the opening of the glass bose using on oxygen-gas flame.

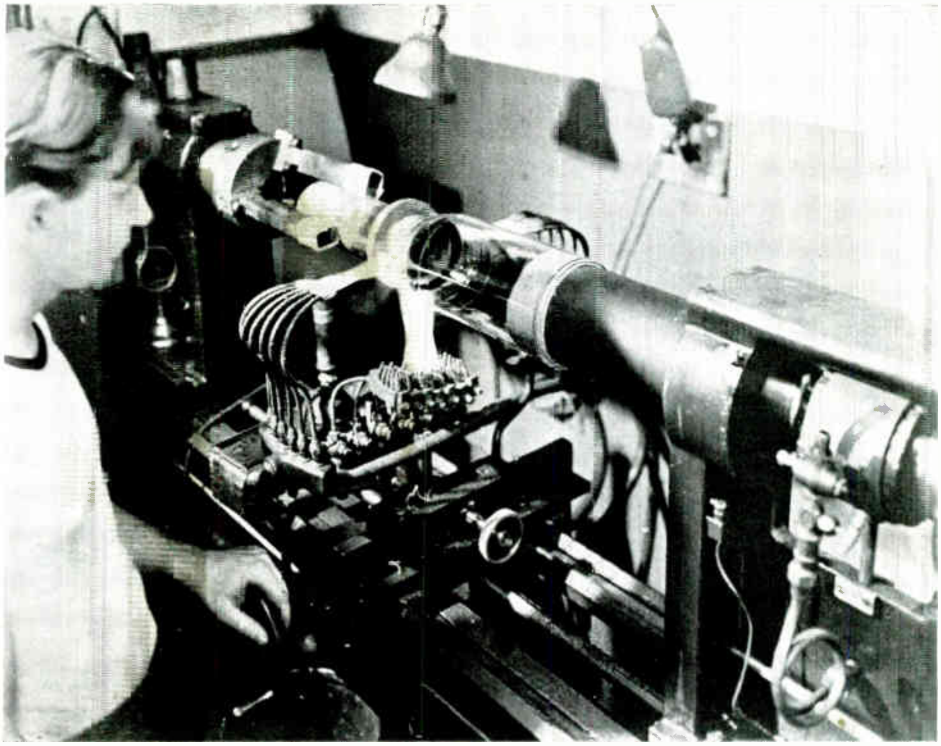
Courtesy of Amperex Electronic Corp.



apparent by a pink or blue glow; and a thoroughly bad seal is revealed by a deep purple gleam. Often the glass seal may have so small a leak that the spark coil will not reveal it immediately. Some plants, therefore, pre-exhaust all tubes and hold them for approximately 24 hours in order to catch these fine leaks. In any event, they will be discovered during the exhaust process by a very sensitive ionization gauge which is part of the exhaust equipment.

Exhaust machines next provide for the evacuation of tubes by a simultaneous pumping and heating action. A 400° C to 500° C temperature drives the moisture and gas from the inner surface of the glass; and for most tubes, high frequency induction heating of metal parts helps to drive out surface and absorbed gases and to break down oxide films.

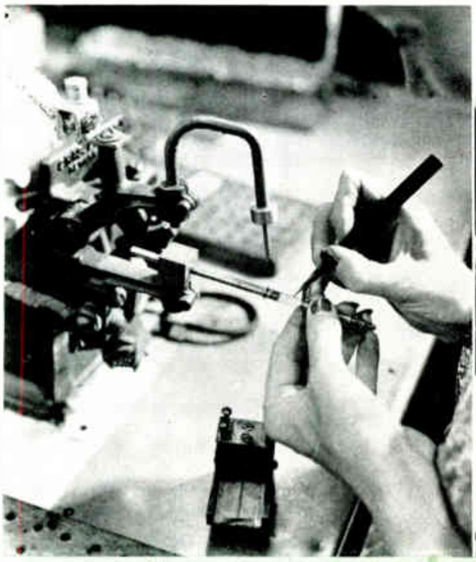
Finally, bases are cemented to the tube which is then ready for inspection, electrical processing, and final tests. Electrical processing involves, among other things, the activation of the cathodes and the aging or seasoning of the tube. The length of time required for aging depends on the tube and varies from a few hours to several days. During this time, the tube is operated at an over-voltage which may cause a defective tube to blow quickly. If it survives the aging, it is likely to be good for years.



Courtesy of Amperex Electronic Corp.

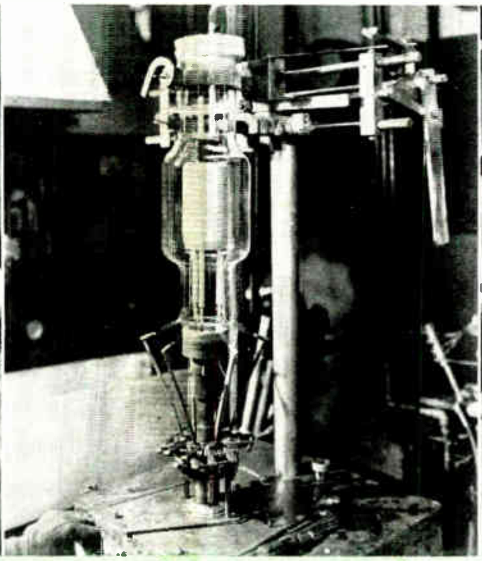
Copper-to-glass seal for an 859 transmitting tube requires intense heat to make airtight joint between glass and feather-edged anode. Ring attached to exterior of anode is nickel which will not deform to cause leaks when tube is in water jacket.

Safe shipping of the tube is the manufacturer's last headache, and a very real one. A large radiator-type transmitting tube is shipped in a "doghouse"—a peak-roofed wooden crate with the tube suspended by springs from its four corners. A flat-roofed crate was substituted for army use so that it could be stacked in the hold of a ship and subsequently carried by one man. The interiors of cardboard boxes are also fitted with a metal or wood frame from which lighter tubes are suspended in slings made of pink two-way stretch elastic. During the war, some of the cardboard was waterproofed so that the boxes could be floated into shore during difficult landings in the Pacific. In addition, some tubes were hermetically packed in foil to protect them from fungi.



Courtesy of Amperex Electronic Corp.

Operator spot welds tantalum grid wires of .007 inch diameter to the tantalum sleeve for a VT90 transmitting tube. The assembly is then placed in the jig (lower center) to see if it is properly aligned.



Courtesy of Amperex Electronic Corp.

Vertical lathe seals anode assembly into the envelope of a ZB3200 transmitting tube. Small rubber hose at top introduces inert gas into envelope to keep supports clean. Corrugated anode which increases plate dissipation, is held firmly by three-column support.

Courtesy of Amperex Electronic Corp.

After heat processes are completed, polariscope reveals glass strains which may be removed by annealing. This HF300 diathermy tube was used for high frequency radio transmitters during the war.

Operator inserts tiny cathodes in a ceramic disc for cathode-ray tubes. From this white tipped cathode is fired a stream of electrons at the phosphorescent screen. A short length of wire is then attached and terminated in one of the tube stem supports.

Operator uses spray gun to coat cathodes for cathode-ray tubes. Held in a special platen, 165 of the tiny tubes have their tips painted simultaneously with chemicals.

Ten of the most important steps in the manufacture of cathode-ray tubes are illustrated on these two pages. All photographs of this process are by courtesy of North American Philips Company, Inc.

Automatic Mass Production

To be produced in very large quantities, a tube goes through four stages in its development and production. First, a new tube is conceived to have certain functions and specifications, and a few laboratory samples are made up according to a rough plan. Next, more samples are made in the laboratory so that the bugs can be ironed out and the tube adapted for economical manufacture. Operations then move to the pilot shop where a larger number are made to determine the economic feasibility of large-scale production and to discover the probable difficulties.

In the factory itself, setting up the machines is an intricate and expensive business. As many as five thousand tubes may be wasted in this process before millions of perfect tubes can be turned out in a steady stream.

Attached to many of the machines in the plant are bright colored pipes leading to central tanks which supply needed gases and pressures. A typical combination leading to a big machine is a yellow pipe with black joints for city gas, a green pipe for low pressure air, yellow with blue joints for hydrogen, yellow with pink joints for oxygen, and green with brown joints for a rough vacuum of 60 to 150 microns.

The big header machines are the workhorses of mass production. One machine for sealing the glass envelope to the basic lead and anode assembly provides three pre-heat positions, four sealing positions, and five annealing positions. Making the circular trip through these positions takes about half an hour, and a tube is ready to be taken off at the last position every two or three minutes.

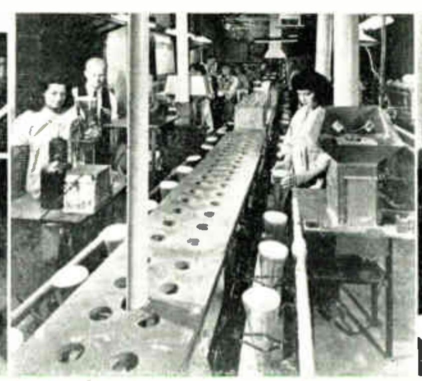
Another header for mercury vapor thyratrons seals the envelope, exhausts the tube, and activates the cathode. First the tube in the envelope is put on the head, the anode is sealed in, and the cathode sealed in. At the next position, the tube is tested by induction arc for leaks in the seal. If the seal is satisfactory, the arc is faint and diverse; a leak causes a blue or pink shade. At this same position, pumping action begins for the evacuation of the tube. It is accompanied by ordinary heating to drive any moisture from the glass, and by high frequency induction to clean metal parts of oxides and gases. The cathode is likewise heated in steps up to 1100 degrees Centigrade in order to drive out the binder and solvent, leaving carbonates which break down to oxides. Some of the oxides eventually are broken down to free metal. All around the machine, the pumping action continues; and the tube is finally removed with its seals made and tested, and its evacuation complete.

Sprinkler System Affected

The glass working and exhaust requirements of tube-making have an interesting effect on the general factory arrangements. For instance, the sprinkler system in some plants has to be set at 212° F rather than 98° F because the hot flames licking at metal and glass might set off an unexpected shower. The need for steady heat in the process complicates the installation of any air conditioning.

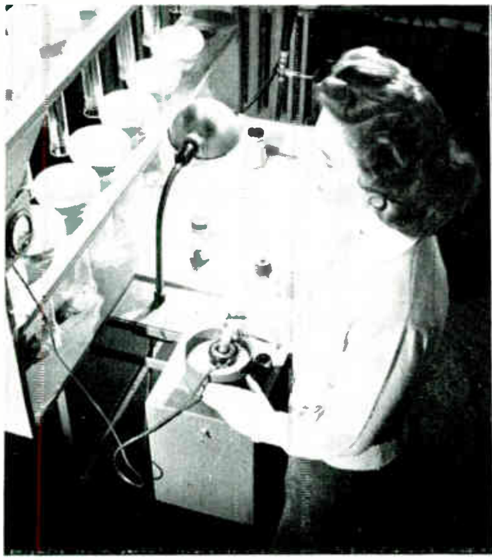
An electrical engineer or radio engineer who goes to work in a tube plant may find a sudden need for knowledge of mechanical and chemical engineering. As a challenge to the mechanical engineer, lathes as long as twelve feet are sometimes built in the plant

Chemicals for phosphorescent covering of cathode-ray screen are mixed in a steam-heated glass-lined kettle. To keep the ingredients absolutely pure, distilled water from the large tank (left) is used, and dust is removed from the atmosphere by electrostatic precipitation.



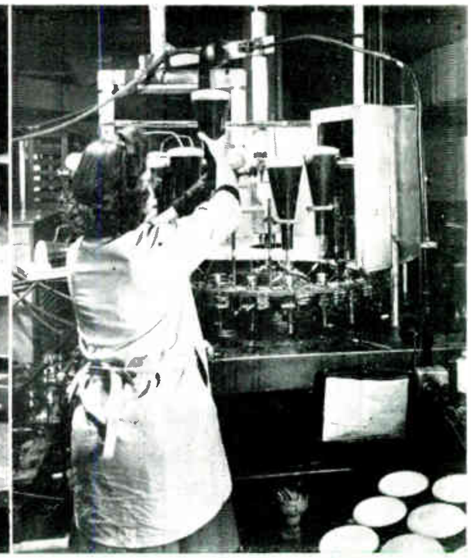
Curved-face cathode-ray envelopes are washed and sent along a conveyor line where screen and sidewall coating are applied at successive stations. At the end of the conveyor, the envelopes go into a large automatic oven where all moisture is removed from the envelope.

With a circular motion, the worker distributes phosphorescent powder over the inner face of the tube which has been coated with a liquid adhesive. Choice of chemical determines color, persistence, and other characteristics of the finished tube.



Evenness of phosphor distribution is tested with light meter. Light from incandescent lamp inside box shines through coating and registers any variation on meter to the left.

Close-up showing application of black aquadag coating to the side of the envelope. As the jig revolves, the operator manipulates a brush with a long wire handle.



In this processing machine, the cathode-ray tubes are baked, bombarded, evacuated, and sealed. A complete tube comes off the machine every two minutes.

for sealing; and the chucks in such an equipment must line up with each other to within ±.002 inch. The mechanical construction of the lighthouse tube in large quantities requires some close figuring, too; the space between the cathode and grid is of the order of .008 inch, and from grid to plate the measurement is approximately .040 inch. As for chemistry, its importance is apparent, for example, in understanding the "getter," a little barium pellet enclosed in a vented metal holder attached to the metal structure of some tubes. The function of the getter is—in good Pennsylvania Dutch—to get the gas out, if any is liberated by an accidental overload. But the tube design engineer can overwhelm the casual questioner about it with a torrent of explanation replete with chemical symbols and formulas.

X-Ray Tube Features

Though tubes for industrial purposes go through the same general process of manufacture, their requirements pose special problems. An X-ray tube, for example, requires the use of Lindemann glass to permit the passage of X rays more readily. Unlike ordinary glass in which lead acts as a deterrent to the X-ray beam, the Lindemann glass is made without lead. In the ordinary glass envelope of this X-ray tube, a glass blower makes the desired number of holes about an inch in diameter, and covers each with a little window of Lindemann glass about .007 to .0012 inch thick. A four-windowed X-ray diffraction tube permits four jobs to be done at once, since four X-ray beams can leave the tube simultaneously through the Lindemann glass windows spaced evenly around the wall of the envelope.

The mechanical assembly of the X-ray tube also presents several interesting variations according to its special uses. While the ordinary X-ray tube is likely to use only one filament a more flexible type is made with two filaments to provide a double focus—a convenient method of shifting the beam within the tube, similar in principal to the two beams in automobile headlights.

A challenging problem in the design and manufacture of these tubes is presented by the intense heat directed to the anode. One way of avoiding tube breakdown under this heat is to provide a tungsten target at the point where the X ray strikes the anode. Fused into a copper casting, the tungsten does not melt below 3000° Centigrade, while copper melts at a mere 1080° Centigrade.

Another way of combating the heat of the X ray is to provide a rotating anode which the beam strikes at different points during its revolution. The manufacture of such an anode is begun by winding a narrow tungsten ribbon until its edges form a flat disc which will stand expansion better than a solid piece of tungsten. This disc is dropped into a crucible, covered with an inch-thick mat of tungsten wool, and copper is melted all around and through it. The copper must be heated to 1350° Centigrade in order to penetrate the tungsten wool and ribbon disc. Then the copper that seeps to the bottom of the crucible must be faced off the surface of the tungsten disc. This disc or target is mounted on a bearing assembly which permits the whole anode to rotate at 3500 rpm. Lubricating the bearing to last the life of the tube requires a special metal powder applied in a machine which takes care of lubricating 28 bearings at one time. After

(Continued on page 18)

A flat-faced, 5-inch model of cathode-ray tube is sealed to the exhaust manifold. The mouthpiece and hose permit control of air pressure in the glass tubing while the dual-burner is manipulated to make the seal.

When tubes are partially exhausted, operator applies spark coil test to the tube. Color of resulting glow reveals leaks.

MECHANICALLY ACTUATED SWEEP

A capacity voltage divider is utilized to generate a linear sweep for a cathode-ray oscilloscope in synchronism with a rotating mechanical device.

By J. H. TAYLOR
Communication and Navigation Engineering

THE GENERATION OF a linear sweep in synchronism with some rotating mechanical device is a necessity in many investigations where a cathode-ray oscilloscope is used. Generally a linear sawtooth voltage is employed to produce a horizontal sweep, and the waveform under observation is presented along the vertical axis of the cathode-ray tube. Such equipment is helpful in studying the ignition system of internal combustion engines, and rotating electrical machinery.

Scanning Antenna Requirements

During recent years another requirement has become of major importance—the generation of an oscilloscope sweep in synchronism with the rotation of a rapid scan radar antenna. In this application, the sweep generator should have the following general characteristics:

1) The sweep voltage must rise linearly with respect to time;

2) Maximum amplitude of the sawtooth voltage must be independent of angular velocity, and constant over long periods;

3) The sweep must work over a wide range of angular velocities (from a few cycles per second up to a hundred);

4) It must provide a reasonably high level output from a low impedance source;

5) It must have a large ratio of useful sweep time to flyback or blanking time;

6) It must withstand severe vibration, and any combination of temperature and humidity conditions encountered in marine service; and

7) Final design must lend itself to production methods of assembly, calibration and test, and give reliable service in the field.

Three methods of meeting these requirements were considered in the design of a sweep generator for the AN/MPG-1 Radar Set[*] at Bendix Radio.

The first method was one in which a photocell is separated from a point source of light by a disc, the outside diameter of which is so shaped that the amount of light reaching the photocell is directly proportional to the angular position of the disc.

A vacuum photocell is necessary because of linearity requirements, and in addition a d-c amplifier having a reasonably high gain must be used. The sawtooth amplitude is a function of photocell sensitivity and amplifier gain, both of which are difficult to hold to the desired accuracy over long periods. Moreover, precautions have to be taken to prevent interfering signals from getting into the necessarily high impedance, low level amplifier input. For these reasons the photocell method was discarded.

A second method considered was one in which a trigger is developed periodically by the rotating device to initiate a linear r-c sawtooth. The trigger can be generated satisfactorily by rotating a slotted disc in a magnetic field. Several tubes, however, are required for the trigger amplifier and the r-c linear sawtooth generator. Moreover, to maintain constant sawtooth amplitude for different angular velocities, circuits have to be developed which set the slope of the sawtooth as a function of angular velocity. With higher speeds, the sawtooth must rise faster to reach the same magnitude than it does at lower angular velocities. This method is relatively simple mechanically but involves complex electronic circuits.

Capacity Voltage Divider

Since neither of the foregoing methods of sweep generation was considered satisfactory, a third system was investigated wherein a capacity voltage divider is connected across an r-f voltage.[†] The ground side of the divider is continuously variable and its plates are so shaped that the voltage across the variable section bears a linear relation to the angular position. The resulting sawtooth modulated envelope is then rectified by a linear detector, and filtered.

[*] For description of Radar Set AN/MPG-1 see Arthur G. Norris, "Mobile Pulse Gunnery Radar," BENDIX RADIO ENGINEER, Vol. 2 (January 1946), pp. 26-33.

[†] This same general method is used on the GCA. Here the condenser oscillates back and forth in synchronism with the squeeze box antenna. See Spicer, W. T., "The GCA Landing System" *ibid.*

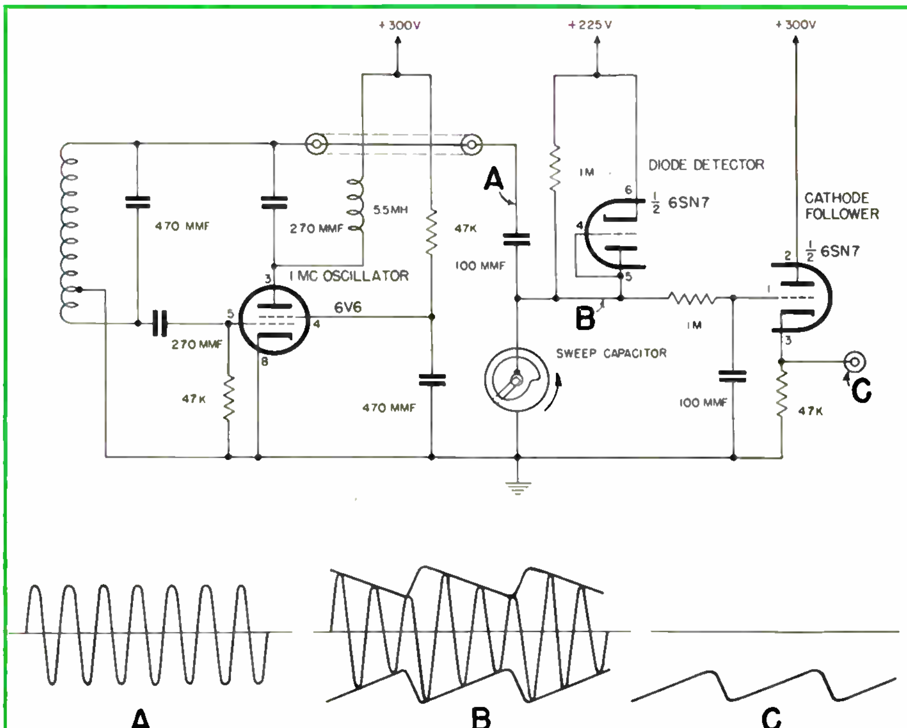


Figure 1—Capacity voltage divider sweep generator circuit, and voltage waveforms derived from the various stages.

This capacity voltage divider sweep generator requires a linear detector, a constant magnitude source of r-f voltage, and a special variable capacitor capable of continuous rotation at high speeds and having the required plate shape. No amplifier is necessary since no low level circuits are involved. Exclusive of power supply, only two tubes are required. Its circuit simplicity makes it easy to produce, and its reliability guarantees good field service.

The remainder of this article is devoted to an analysis of this capacity voltage divider sweep generator. Since the variable capacitor is the only unusual component it will be discussed in detail.

The sweep generator circuit is shown in figure 1. R-f voltage may be obtained from any source provided its amplitude is constant over long periods, that it is not affected by the variable load across it (sweep capacitor), and that it is of sufficient magnitude. These specifications can be met with a simple vacuum tube r-f oscillator operated from a regulated d-c power supply. It is not necessary to regulate the heater voltage if variations do not exceed ±10%. The absolute frequency, or the frequency stability, is relatively unimportant. With the constants shown in figure 1, the circuit oscillates at approximately one megacycle, and peak-to-peak amplitude is between 400 and 500 volts. The capacity voltage divider is across part of the oscillator inductance, and therefore shifts the frequency as the sweep capacitor rotates. This frequency modulation gives no trouble since the amplitude remains essentially constant over the limited frequency swing.

The linear diode detector, r-f filter, and cathode follower are conventional. The output voltage from the rotating capacitor is applied to the diode detector. When the r-f oscillator is not operating, the plate of the detector assumes approximately the same potential as the cathode. When the r-f oscillator is operating, this voltage appears on the plate of the detector and swings positive and negative with respect to the reference d-c plate potential. Since the diode conducts on positive swings and presents a low impedance to ground, only the negative swing is preserved. Among other things the amplitude is determined by the angular position of the sweep capacitor. As the capacitor rotates, the negative swing of the r-f envelope varies in a sawtooth manner. The r-f filter completes the formation of the sawtooth voltage. Circuits are d-c coupled to insure a true transfer of waveform. The heater of the 6SN7 is operated above ground so that the heater cathode voltage rating is not exceeded.

Electrical Characteristics

As for the variable capacitor, it must be designed to satisfy the following relationship

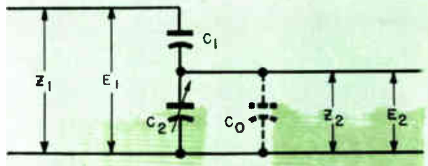


Figure 2—Simplified functional diagram of voltage divider.

in the simplified circuit shown schematically in figure 2:

$$C_2 = C_1 \frac{K - \theta}{K + \theta} - C_0 \qquad (1)$$

where

C_1 = capacity of fixed section,
C_2 = capacity of variable section (effective),
C_0 = stray capacity across variable section (total),
θ = angular position of variable section,
K = constant (to determine slope of saw-tooth).

(For mathematical development of this equation see appendix.)

An infinite number of capacitor designs will satisfy the general relation indicated by the formula. Space and weight limitations, form factors, required accuracy, and operating conditions are practical considerations which influence the design of the final product.

To maintain a low minimum capacity and produce a unit capable of withstanding rotation at high angular velocities it seems desirable to insulate the rotor and keep the rotor plates as small as practical. For such a design the rotor plates can be rectangular blades rotating within the stator assembly.

Blade width is a compromise between allowable flyback time, number of plates, and physical strength. Blade length is dependent on hub diameter and allowable capacitor diameter. Blade dimensions of 2½ inches long by ½ inch wide are reasonable. This size allows an effective rotation of about 320° out of 360°, and determines the diameter of the capacitor. Relationship between area in mesh and angular position of the rotor is shown in figure 3.

In the deviation of the general formulas one point on the curve has been defined: when $\theta = 0$, then $C_1 = C_2 + C_0$. To determine the exact electrical characteristics of the capacitor, this point of zero electrical degrees must be defined in absolute terms. An estimate of the probable total minimum capacity must be made and C_1 evaluated. These terms influence the final length of the capacitor. Several values were considered and the following seem reasonable. Make C_1 = 100 μμf and C_0 = 45 μμf.

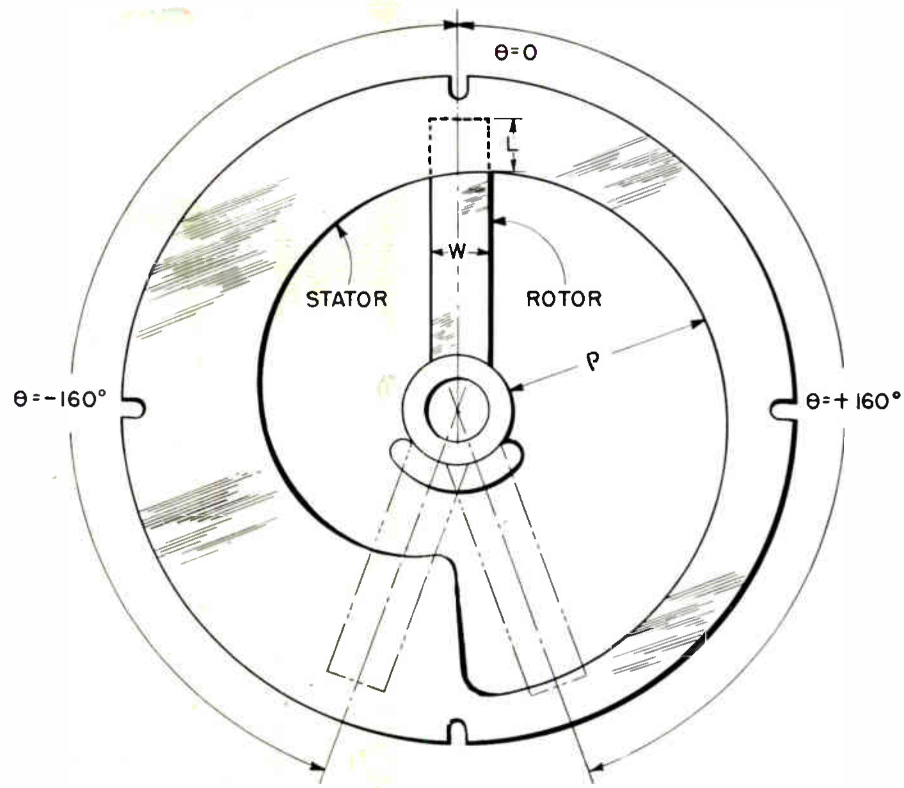


Figure 3—Rotor-stator plate relation.

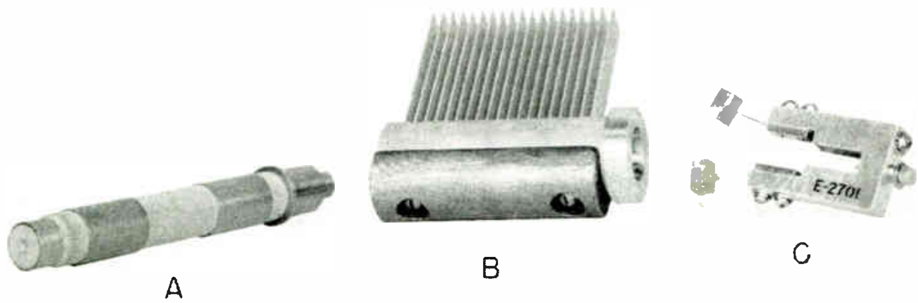


Figure 4—Rotor assembly of variable capacitor voltage divider. A. Steatite shaft; B. Rotor blades on hub; C. Brush assembly.

Thus C_2 must be 55 $\mu\mu f$ when $\theta = 0°$. To define completely the point of zero electrical degrees and compute the required number of plates, the area in mesh at this point must be evaluated. Let $L = \frac{1}{2}$ inch when $\theta = 0°$. (See figure 3.) Then:

$$C_2 = \frac{(0.2244\ KLw)n}{d}\ \mu\mu f \qquad (2)$$

Where

- K = dielectric constant (1 for air),
- L = length of area in mesh (inches),
- d = thickness of dielectric (inches),
- n = number of dielectrics, and
- w = width of area in mesh (inches).

Spacing between adjacent plates is made .040 inch. Substituting known values into the equation, we have the relation

$$55 = \frac{(0.224 \times 1 \times 0.5 \times 0.5)\ n}{.040}, \qquad (3)$$

$$n = \frac{.040 \times 55}{.25 \times 0.2244} = 39 \text{ dielectrics (approx.)}. \qquad (4)$$

Since approximately 39 dielectrics are required, it is desirable that there be 20 stator plates and 19 rotor plates. This division helps keep the minimum capacity low.

Equating the values of C_2 in equation 2 and equation 1, $(n = 38)$,

$$\frac{(0.224\ kwL)\ n}{d} = C_1\left(\frac{k-\theta}{k+\theta}\right) - C_0. \qquad (5)$$

Substituting known values and solving for L,

$$L = 0.9\left(\frac{k-\theta}{k+\theta}\right) - 0.4 \text{ inches}, \qquad (6)$$

$$\rho = (2.5 - L) = 2.5 - 0.9\left(\frac{k-\theta}{k+\theta}\right) + 0.4 \text{ inches} \qquad (7)$$

The rate of change of capacity with angular rotation or slope (k of equation 7) now must be evaluated. This slope should be as large as possible in order to obtain maximum sawtooth amplitude. Slope, however, is restricted by two factors. First, the rotor must have some appreciable mesh with the stator at the low capacity end; and second, the rotor must have sufficient clearance from the stator to limit minimum capacity. One point on the curve has already been fixed (when $\theta = 0$, $L = \frac{1}{2}$ inch); but one point does not determine slope. Several values of k were tried in equation, and 530 seemed a good compromise. For this value of slope the length of the rotor in mesh is 0.082 inch when $\theta = +160°$, and 1.28 inches when $\theta = -160°$. The final exact equation of ρ in terms of θ becomes:

$$\rho = 2.9 - 0.9\left(\frac{530-\theta}{530+\theta}\right). \qquad (8)$$

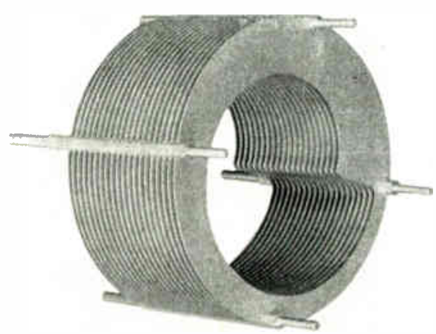


Figure 5—Stator assembly.

Since the constants of equation 8 are based on approximations which are related to the physical aspects of the condenser they need not be expressed to more than one decimal place. The values of C_1 and C_0 can later be adjusted to fit the particular condenser if necessary. The θ vs. ρ relation should be expressed to three places since it is this relation which chiefly determines the linearity of the final capacitor.

The ρ vs. θ relation is based on the assumption that ρ is constant over the width of the rotor blade. This assumption is not true since ρ varies plus and minus about its center position in accordance with the stator plate curve. More capacity is added on one side of center than is subtracted on the other. (See figure 3.) This error increases as the rate of curvature increases and reaches a maximum at the high-capacity end. To compensate partially for this error, the value of ρ is increased by 2 per cent when $\theta = -170°$, and this correction tapers linearly to zero when $\theta = -50°$.

The radius vector was computed to the fourth decimal with the foregoing correction included, for all values of θ in one degree steps from $-170°$ through $0°$ to $+170°$.

Mechanical Design

The grounded stator construction requires a strong insulated shaft. Steatite is used, and each end has a metal tip shrunk over sputtered copper. Two more copper bands are sputtered in the central section, and carry the rotor hub which is held in place by setscrews. The rotor blades are hard soldered to the hub and are ground to final dimensions with respect to the shaft center. A slip ring then is pressed on the hub and the complete rotor assembly is accurately balanced. The rotor is carried by two grease-sealed ball bearings, and an Oldham coupling connects the shaft to the driving force. (Refer to figures 4 and 5.)

The stator plates were produced from a tool which stamped the outside diameter, inside curve, and locating slots all in one operation (see figure 6). This tool was made in the Bendix Model Shop, and in production it consistently produced plates which are closer than ± 0.002 inch of the desired curve as indicated on the shadowgraph. All plates were made of 0.030 inch cold rolled steel.

The 20 stator plates, 4 tie rods and 3 spacer rods are assembled on the two cast end bells. These end bells serve as a soldering jig. After soldering the tie rods to stator plates, the assembly is dismantled and the individual parts tagged. These parts maintain their identity through the finishing processes and are finally reassembled in the same relative position as they occupied during the soldering operation. This manufacturing procedure allowed wider tolerances on details, and avoided the use of elaborate jigs. Preliminary calibration was accomplished by visual alignment before the unit was assembled into its housing.

Figure 6—Tool for producing stator plates.

Through a combination of hub movement on the shaft and longitudinal shift of the stator by means of tie rods, the plate spacing was made approximately uniform through 360° of rotation.

The housing and two end bells are cast of 195T6, a heat-treated aluminum alloy. After machining they are anodized and painted. The plates, tie rods, space rods, and hub are cadmium-plated steel.

The two brushes, made of copper graphite (CuAg5 as made by St. Marys Carbon Company), are copper flashed and soldered to phosphorous bronze arms. The assembly, complete with damping springs and captive mounting screws, can be replaced through an inspection window. The slip ring is made of coin silver with a polished surface. This combination gives exceptionally long life. The slip ring requires no lubrication and, since the bearings are grease packed and sealed, the capacitor never has to be lubricated.

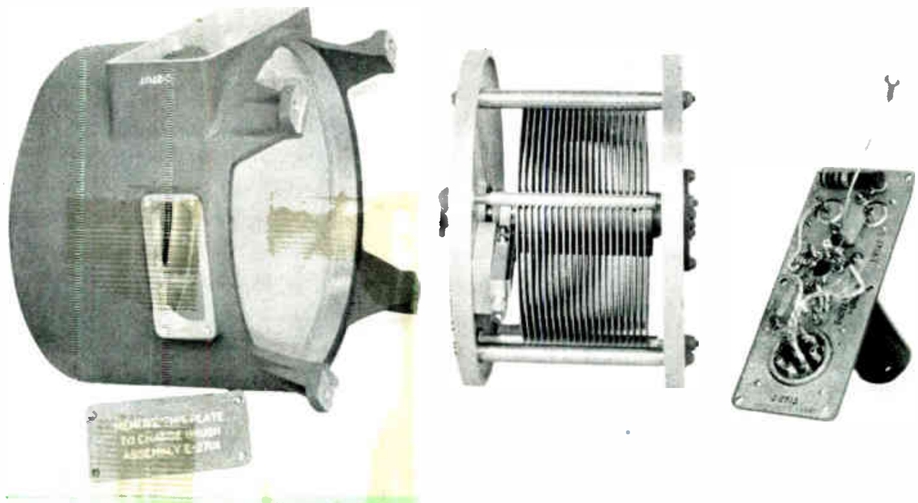


Figure 7—Capacitor dismantled.

Calibration and Test

Calibration was performed by a longitudinal movement of the four tie rods which are free to move with respect to the rotor. At any point the capacity is a minimum when the rotor blade is equidistant from adjacent stator plates. A shift of stator assembly in either direction increases capacity at that point. More control becomes available (more points can be adjusted to the desired curve) as the number of tie rods is increased. In this case, one rod in each quadrant is sufficient. This unique calibration procedure is performed while the capacitor is rotating, and allows a smooth and continuous rate of adjustment. Sufficient range was available to compensate for changes of ±10 per cent in C_1, the fixed section of the voltage divider. Elastic stop nuts are used on the outside of each end of the tie rods and plain hex nuts are used inside. All nuts are glyptalled in place after final calibration.

Capacity vs. angular position data were taken. Results showed that the measured values of capacity agreed reasonably closely with calculated data and the desired linear relation could be obtained by adjusting the stator tie bars. This test equipment indicated changes in capacity in the order of ±0.1 µµf, and θ could be set to ±10 minutes of angle. Such a setup was not practical for productive calibration. Since a linear sawtooth voltage output was the criterion, no further attempt was made to calibrate by means of capacity measurements.

Calibration was possible by plotting d-c output voltage vs. angular position. This method was accurate but too slow for production.

An electromechanical setup was arranged so that the output voltage was presented on a cathode-ray tube. This method eliminated the error in setting the angular position, and was sufficiently accurate for production calibration and test. Calibration was performed in two steps as follows:

1) The waveform was observed on a test oscilloscope and initial adjustments made to obtain an essentially linear sawtooth.

2) Calibration markers were produced by a photocell unit whose slotted disk was mechanically connected to the rotating capacitor under test. These eleven marks were produced by eleven slots accurately spaced 32° apart. The sweep voltage and calibration marks were displayed simultaneously on the test oscilloscope. A manually operated cursor was moved from one mark to the next and a dial before the operator indicated the distance between marks. Calibration was complete when all markers appeared the same distance apart. A tolerance of ±2 per cent was maintained (i.e., the greatest deviation between any two of the eleven marks must be within 2 per cent of the distance between adjacent marks). Since the accuracy at either end of the sweep was of little importance in the final application a somewhat wider tolerance was allowed on the extreme ends.

The absolute value of the sawtooth amplitude varied from unit to unit but was always greater than 80 volts. For most requirements, the exact amplitude is not important so long as it is enough and remains constant over long periods.

Vibration measurements were made at different angular velocities. Strobotac observations indicated that the unit could be safely operated at any velocity from zero up to 5000 rpm.

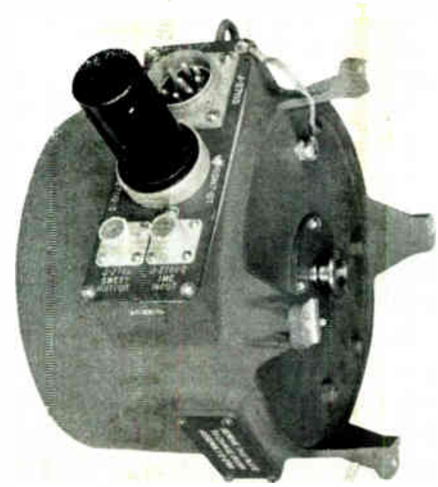


Figure 8—Mechanically driven linear sweep generator as used in Radar Set AN/MPG-1.

Conclusions

The mechanically driven linear sweep generator shown in figure 8 meets all the requirements set forth at the beginning of this article. For production units the linearity is better than two per cent for a flyback time of less than 15 per cent. Amplitude of the sawtooth is independent of angular velocity and represents about 90 volts from an impedance of less than 1000 ohms. The circuits are simple and straightforward, and no lubrication or alignment of the assembly is necessary in the field. After 5000 hours of operation under actual service conditions no trouble was experienced with the unit, and upon inspection it appeared in perfect condition both mechanically and electrically. The slip ring wear was negligible, and the original brushes had worn down less than a thirty-second of an inch. The life test was conducted at a speed of approximately 1000 rpm.

Appendix

The equation which governed the electrical design of the variable capacitor was derived as follows:

In figure 2, in addition to the conditions already set up, let

Z_1 = Impedance of total voltage divider, and

Z_2 = Impedance of the variable section,
E_1 = Voltage across Impedance Z_1,
E_2 = Voltage across Impedance Z_2,
$C = C_2 + C_0$ (for convenience).

Then

$$Z_1 = \frac{1}{\frac{j\omega(CC_1)}{C + C_1}}; \qquad (1)$$

$$Z_2 = \frac{1}{j\omega C}; \qquad (2)$$

$$\frac{E_2}{E_1} = \frac{Z_2}{Z_1} = \frac{\frac{1}{j\omega C}}{\frac{1}{\frac{j\omega(CC_1)}{C+C_1}}} = \frac{\frac{1}{C}}{\frac{C+C_1}{CC_1}} = \frac{C_1}{C+C_1}; \qquad (3)$$

hence

$$E_2 = E_1\left(\frac{C_1}{C+C_1}\right). \qquad (4)$$

To maintain a linear relation between E_2 and θ, we have the general equation

$$E_2 = n\theta + A \qquad (5)$$

where n and A are constants.

Equating 4 and 5 for E_2,

$$n\theta + A = E_1\left(\frac{C_1}{C + C_1}\right). \qquad (6)$$

Now let $C = C_1$ when $\theta = 0$. Then

$$A = \frac{E_1}{2} \qquad (7)$$

Substituting the value of A in equation 6

$$n\theta + \frac{E_1}{2} = \frac{E_1C_1}{C + C_1}, \qquad (8)$$

$$C\left(n\theta + \frac{E_1}{2}\right) + C_1\left(n\theta + \frac{E_1}{2}\right) = E_1C_1; \qquad (9)$$

$$C = \frac{E_1C_1 - C_1\left(n\theta + \frac{E_1}{2}\right)}{n\theta + \frac{E_1}{2}}; \qquad (10)$$

$$C = \frac{C_1E_1 - C_1 n\theta - \frac{C_1E_1}{2}}{n\theta + \frac{E_1}{2}} = C_1\left\{\frac{\frac{E_1}{2} - n\theta}{\frac{E_1}{2} + n\theta}\right\}; \text{ and} \qquad (11)$$

$$C = C_1\left\{\frac{\frac{E_1}{2n} - \theta}{\frac{E_1}{2n} + \theta}\right\}. \qquad (12)$$

Since $\frac{E_1}{2n}$ is a constant, let a new constant

$$k = \frac{E_1}{2n}. \qquad (13)$$

Then

$$C = C_1\left(\frac{k - \theta}{k + \theta}\right). \qquad (14)$$

By definition, $C = C_0 + C_2$. Therefore,

$$C_2 = C_1\left(\frac{k - \theta}{k + \theta}\right) - C_0. \qquad (15)$$

J. H. Taylor

VIRGINIA-BORN J. H. TAYLOR received his Bachelor's degree in Electrical Engineering from Virginia Polytechnic Institute in 1935. He was president of the student Short Wave Club in his senior year and was elected to membership in Phi Kappa Phi. Awarded a teaching fellowship, he was instructor in the Electrical Engineering Department at VPI while preparing the thesis on ultra shortwave propagation for his Master's degree which he received in 1936. During the next two years he gained varied experience in the coil department, in equipment test, and on broadcast receivers in the Philco radio laboratory. Prior to coming to Bendix in 1940 he spent a brief period in the Army as first lieutenant in the Coast Artillery. He was associated with the design of the RA-10 Receiver, the SCR-274 Command Set, and the BC-639 UHF Ground Station Receiver. Transferring to the Microwave Section in 1943, he developed the range and indicator circuits for the Bendix version of the MPG. He was one of the engineers observing system performance on the first model of the MPG at Fort Hancock, New Jersey, and also observed target practice with major caliber guns at Fort Monroe, Virginia, when radar data from the second MPG was used.

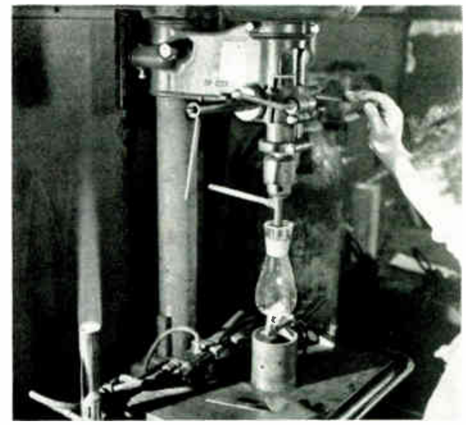
Tubes In The Making

(Continued from page 13)

24 hours of revolving on the shafts of this machine, the bearings are ready to be sealed into the tube and need no further lubrication during its period of use.

A smaller tube with an interesting application in the measurement of all types of radiation is the Geiger-Muller tube. With this tube as the heart of the spectrometer, the intensity of any such beam may be measured. The long narrow envelope of the tube has a Lindemann glass window at the end through which the beam enters; and the impulses from the beam are picked up by a sensitive wire running through the longitudinal axis of the envelope. Then the mechanism of the spectrometer counts the pulses and registers them on a specially calibrated indicator which reads like a voltmeter, or automatically records them on a chart.

Samples of soil from the atom bomb site in New Mexico register definite radioactivity in the Geiger-Muller spectrometer almost a year after the bomb was dropped. More mysterious is the measurement of cosmic rays which are strong enough to light up a glow lamp in the equipment about twice every minute.



Courtesy of Amperex Electronic Corp.

For 834 (VT62) hf tube, two oxygen-hydrogen jets heat glass to pliable state, air pressure is applied inside envelope, and glass forms two stems at points provided in the mold.

The infinite variety of tube designs and manufacture is matched only by the endless variations in their use. Though the first electronic tubes taught radio to talk, later tube designs provided the miracle of sight for accurate counting, measuring, and testing at close range, or for seeing beyond the scope of human vision. Nothing seems impossible now that, with the aid of radiation-measuring tubes, man can literally take the pulse of the universe.

Acknowledgments

Through the generous cooperation of Mr. V. W. Palen, Director of Publicity for North American Philips Company, Inc., 100 East 42nd Street, New York, material concerning the cathode-ray and Geiger-Muller tubes was provided. He also arranged a sightseeing trip through Amperex Electronic Corporation where Mr. Myron Youdin kindly explained technical details about the manufacture of radio transmitting tubes. Automatic mass production of small tubes was explained by Mr. W. E. Brodell, engineer in the Electronics Department of General Electric at the Schenectady Tube Division.

HIGH GAIN I-F AMPLIFIER FOR FM*

A description of circuit arrangements devised to provide high sensitivity and selectivity in a very high frequency FM receiver for emergency services.

By DAVID W. MARTIN
Communication and Navigation Engineering

There are two advantages in using an i-f amplifier in a superheterodyne receiver. First it is easier to secure a large amount of gain in an amplifier tuned to a fixed frequency, and second, the i-f amplifier contributes the major portion of the selectivity needed for receiver rejection of adjacent channel interference caused by other transmitters operating in the region. The latter function is particularly important at very high and ultra high frequencies.

In ultra-high-frequency receivers, where ambient noise level is low, it is desirable to work down to the threshold noise level introduced by first circuit noise (Schott noise and circuit noise). In many instances threshold operation is imperative since small mobile transmitters are used and the receiver has very little signal to work with. Threshold operation is then the rule rather than the exception. This is particularly true in police, fire and railroad applications.

Basic Design Factors

Because of the stringent requirements of the emergency services, certain factors are basic in the design of their communications equipment. Most important, the equipment must be extremely rugged, and easy to maintain and tune. This is necessary since the equipment is subject to considerable vibration, and since repairs usually are made by persons who have only limited experience with the equipment.

In so far as the receiver itself is concerned, it must operate under extreme temperature variations with excellent stability, and it must have good image and spurious response rejection. This latter requirement has become increasingly important because of the more complete utilization of the available frequency spectrum. Fast limiter action is necessary since most of the interference encountered in the emergency service band of 152 to 162 mc is of the impulse noise type, such as ignition noise.

It is very important also that the receiver have extreme sensitivity. By extreme sensitivity is meant complete limiting ability when signal strength is well under one microvolt. The reason for this requirement will become evident when it is considered that transmitters used by the services have relatively low power outputs, and that operation is usually desired at the extremes of the radiation pattern.

Circuit Arrangements

There are several ways of building a receiver suitable for these services. The first and most direct approach is to use a simple superheterodyne (see figure 1). This circuit has the advantage of simplicity. In addition, good image rejection can be obtained and less trouble is had with the spurious responses than with the double superheterodyne. Since only one i-f frequency is used, it is simple to change the received frequency merely by shifting the crystal oscillator frequency. This circuit, however, suffers from one severe limitation. It is difficult, almost impossible, to obtain sufficient stable gain to make receiver sensitivity less than one microvolt. This fact may not be immediately apparent since AM receivers have been built which use a simple superheterodyne, and give a ten-to-one signal-to-noise ratio well under one microvolt. If the same receiver, however, were converted to FM, it would be necessary to add a double limiter in place of the original AM diode detector. This limiter unfortunately contributes an additional gain, so that the AM set might have a gain of about one million while the gain of the FM set would be on the order of three to five million. The gain cannot be reduced ahead of the limiter since it takes from 0.5 volt to 2 volts to saturate a limiter.

In order to obtain the extremely high gain desired, many manufacturers are using the double superheterodyne in which there are two mixers in cascade. One form of the double superheterodyne is shown in figure 2. This type uses only one crystal oscillator, and mixing is accomplished by using different crystal harmonics on the two mixers. As indicated, gain is taken at both i-f frequencies. With this setup, it is relatively easy to get the desired stable gain. It is easy also to obtain sharp bandwidth. However, the spurious response problem is always magnified when a double superheterodyne is used. The circuit shown in figure 2 has another important limitation in that the first i-f must be tuned when it is desired to change frequency.

The latter difficulty may be overcome by using the circuit of figure 3. Here, a second crystal oscillator has been added, and hence it is not necessary to retune the i-f stage when changing received frequency. But the circuit is even more troublesome in so far as spurious

* Patent applied for.

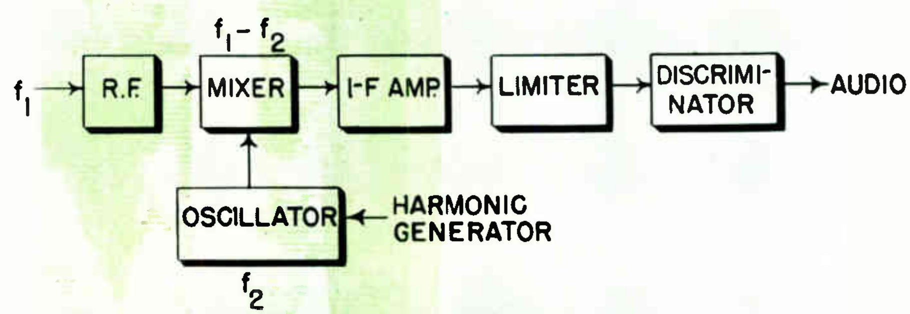


Figure 1—Block diagram of simple superheterodyne FM receiver for the emergency services.

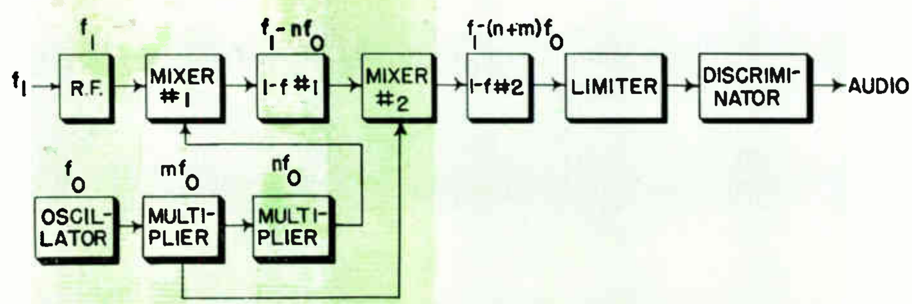


Figure 2—Layout of a double superheterodyne FM receiver using a single crystal.

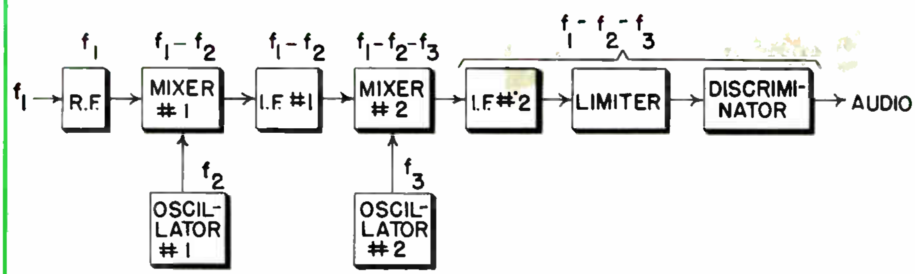


Figure 3—Re-tuning of first i-f stage is not necessary when changing frequency with this double superheterodyne using two crystals.

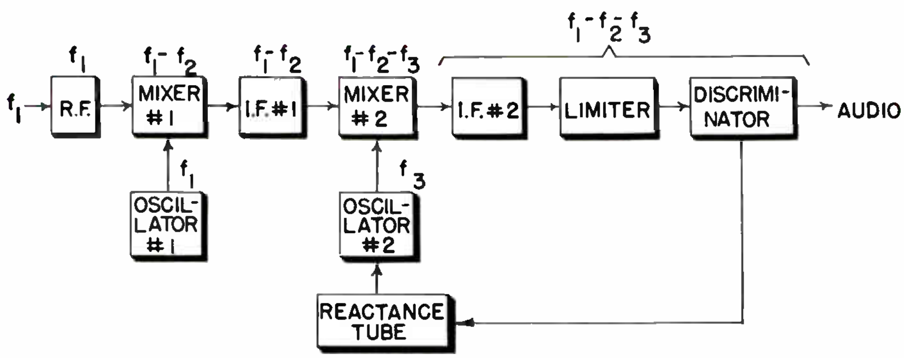


Figure 4—Double superheterodyne using automatic frequency control eliminates drift of second oscillator.

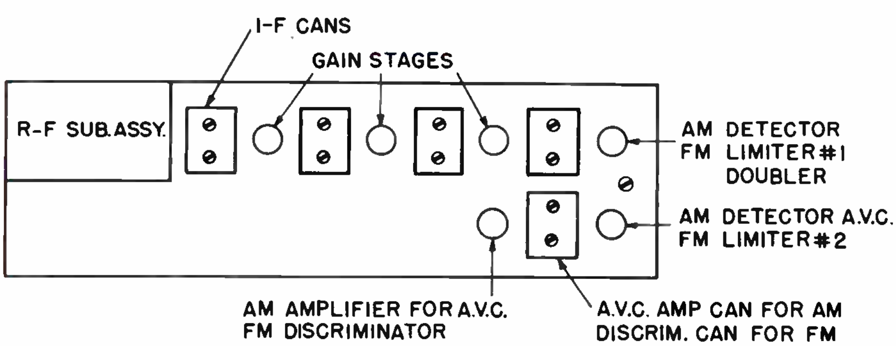


Figure 5—Physical layout of AM-FM emergency service receiver.

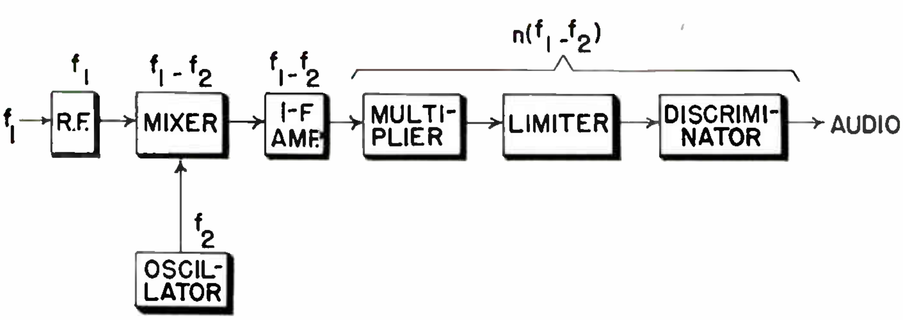


Figure 6—Block diagram of single superheterodyne with multiplier that makes it possible to obtain the stable gain required of FM reception in the emergency services.

responses are concerned, since the new crystal oscillator is not related harmonically to the first oscillator. In addition, there is the drift of the second oscillator to be considered. The circuit of figure 4 eliminates the drift trouble by having the second oscillator which is now a free oscillator, controlled by the discriminator through a reactance tube. In this type of circuit, however, there is the possibility of having the reactance tube "pull" so far that signals in adjacent channels are received.

Approach to Problem

Our particular problem in i-f design was intensified since the original plans for the receiver under discussion called for an AM receiver having amplified avc. After the AM design was completed it was decided that it should be revised to make the receiver convertible to FM. It was, of course, desirable to keep the number of changes to a minimum, and the most economical layout for FM was that which meant moving the fewest parts. Since the receiver was part of a complete communications unit including both receiver and transmitter, there was very little room for the addition of new parts. The first and most obvious solution was to use a single superheterodyne with the i-f layout shown in figure 5. The problem of obtaining sufficient stable gain to saturate the limiter at low level was intensified because the discriminator is close to the input of the i-f amplifier. Since the i-f frequency chosen to meet the selectivity requirement was 9.5 mc, radiation from the discriminator to the input of the i-f amplifier was a severe problem. It was not possible with this layout to obtain a "cool" i-f system having the desired gain. The possibility of using a double superheterodyne of the types described earlier was investigated, but was rejected since space was not available for the added parts, and because of its inherent limitations.

The problem of obtaining an adequately stable gain in a sensitive FM receiver was approached, therefore, from a different direction. Remember, that in FM amplitude distortion in the i-f amplifier is of no importance if the original frequency distribution is not disturbed. It was on this premise that the circuit of figure 6 was developed. An i-f frequency was chosen to give the required bandwidth and i-f rejection. As much stable gain as is possible is taken up to the multiplier, which is designed to double efficiently at low-input levels so that the i-f band is transposed to twice its original frequency. More gain can thus be taken in the limiter without introduction of unwanted feedback. In so far as the FM spectrum is concerned, it can be shown that the original relationship of side frequency pairs to the carrier has not been disturbed, for both the deviation ratio and the new carrier frequency are doubled. (See appendix for mathematical corroboration.) This means that the discriminator offers no more of a problem than it would if the original spectrum were used on the lower i-f frequency.

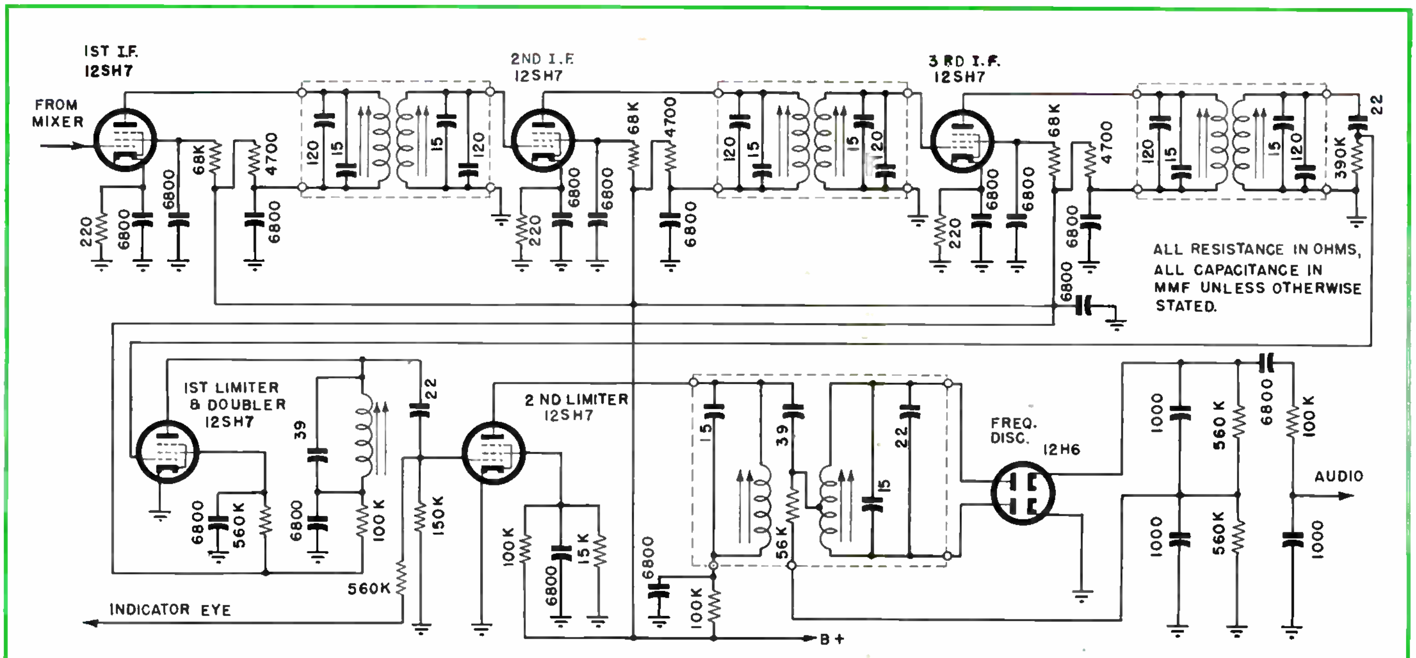


Figure 7—Schematic diagram of single crystal FM receiver using i-f mutiplier to obtain stable gain.

Squelch Properties

A schematic diagram of the actual circuit is shown in figure 7. With this circuit, the i-f sensitivity measured at the first i-f grid is 50 microvolts for limiter saturation. The doubler-limiter saturates completely with 0.75-volt input. When measuring at the grid of the first 12SH7, it will be found that the intermediate frequency is completely squelched in the absence of signal because of the square law response of the doubler. Therefore, the circuit exhibits useful no-signal squelch properties when the over-all gain is not great enough to cause doubler action. When measurement is made from the antenna to the first i-f grid, the front end shows an over-all gain of about 100. The limiter, therefore, is theoretically saturated at about 0.5-microvolt input. Actually, saturation is nearly complete in the absence of signal due to first circuit and tube noise.

The front end is perhaps worthy of mention at this point. All circuits for the r-f stage, mixer stage, and the harmonic generator string are built on a small removable chassis. The purpose of this chassis is twofold. It may be removed if it becomes necessary to change frequency outside of the 152 to 162 mc band, and, because of the necessity for short leads, it is easier to wire this chassis as a separate assembly rather than as a part of an already crowded main chassis. All circuits are screw-driver adjusted. Slug tuning is used in the harmonic string and small variable capacitors are used on the r-f circuits. The coils are padded and adjusted to allow full coverage of the 152 to 162 mc band with overlap at each end. To facilitate tuning, an electron eye tube (type 1629) has been incorporated in the receiver. This eye may be switched to read grid drive in the harmonic string at the crystal oscillator, tripler and the doubler, and it may also be used to check developed voltage at the second limiter. By using this tube, it is extremely simple to tune up the receiver. First, the desired crystal is plugged in, then the eye is switched to read developed tripler grid voltage (position #1). The oscillator screw is adjusted for maximum closing of the eye. Then the eye is switched to position #2 to read grid voltage on the doubler, and the tripler tank is tuned for maximum closing of the eye. Now the harmonic string is tuned correctly except for the doubler plate tank, and the eye is switched to position #3 to read second limiter voltage. A signal of the desired incoming frequency is fed the receiver through the antenna lead. The r-f grid and plate-tanks, and the mixer grid and doubler plate-tanks then are adjusted to give maximum closing of the eye. It is also possible to align the i-f circuits using this position of the switch.

The i-f string consists of three cascaded gain stages using 12SH7 tubes. These are used in preference to 6AC7's because sufficient and more consistent gain can be attained with the 12SH7's. Three stages are needed to give the desired pass band characteristics. All i-f transformers are permeability tuned and temperature compensated so that the maximum i-f drift from −50° C to +80° C is +6−2 kc. To further reduce drift, the crystals are AT cut units ground to an accuracy of 0.005% and held in a temperature controlled oven at 70° C.

Over-all Characteristics

In order to obtain the maximum stable gain and to reduce regeneration to a minimum, extreme care in mechanical layout was exercised to ensure short, direct grounding and bypassing. Even a seemingly slight increase in the lead lengths of the bypasses results in the introduction of much undesired regeneration.

After the i-f strip comes the two-stage limiter which uses the doubler technique described. It is of interest to note that the only part added to use this circuit was a plate tank tuned to twice the i-f frequency in the first limiter. The second limiter is conventional. In both limiters, the time constants were kept short. This tank does not have to be shielded, and is slug-tuned through the chassis. The discriminator is also slug-tuned, since it was found possible to accomplish this without sacrificing limiter linearity.

The squelch system is operated from the voltage developed across the second limiter grid resistor. A d-c amplifier (12SN7) is used to allow operation of a telephone type relay. The relay operation is positive and there is no tendency to "chatter." By using a d-c amplifier, it is possible to insert a resistance-capacity filter in the second section of the amplifier to prevent relay operation on noise pulses. Relay-operated squelch has certain advantages over electronic squelch. First, it is possible to remove B+ from the audio amplifier, thereby reducing the stand-by current of the receiver. Second, there is no "knee" to worry about in which distortion is severe. Finally, it is possible to actuate external alarm devices such as bells or lights from the squelch system.

Because of the extremely high over-all gain, reliable squelch operation is possible on a small fraction of a microvolt, even below limiting. Of course, the problem of obtaining reliable, accurate measurements is extremely serious in the 152–162 mc band. No commercial FM signal generator is available. We have built for this job a special unit which has been satisfactory for checking limiter operation from the front end and over-all sensitivity. AM measurements were made on a Ferris 40-A generator and a Bendix IF-15A generator. I-F measurements were made on a Ferris 16-C generator.

The doubler circuit has resulted in an FM set having extreme sensitivity with excellent stability. The intermediate frequency in the practical receiver doubles back on itself without introducing any instability. In addition, the problem of spurious responses present in the double superheterodyne has been eliminated, and the simplicity of the single superheterodyne has been retained. A most satisfactory receiver, using this circuit, can be easily manufactured for the emergency services.

Appendix

Amplitude distortion in the i-f amplifier of an FM receiver is of no importance if the original frequency distribution is not disturbed. It can be shown that doubling the i-f frequency does not disturb the relationship of side frequencies to the carrier frequency as follows:

In the original FM carrier

$$I_t = I_m \sin(\Omega t + \beta \sin \omega t),$$

where

I_t = instantaneous carrier level,

I_m = maximum carrier level,

Ω = $2\pi F$ (where F is the carrier frequency),

β = modulation index $\left(\beta = \dfrac{\Delta F}{f}\right)$

ω = $2\pi f$ (where f is the modulation frequency).

The spectrum solution of this original equation is:

$$I_t = I_m \Big\{ J_0(\beta) \sin \Omega t + J_1(\beta)[\sin(\Omega + \omega)t - \sin(\Omega - \omega)t] + \ldots + J_n(\beta)[\sin(\Omega + n\omega)t + (-1)^n \sin(\Omega - n\omega t)]\Big\}.$$

Assume that both ΔF and F are doubled, which they are when the r-f current is fed through the doubler. Then $\beta_2 = \dfrac{2\Delta F}{f} = 2\beta$; hence the deviation ratio is doubled. Since the r-f carrier is doubled

$$\Omega_2 = 2\Omega.$$

The spectrum solution then becomes

$$I_t = I_m J_0(\beta_2) \sin 2\Omega t + J_1(\beta_2)[\sin 2\Omega + \omega)t - \sin(2\Omega - \omega)t] + \ldots J_n(\beta_2)[\sin(2\Omega + n\omega)t + (-1)^n \sin(2\Omega - n\omega)t]\Big\}.$$

Since Ω is much larger than ω, this equation shows that the vectors representing spectrum component values are rotating at twice the r-f rate, and β_2 shows that their maximum values are doubled. The basic spectrum distribution, therefore, has not been disturbed, and the resultant FM wave, which has a greater deviation ratio, and a higher basic carrier frequency, is a true replica of the original.

David Martin

BUSY, GOOD-NATURED Dave Martin has been engineer on the design of AM and FM receivers for railroad use from the time the project was initiated, and participated in the first B & O tests using equipment of his design. He was one of the Bendix group which made an exhaustive study of the relative merits of AM and FM for this application prior to the adoption of the present FM equipment. The circuit described in the accompanying article is an outgrowth of difficulties encountered in getting FM operation. Martin has been associated with the development of Bendix Radio automatic compasses and receivers ever since receiving his E.E. degree from Drexel Institute in 1940. More recently he has engaged in general design on D/F and special receivers for classified wartime projects and at present is building a commercial airborne receiver.

Earth-Moon Radio Circuits

(Continued from page 3)

Appendix

Calculation of signal-to-noise ratio to be expected for the radar reflections from the moon are given below.

The equipment used in the experiments conducted under the direction of Lt. Col. John H. DeWitt, Jr., at the Evans Signal Laboratory, Belmar, N. J., had the following characteristics:

P_T = Power of transmitter = 4 kw,

G_T = Transmitter antenna gain = 23 db,

A_R = Receiving antenna area = 1600 square feet,

NF = Receiver noise figure = 8 db,

Bandwidth = 50 cycles.

Physical constants required are:

KT = Boltzman's constant $\times$ temperature = 4.1×10^{-21},

R = Distance to moon (variable) = approximately 250,000 miles,

Diameter of moon = 2000 miles,

A_m = Area of moon = $\pi r^2 = 10^6 \pi$ square miles.

Power flow in the beam of the transmitter—expressed in watts per square foot—is

$$\frac{P_T G_T}{4\pi R^2}.$$

Power, in watts, striking the moon is

$$\frac{P_T G_T A_m}{4\pi R^2}.$$

This power is re-radiated isotropically, and produces, as a result of P_T, a power flow coming from the moon

$$\frac{P_T G_T A_m}{(4\pi R^2)^2}$$

watts per square foot.

If the receiving antenna has an area A_R, the power intercepted is

$$\frac{P_T G_T A_m A_R}{(4\pi R^2)^2} \text{ watts.}$$

This power gives a signal-to-noise ratio of

$$S/N = \frac{P_T G_T A_m A_R}{(4\pi R^2)^2 NF\ KTB}.$$

Substituting values, we have

$$\frac{(4000 \text{ watts})(200)(\pi[1000 \times 5280]^2 \text{ sq. feet}) \times (1600 \text{ sq. feet})}{([4\pi(250{,}000 \times 5280)^2]^2 \text{feet}^4)(6.3)(4.1 \times 10^{-21} \text{ watt-seconds})50 \frac{1}{\text{sec}}}$$

$$= \frac{4 \times 10^3 \times (2) \times 10^2 \pi (1 \times 5.28)^2 10^{12} \times 1.6 \times 10^3}{(4\pi)^2 (2.5)^4 (5.28)^2 \times 10^{32} \times 6.3 \times 4.1 \times 10^{-21} \times 5.0 \times 10}$$

$$= \frac{(2)(1.6)10^{20}}{(4\pi)(3.9)(2.8)(6.3)(4.1)(5)10^{14}}$$

$$= 180$$

$$= 22.6 \text{ db.}$$

These calculations are for the free space condition. With perfect ground conductivity the field strength will be doubled for each direction, in the maximum of the lobe, giving an additional 12 db.

The observed value in the Belmar tests was 10 to 20 db. The discrepancy probably is caused by absorption on the moon and in the ionosphere, and variation in ground reflection conditions.

It was mentioned in the text that transmitter beamwidths of less than ½ degree would be useful even though all of the moon would not be illuminated. This is true because all of the reflected energy comes from the first Fresnel zone, the effects of other zones being largely canceled by their adjacent zones. The effective echoing area would thus remain constant as long as a large number of zones were illuminated. The diameter of the first Fresnel zone on the moon, at 100 mc, is approximately one mile.

RAILROAD RADIO DEVELOPMENTS

Slowtone Warning Unit designed to supplement railroad signal systems; first permanent vhf system installed at New Castle, Pennsylvania

By WILLIS G. JONES
Technical Publications

RECENT ACTIVITY IN railroad radio at Bendix includes the development of the Slowtone Warning Unit and more conclusive tests and experiments with tunnel transmissions.

When successful two-way radio communication over the very high frequencies showed definite savings of both time and labor for the railroads, the Communications and Navigation Engineering Department turned to the problem of providing adequate warning signals from a train in distress. To supplement present signaling methods from the train which stops unexpectedly on a right-of-way, for instance, the Slowtone Warning Unit in conjunction with the Bendix vhf railroad radio system provides automatic signals by electronic means. J. L. Parlas and H. K. Bradford, engineers in the Communications and Navigation Engineering Department, designed this new warning unit.

Automatic Alert

Combining electronic and mechanical principles, the Slowtone (figure 1) automatically transmits warning signals over the radio system to any vhf radio-equipped train or fixed station within a radius of approximately five miles. Receipt of a Slowtone signal is an automatic alert for crew members of all mobile and fixed stations within the range of the equipment.

A feature of the Slowtone Warning Unit is its operating simplicity and ease of maintenance. A minimum of moving parts is used and these are designed for long periods of trouble-free operation.

In the event of an unscheduled stop caused, for example, by a hotbox, a crew member has merely to turn the red knob on the panel to put the warning signal on the air. Even if the Type MRT-1 Communications Unit is not turned on, rotation of the red knob will turn on the entire system and start transmission of the warnings in a few seconds. Once the switch is thrown, the crew member can perform his other duties without further attention to the radio equipment.

The emitted warning signal consists of a series of five consecutive tone pulses of about .12 second duration each. The five tones cover a total interval of about 1.5 seconds. The signals are fed through suitable cables to the microphone input transformer of the transmitter modulator and thence out into the ether. As soon as the five single tones are transmitted, the communications unit automatically returns to the receive position for a period of about 3.5 seconds. During this interval, incoming signals can be heard on the receiver in the normal manner. The transmitter may also be used for voice transmissions while the Slowtone is operating by holding down the microphone press-to-talk button. During voice transmissions, the warning signals are still audible in the background.

When a Slowtone warning signal is received by another train, it may slow down, or stop, depending upon operating procedures prescribed by railroad operating rules. The Type MRT-1 Communications Unit can then be used to transmit and receive necessary orders. Since radio-equipped control towers within the range of the mobile transmitter will also receive the warning signals, it is possible that techniques will be developed for centralized control from the towers in emergencies.

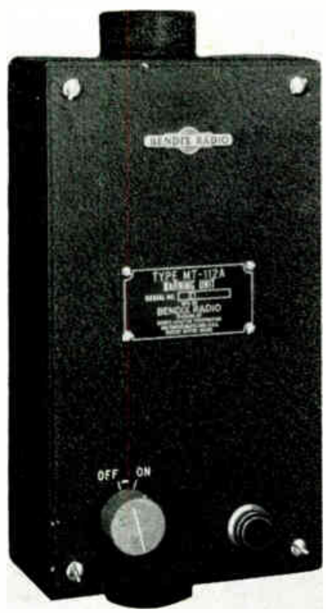


Figure 1—Slowtone Warning Unit used in conjunction with the railroad radio communications equipment.

Slowtone Circuit

Reference to the diagram (figure 2) will assist in understanding the operation of the unit.

Three switches (S1, S2A, and S2B) are actuated by a pair of specially shaped cams on a common shaft which is connected to a 12-volt constant speed d-c motor through a worm and gear arrangement. The motor also drives a disc-type tone generator. The tone generator is a metal wheel, with small holes at regular intervals around its outer diameter, which rotates in a magnetic field created by the current in a field coil. Interruptions in this steady magnetic field caused by the holes in the rotating wheel produce a continuous 750-cycle audio tone which is coupled to the volume level control by a pick-up coil. When switch S2A is closed, the signal is fed into the transmitter modulator input.

Switches S2A and S2B are ganged together and operate simultaneously. S2A is actuated by the five teeth occupying an 80° arc on the rim of the cam. Each one of the teeth closes S2A momentarily and allows the tone to be fed to the modulator for an interval lasting .12 second. At the same time, since S2B is mechanically connected to S2A, it closes the pilot light circuit for the same interval and produces a flash for each tone pulse. This provides visual indications that the unit is operating. The rotor of S1 is exactly aligned with that of S2A so that its single actuating segment closes the switch while the five teeth are pulsing the warning tone. Switch S1 operates the press-to-talk relay on the communications unit which places the equipment in the transmit position for the 1.5 second period required by the five teeth to complete their cycle. For the remainder of the 360° rotation, S1 is open and the equipment is in the "receive" position for approximately 3.5 seconds.

Thus, a total of about five seconds is required to complete one revolution of the rotors. One and a half seconds of this period is used to emit the five tone pulses while the transmitter is on the air. During the remaining 3.5 seconds, the equipment is in the receive position where it remains until one revolution is completed.

Although Slowtone was announced only recently, it has already aroused considerable interest in the railroad industry.

Progress in vhf Operations

The first permanent railroad yard installation of Bendix vhf space radio has been set up in the Baltimore and Ohio hump yard switching system at New Castle, Pa. It employs the Bendix MRT-1A train communications unit operating on a frequency of 159.27 mc.

Supplementing the color-light and hand signals which were frequently obscured by

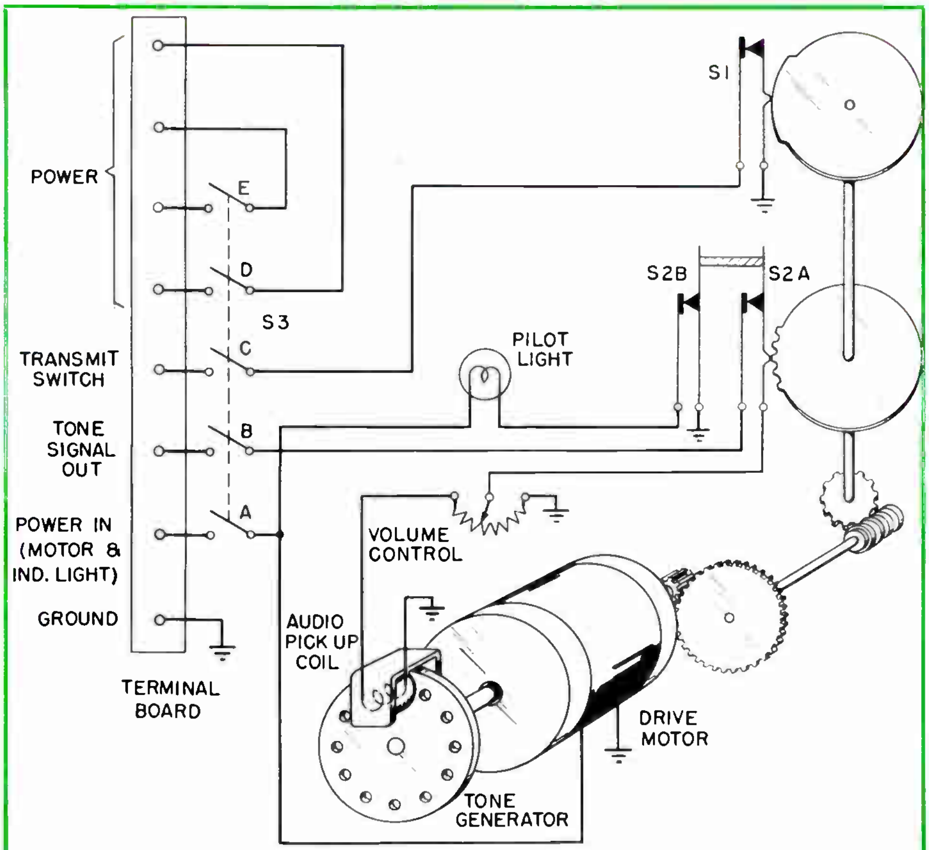


Figure 2—Diagram showing operation of Slowtone Warning Unit.

the fog, use of space radio has made all-weather operation possible. It also speeds up the movement of the cars because the dispatchers are able to give the engineers more specific instructions verbally than by use of signals alone.

Test runs on the main line of the Great Northern Railway and on the Mesabi Division, have been concluded by L. B. Gilmer, Bendix sales engineer, in cooperation with R. C. Thayer, Great Northern Superintendent of Telegraph, and Allen Fox, Assistant Superintendent. The transfer operations in the vicinity of the iron mines offered special problems due to heavy underbrush and irregular terrain, but the experiments were said by P. B. Tanner, Bendix manager of railroad radio sales, to have proved conclusively that a vhf circuit can be designed to operate successfully in this area with resultant operating economies. End-to-end transmission was successful on trains of great length, at times numbering 180 cars hauled by a single engine.

Initial road tests, using Bendix MRT-1B FM unit for wayside to train communication, were made on the B & O between Washington and Baltimore. Leo Sands, sales engineer in charge, states that two-way communication of excellent quality was obtained from the Washington fixed station to the moving train up to a distance of 30 miles, and between the Relay, Maryland, fixed station approximately 4½ miles to the train standing under the sheds at Camden Station,

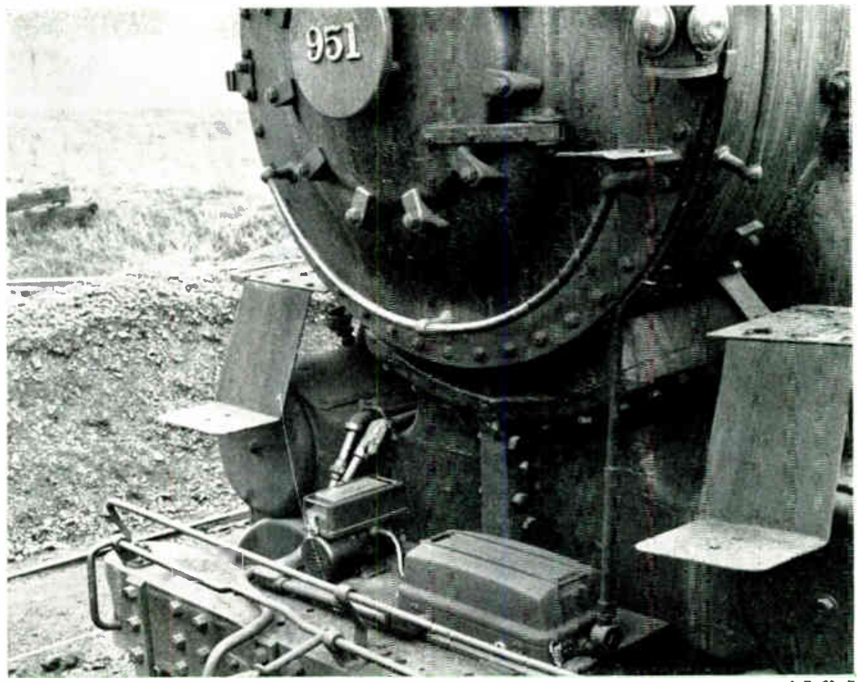
Figure 3—Portion of B & O west-bound classification yard at New Castle, Pennsylvania, where first permanent installation of Bendix railroad radio is in operation.

Courtesy of B & O

Baltimore. No flutter was noted except at the extreme edges of the range. Fixed stations at Relay and Laurel, Maryland, and at Washington, at first locally operated but later controlled via telephone lines from Camden Station, used the Bendix MS-110A biconical antenna. V. A. Meinhardt of Bendix and Norman Morrison of the B & O assisted in the tests.

The MRT-1B FM unit introduces circuit changes which yield somewhat improved performances in receiver selectivity and audio fidelity over AM equipment previously described,* according to R. B. Edwards, principal engineer. It can be converted to AM, if desired, with a few minor changes. A wrap-around support has been added to the flat chassis of the AM model so that the FM unit, housed in the new shockmounted sheet metal case, can be installed in any location or in any position to conform with the space available. It also will fit into the original cast metal case which mounts only in an upright position. A standard FM pack set is now being designed by A. S. Bainbridge to be used in conjunction with the MRT-1B.

Several modifications of the present AM pack set, on which Bainbridge is also engineer, are in development. These include change in the mounting of earphone and the microphone; substitution of a push-to-talk button for the present toggle switch to place the set in operation; and modification of the vibrator power supply, using a 6-volt chargeable battery.



Courtesy of B & O

Figure 5—MRT-1A communications unit and power supply installed on front of engine at New Castle.

Tests in Tunnel

Investigations on the problem of transmitting a signal inside a tunnel, conducted by John Shanklin at the Baltimore Filtration Plant, have confirmed previous evidence that a signal transmitted at 156 mc cannot be passed through a tunnel without a system of transmission lines although satisfactory transmission can be obtained at 3000 mc. With the use of transmission lines in the 300-foot tunnel in which the experiments were made, there was no measurable drop in signal strength at 156 mc.

Directive antennas, located at each end of the tunnel, pick up the signal and feed it into a transmission line. From the transmission line it is radiated all through the tunnel and picked up by standard train equipment. The efficiency of this system depends on the development of an antenna with a very large front-to-back signal ratio. In order to test it in actual operation, plans are under way for installation in the ½-mile B & O tunnel at Mount Airy, Maryland. On the basis of the 300-foot tunnel experiments, it is expected to operate successfully when the entire train is inside the tunnel, when either end extends beyond the limits of the tunnel with the opposite end inside, or when both ends are outside of the main portion of the train in the tunnel.

Shanklin is also conducting experiments on a one-channel relay station which will, in effect, resemble a telephone "party line." Its advantage over a two-channel relay, construction of which offers no major engineering difficulties, lies in the simpler equipment made possible by elimination of both the dual frequency and the double channel required for remote control.

* BENDIX RADIO ENGINEER, October, 1945, p. 33.


Courtesy of B & O

Figure 4—MS-101A ground plane antenna atop signal pole at one of the B & O fixed stations.

Books Received

AERIAL NAVIGATION, by H. E. Benham. John Wiley & Sons, Inc. Price $4.00. Fundamental theory including radio and celestial navigation.

ELECTRONICS DICTIONARY, by Nelson M. Cooke and John Markus. McGraw-Hill Book Company, Inc. Price $4.00. Over 6,000 terms used in the electronic industry with numerous illustrations.

PRINCIPLES OF RADIO FOR OPERATORS, by Ralph Atherton. The Macmillan Company. Price $3.75. A text for radio operators with suggested experiments and review questions.

THE ELECTRONIC ENGINEERING MASTER INDEX, edited by Frank A. Petraglia. Electronics Research Publishing Company. Price $17.50. A compilation of articles from leading technical periodicals indexed by subject and date.

INSIDE THE VACUUM TUBE, by John F. Rider. John F. Rider Publisher, Inc. Price $4.50. An excellent text on vacuum tube theory with novel illustrations.

AN INTRODUCTION TO ELECTRONICS, by Ralph G. Hudson. The Macmillan Company. Price $3.00. Fundamental electronics and some applications.

PRACTICAL MARINE ELECTRICITY, by Samuel N. LeCount and H. S. Dusenbery. The Macmillan Company. Price $3.50. Clear explanations of electrical installations for ship and shipyard, including communications systems.

Cross Sections

Most Airlines Use Bendix Installations

Installation of Bendix Radio equipment in military planes adapted for commercial use is keeping pace with the aircraft conversion program, according to R. L. Daniel, Manager of Airline Radio Sales. Working in cooperation with the manufacturers, especially with Glenn L. Martin, Douglas Aircraft and Republic Aviation, where a major portion of the conversion jobs are being done, Bendix engineers have been consulted by communications experts of literally 100 per cent of the nation's major airlines and personally supervise the installation of communication and navigation facilities on the luxury planes.

A radio system of Bendix design has been adopted for the four-engine Douglas C-54 transports converted to passenger DC-4's for Delta, American, Pennsylvania Central, Eastern, Chicago & Southern, Braniff, National, and American Overseas Airlines, and for the brand new DC-4's just coming off the line at Santa Monica, on order for Northwest, National, Western, and airlines in South Africa, France, Sweden, Belgium, Australia and Holland. Each craft carries most of the standard Bendix equipment.

The MN-31 Dual Automatic Compass, MN-53A Marker Beacon Receiver, RTA-1 Communication Equipment, and MI-32 Interphone, together with two sets each of AN/ARC-1 vhf Communication Unit, RC-103 Localizer and ARN-5 Glide Path Receiver supplied from other sources, are all tied in with the pedestal control panel, MS-114 or MS-115, especially designed by E. F. Wilbur, for pilot and co-pilot operation. Bendix Radio Jack Box MS-92D, one of three available models, is used for headphones, microphone and range-filter selection.

H. B. Yarbrough, Sales Engineer, designed the radio operator console control panels for the American Overseas Airlines fleet of DC-4's. This installation includes the RA-1B Receiver, the MN-62A Radio Compass Receiver, commercial equivalent of the AN/ARN-7, and an extra MN-26K used as a manual direction finder. Dual control for all communication and navigation facilities is provided for overseas use.

Pan American World Airways' DC-4's and the Constellations, peacetime version of Lockheed C-69 transport planes, carry two MN-62A Compass Receivers, an MN-60 Iron Core Loop, and an MN-53 Marker Receiver, along with miscellaneous equipment of their own and other manufacture.

On the United Airlines fleet of DC-6's, installations are similar to those in DC-4's except for the use of the MN-61A Marker Beacon Receiver, a variation of the MN-53, which introduces the longer case and rear plug connection.

TWA 300-mile-an-hour Constellations, in service in cross-country and Washington-Paris flights, are equipped with two MN-62A's, an RTA-1B and two MN-53A's, plus other units, all controlled from a cockpit panel designed by engineers of the West Coast Branch.

Installation of Bendix equipment in the forthcoming Martin 202 will be made along similar lines in accordance with the purchasers' specifications.

Webb and Gordon Give IRE Papers

As a feature of the Radio Navigation Aids program, at the IRE Winter Technical Meeting in New York, W. L. Webb, Bendix Radio Director of Engineering and Research, read a paper prepared in collaboration with A. C. Omberg, Chief of Research and Development, describing the Bendix-designed Aircraft Automatic Ground Position Plotter.

James F. Gordon, of the Research and Development staff, appeared on the New Circuits Development program at the same meeting. Gordon described the new system of angular velocity modulation which he has developed.

W. L. Webb served on the Sections Committee for the meeting, and D. W. Martin on the Committee on Railway and Vehicular Communications.

Other Bendix executives and engineers attending the sessions included W. P. Hilliard, A. E. Abel, Harold Goldberg, F. R. Norton, L. C. Truesdell, H. K. Morgan, R. T. Killman, R. J. Davis, Howard Walker, R. B. Edwards, W. H. Sims, W. O. Bradford, R. F. Smeltzer, Edwin Cornet, R. G. Franey, W. R. Strauss, R. J. Pfeiffer, G. R. White, J. S. O'Gorman.

At the February meeting of the District of Columbia Section of the IRE, A. C. Omberg read a paper prepared jointly with Kenneth A. Norton of the Signal Corps, on the Maximum Range of Radar.

Unique Dial Design For Broadcast Set

Included among the Bendix broadcast receivers now in process of production, are several 5-tube plastic-cabinet models, a 5-tube model in a wood cabinet, a 6-tube, 1-band a-c, d-c model in a wood cabinet, a 6-tube table radio-phonograph combination, and a 6-tube drop-leaf end table model introducing the Phantom Dial.

The two-drawer mahogany end table set is an attractive piece of living room furniture without any external evidence of its adaptation to radio, until what appears to be a drawer knob is turned to illuminate a concealed dial. This innovation in dial design uses Sans-Arb plastic veneer, cemented to a ¼-inch panel of plate glass, as the front panel of the upper table drawer. The Sans-Arb, which is in reality two films of hard rolled lacquer, has a mahogany-grain design printed on the face to match the wood of the table. The reverse side of the film is opaqued except for the narrow semi-transparent portion where the dial figures are printed. Adhesion of the film to the glass is accomplished by spraying the printed opaque surface with a soft coat of lacquer which becomes tacky when immersed in the cement solution. The film can then be applied smoothly and firmly. When the switch knob is turned, lighting the lamp inside the panel, only the semi-transparent dial is illuminated, showing the dial figures. The station pointer, which casts a shadow-line on the dial, is operated in the usual way by a tuning control knob located on the right of the lower drawer.

All chassis now in production, with the exception of the 5-tube models, include a tuned r-f stage of amplification.

Edwin Cornet, coil engineer of long experience, has recently been placed in charge of all r-f coil and r-f transformer design for broadcast receivers. Cornet was for nine years head of the coil laboratory at the Philco Corporation, and previously was engineer for test equipment design at Baer Television Corporation, Boston, and Pilot Radio Corporation at Lawrence, Mass., and in charge of receiver design at Automatic Radio Corporation of Boston. He recently completed special studies in television at Temple University.

To take care of expanding operations of Broadcast Receiver Engineering, plans for an extension of the front building at Towson to provide facilities for television receiver design have been drawn and building operations will be started soon.

Weight Reduced In New ADF

An automatic radio compass for aircraft use which introduces a number of new features is under development in the Communication and Navigation Laboratory, with Malcolm Taylor as principal engineer.

Smaller and lighter than any of the present compasses, the entire equipment including the loop is expected to weigh less than 35 pounds. The use of a very small iron core loop antenna contained in a streamlined housing of proportionately small size will result in reduced air drag.

To get efficient pickup from the small loop, the loop will be directly tuned instead of being coupled through a transmission line to the primary winding of a remote tuned circuit. A. A. Hemphill is engineering this feature. The entire receiver r-f assembly will be mounted inside the skin of the plane adjacent to the base of the loop. The i-f amplifier, audio, loop control and power supply circuits will be built into a separate case. This arrangement is a departure from previous design in which the entire equipment is built in a single case. There will be control boxes for both navigator and pilot, as in present compasses.

J. T. McNancy is engineering another innovation, an electrical remote tuning system between the control box and the tuning unit to replace the tach shaft.

The equipment is being designed for operation either on 28v d-c only, using a 400-cycle vibrator, or on 28v d-c and 400 cycle a-c so that the vibrator can be dispensed with in planes having 400-cycle power. Only a slight modification will be required to make the shift from one type of operation to the other.

The loop and drive mechanism and the indicators for this project are being designed by Kearfott Engineering Company. All components liable to be affected by humidity, including loop, r-f circuits and indicators, are hermetically sealed.

New Appointments For Bendix Men

W. L. Webb, Bendix Radio Director of Engineering and Research, has been appointed a director of IRE for the year 1946.

Webb has also been named on Technical Committee 5 of RTCA, with Howard K. Morgan as alternate. This committee, after studying miscellaneous technical questions such as precipitation static, aircraft antennas, aircraft electrical systems, airport lighting, instrumentation, and automatic flight control, makes appropriate recommendations to government agencies, commercial organizations or users of aeronautical radio facilities.

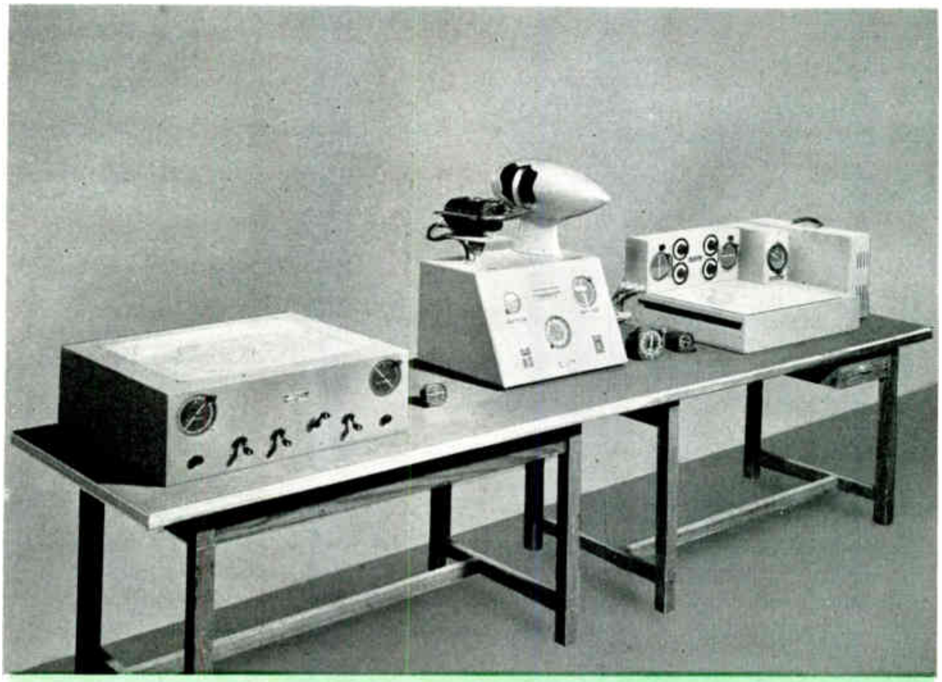
Awarded Contract For Transformers

Ability of the transformer engineers to meet exacting specifications drawn up by the Hazeltine Corporation for the transformers used in a Navy radar equipment has resulted in award of the contract to Bendix for the units going into the 160 sets now in process of manufacture.

As described by H. J. Oosterling, Bendix Radio principal engineer on transformer development, design specifications, especially those covering an intricate type of overlapping rim and special bushings with space limitation requirements, presented particularly knotty production problems.

Safeguards in excess of ordinary hermetic sealing have been specified to insure against failure due to the breathing action of the tin in order to eliminate even the remote possibility of the lid ripping loose from the can when subjected to vibration, or when exposed to contraction and expansion under varying temperature conditions. A number of units have been completed which satisfactorily meet all mechanical tests and are now undergoing routine electrical tests.

All sheet metal parts required are being made in the Model Shop under the direction of G. A. Exley, section chief.



The two Automatic Ground Position Plotters described by W. L. Webb and A. C. Omberg at the IRE meeting in New York and demonstrated in the Research and Development Laboratory for Bendix Radio department heads. Left: two light beams intersect to show aircraft's position on map placed over glass top of polar coordinate plotter. Center: combined flux gate and automatic radio compass indicator which gives true bearing of aircraft. Right: single spot of light indicates plane's position on map placed atop rectangular coordinate plotter.

RR Yard Paging System Devised

A YARD TALK-BACK and paging system for voice communication is being developed by S. R. Fund primarily for use in the switch yards of domestic railroads, though various other applications are foreseen. It is purely an audio system, and has a 300 to 3000 cycle range.

Control functions, together with a speaker-microphone and built-in map of the area covered, are conveniently located on a console desk for the operator at the central station, which is connected by underground wire to loudspeakers up to 2000 feet away. The control panel provides 80 talk-back positions, numbered to conform with the designations of the corresponding yard installations. In the present equipment only 35 of the available positions are used.

A 48-volt power supply for relay operation, and 10-watt and 100-watt amplifiers are located in a separate cabinet.

University IB-8 Speakers for yard use are mounted on stanchions about 8 feet high with a single push switch for initiating the call. When the yardman presses the switch button, a light shows on the operator's control panel identifying the station from which the call is made. The operator throws the corresponding toggle switch on the control panel to complete the connection. Meanwhile the light on the panel goes out. As long as the toggle switch remains in an upward position the operator can maintain two-way conversation with the yardman, simultaneously receiving calls from other yard stations which are handled in the same way. From the time the operator first answers the call, operation is "step-to-talk," with foot control of the circuit. A pedal is depressed while the speaker is being used as a microphone, and is released when it is used as a loudspeaker.

A built-in map of the switching facilities and the loudspeaker installations in the yard is spread out on the flat surface of the console in full view of the operator. The location of each yard installation is marked by a small light which glows when that station calls in.

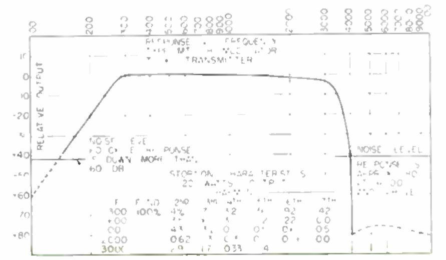
Ten watts of audio power are supplied in the talk-back circuit. The yardman can move around the yard within a radius of approximately 100 feet of the loudspeaker and still engage in conversation with the operator as long as his voice is stronger than prevailing background noises.

A 100-watt amplifier, in conjunction with a number of 25-watt speakers, is provided for paging large areas for the purpose of making general announcements. A separate 20-switch section on the console desk enables the operator to select the area he desires to page, using the same microphone as in the preceding operation. This is exclusively a one-way service, with no talk-back facilities.

An impressive demonstration of the system was made earlier in the year, using an installation adjacent to the Towson plant, for a group of officials and visitors including C. T. Zaoral, General Manager of Bendix International, C. A. Adams, Assistant General Manager, and Carlos Cuddell Goetz and A. de Souza Santos, representatives of the Portuguese Government, who are making investigations of railroad radio for installation at Lourenco Larques, Mozambique, Portuguese East Africa.

TG-16 Transmitter Performance Data

PERFORMANCE DATA MEASUREMENTS for the low power Transmitter TG-16,* on which C. S. Chambre is engineer, have been made available by W. H. Sims, principal engineer. The measured power output in the low and high frequency units, covering a frequency range of 200 to 400 kc and 2.5 to 13 mc, respectively, are in excess of 160 watts for radiotelephone operation and more than 190 watts for radiotelegraph. The power output of the vhf unit which operates between 118 and 132 mc on radiotelephone only, is 125 to 145 watts.



Audio frequency characteristics of Type MT-100B Modulator for the TG-16 Transmitter.

The audio frequency characteristics of the modulator, which is designed for voice transmission, are shown in the accompanying graph. Audio frequencies of 4000 cycles and higher are attenuated approximately 80 db, to prevent interference with nearby transmitters operating on adjacent channels. Distortion components of higher audio frequencies also are attenuated by output filters to prevent adjacent channel interference. When operating at 85 per cent modulation, an increase of 20 db in the input signal does not result in more than 94½ per cent modulation. Besides eliminating high order distortion components, the limiter circuit also prevents generation of high voltages in the modulator output. The characteristics of the limiter are such that with the load on the modulator removed entirely and with full input, the output voltage does not exceed that normally obtained at 100 per cent modulation. Full output may be obtained from an input signal approximately 33 db below 6 mw at 600 ohms.

*Described in the April, 1945, BENDIX RADIO ENGINEER, p. 27.

Equipment Layout Changes Made

CHANGES IN THE physical layout of aircraft radio equipment, to improve performance or to conform with new requirements, have recently been undertaken in the Communication and Navigation Section.

Improved shockmounting has been provided to meet all CAA specifications with the MS-92A Jack Box. This equipment serves to isolate headphones in order to eliminate interference when crew members tune in on different receivers. L. H. Holzer is in charge of the project.

Another project under Holzer is a variation of Marker Receiver MN-53A, designated the MN-61A. It is used in aircraft installations requiring rear connections, and introduces a plug built in to the case and a receptacle built into the shockmount.

Automatic Radio Compass MN-62A, commercial equivalent of AN/ARN-7, uses Cannon type plugs and improved shockmount with a brace added in the rear of the chassis to give better performance under vibration. In the new version, as pointed out by A. A. Hemphill, engineer in charge, a 30-foot (maximum) loop cable and a 30-foot (maximum) antenna cable can be used.

Production follow-up on these design changes is under the direction of Howard Walker, Assistant to the Chief Engineer.

Primary Standards Room Constructed

PRIMARY STANDARDS EQUIPMENT in the future will be housed in a specially constructed 12 x 14 foot dustproof room with double walls of solid copper sheet, and double screened window. In order to prevent factory vibrations from being communicated to the calibration area the entire room rests on rubber shock absorbers mounted on a floating slab of concrete. Room temperature is controlled at 25° C by specially designed refrigerating equipment, and the relative humidity never exceeds 40 per cent.

Other recent additions to the Measurements and Standards Laboratory equipment, according to G. R. White, section chief, include voltmeters, and two inductance bridges built by the laboratory personnel.

The Munsell Color Standard has been adopted for use throughout the plant on all engineering specifications requiring the use of color. This system of color charts, presenting standardized scales of the three dimensions of color, is the basis for a code whereby each variation of color is identified by a notation designating the exact hue, value and chroma desired.

Foreign Students Completing Course

ANOTHER GROUP OF university students from other countries is completing the Bendix Radio practical training course. Several of the students will now return to their native countries while others continue on in the shops of various aircraft manufacturers to round out their education in North American electrical engineering techniques and production methods.

The students from Latin America, here by arrangement with the International Training Administration, and others who have come directly through the Chinese government, have been steered through the successive stages of radio manufacture, tests, inspection and maintenance by O. L. Peterson, Personnel Co-ordinator.

Alfonso Calatayud-Vera, a graduate of the National Ayacucho of La Paz, Bolivia, was in the employ of the Bolivian national airline, Lloyd Aereo Boliviano, and will return to that company as radio engineer. His training in the United States has been sponsored by the CAA.

Leonel Correa-Lago completed engineering studies at Gosch Institute, Porto Alegre, Brazil. As an officer in the Brazilian Air Force he was patrol flier for six months in the Italian war theater, returning to Brazil to become army instructor in aircraft navigation. Under the sponsorship of CAA he has spent some time with TWA studying airport traffic control, and upon completion of his training program will return to the Brazilian Army.

Emiliano Ruiz-Diaz, an accredited college instructor and outstanding electrical engineer of Paraguay, graduated from the National University of Asuncion. He had a period of training with the United Air Lines before arriving at Bendix Radio and plans further airport control studies with other airlines before establishing his own servicing business in Paraguay.

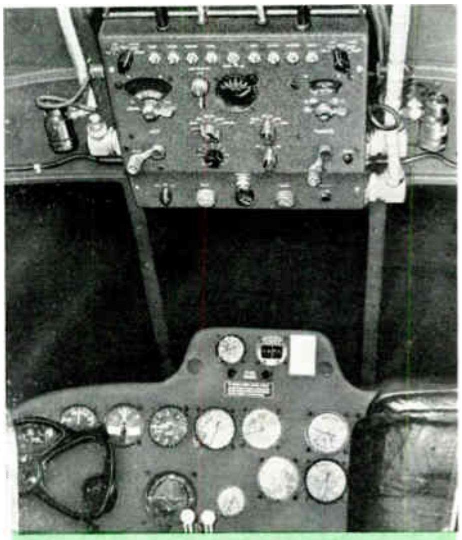
Roberto Rico received his E. E. degree at Superior College of Electrical Engineering in Mexico City. After approximately a year of study in this country he will return to his native city as a consulting engineer and plans to organize an electrical contracting business with facilities for manufacturing radio parts which are at present difficult to obtain in Mexico.

Guillermo Rodriguez-Rubiano completed the engineering course at National Colegio Botero, with further specialized studies in electronics. He spent six months with United Air Lines, based in Chicago, and assisted in setting up several radio beacon stations in the west. On his return to Colombia, he will be radio operator for his previous emp ers, the Colombian Petroleum Company.

Hwa Chen and Lin-shu Chu are in this country under the direct sponsorship of the Chinese government. Chen is a graduate electrical engineer from Hangkow University and Chu a graduate of Chungking. Both have had considerable previous radio operating, servicing and maintenance experience as officers in the Chinese Army and on their return to China will be government radio engineers.

Control Panel for Executive Planes

A RADIO CONTROL PANEL has been designed by J. D. Scalbom, Sales Engineer, for use in the Beechcraft 18S and other executive type airplanes, or for commercial operations in which night-instrument flying is required. A number of installations already have been made.



MS-117 Panel mounted in a Twin Beech cockpit.

A single master control panel, which is a completely self-contained unit, mounts in the roof of the cockpit with the front edge directly behind the windshield. This control panel which is a 13 x 14 inch wedge-shaped box, has a 3½-inch maximum depth, and weighs approximately 12 pounds including base and plugs. It contains all tuning controls, audio selection and filter switches, and headphone and microphone jacks. Red knobs and cranks are used for adf controls, and green knobs for the range receiver.

At present the panel is set up to control the MN-31 Automatic Direction Finder (or its military versions, SCR-269G and R-5/ARN-7), an RA-10 Communication Receiver, an MN-53A Marker Receiver and an RTA-1B Communication Equipment. It is however, very flexible in application, so that with a few slight changes in components and wiring, other units, such as TA-17, can be substituted as they become available, and vhf controls can be introduced.

Stuart Branch was assistant engineer on the project.

C. C. Bath Gets Service Citation

C. C. BATH, ASSISTANT project engineer on microwave communications, in the Research and Development Section, has recently been awarded the War Department's Medal of Freedom for distinguished overseas service. Notification came from the Adjutant General at the direction of the President. The citation follows:

"Carl C. Bath, American Civilian, for exceptionally meritorious achievement which aided the United States in the prosecution of the war against the enemy in Continental Europe as Technical Observer, Technical Liaison Division, Office of the Chief Signal Officer, from 18 August 1944 to 16 April 1945. Disregarding his own personal comfort, he traveled thousands of miles in performing outstanding service in the work of maintaining vital radar equipment for operational forces. By his technical skill, resourcefulness and extreme devotion to duty, he aided materially in prosecuting the war against the enemy."

Tests on Color Finishes Completed

AS A MEANS OF determining the most efficient finish for transformer and reactor cans and for the inside and outside surfaces of radio equipment cases, an investigation of the heat absorption and heat radiation quality of different colors has been undertaken in the Communication and Navigation Laboratory.

The radiation and absorption efficiency of the surface finish is judged by its ability to radiate the heat from the coils penetrating to the outer surface of the transformer can, without at the same time absorbing the heat from adjacent power tubes. Special equipment was set up by M. W. Mericle for tests on a number of specially treated transformer cans.

These tests recently have been completed, and cans treated with the paints found to be most efficient are now undergoing final test in the transformer laboratory.

Engineering Plane Due Next Month

THE ENGINEERING DEPARTMENT'S new five-passenger Beechcraft Model 18S airplane, scheduled for delivery in May, will be equipped with a Pioneer automatic pilot and standard Bendix Radio installations.

Powered by a Pratt & Whitney engine, it will have a cruising speed of 206 mph at 10,000 feet. The craft, based at the Municipal Airport, will be used for ferrying and experimental purposes. Ruel Colvin, Chief of Flight Research, will be pilot.

Flightweight Units Now in Production

THE LOW FREQUENCY PAR-70 Range and Broadcast Receiver, a Flightweight product for the Bendix small personal planes, is now in production, and George Myrick, Manager of Personal Aviation Radio Sales, states that shipments already have been made to dealers throughout the country.

This unit, on which Harry Odneal and W. G. Yates are project engineers, provides radio range reception on 200 to 400 kc, and broadcast station entertainment and navigation facilities on 550 to 1500 kc, using either loudspeaker or headphone. Provision is made for aural null direction finding in conjunction with a PMN-1 rotatable loop. Design of the receiver, which employs seven miniature tubes and has a push-pull output stage, includes a built-in range filter and noise limiter. It weighs approximately 5 pounds, including the self-contained vibrator power supply and integral shockmounts, and is available in different color combinations to harmonize with the aircraft decoration.

Flightweight Transmitter PAT-40, operating on 3105 kc, has been released for limited production only, pending conversion of CAA towers and ground stations to the recently allotted vhf frequencies for non-scheduled flying. This unit weighs approximately 6 pounds, employs three 6V6 tubes and has a carrier output of 5 watts. It has a built-in loading coil for fixed antenna operation.

Ray La Force, of the Production Department, supervised the building of 20 models of these two equipments in the Engineering Laboratory, a departure from usual procedure adopted in order to familiarize production personnel with the equipment before it is turned over to the Production Department.

Other Flightweight units are under development and, according to Vernon Moore, principal engineer, will be available in the near future. The vhf Transmitter, PAT-50, will largely replace the low frequency Transmitter PAT-40 as soon as conversion of control towers and range stations to vhf has been completed. This unit on which P. V. de la Cova and Lee Reed are engineers, provides operation on five crystal-controlled frequencies. At present the 131.9 and 131.7 mc channels have been assigned for control tower and range station use. Three additional channels may be utilized when assigned by the FCC merely by plugging in extra crystals.

The transmitter has an r-f output of ½ watt, which feeds into a 26-inch vertical antenna of much simpler design than either the fixed or trailing antenna of the low-frequency model. In tests conducted by Ruel Colvin, Chief of the Flight Research Section, transmission over distances as great as 100 miles was found possible with this low power. Perfectly reliable communication is obtained at 60 miles. On a recent return flight from Boston, in the Sales Department's Stinson Voyager, W. L. Webb and A. C. Omberg were in communication with the Towson Plant from Wilmington, Delaware, and were enthusiastic in their reports of the Flightweight radio performance.

New Bendix Ercoupe.

Engineering is going forward on the vhf and medium frequency Flightphone PATR-10, which will be a combination range and broadcast receiver and vhf transmitter. It will be 7 x 7 x 5 inches, weighing 7 pounds. Development is in charge of Harry Odneal and Leif Frandsen.

Another project on the same program is TA-17, a 50-watt, 4-channel, high frequency transmitter to cover airline communication frequencies, which is being developed by Henry Bradford. This equipment is expected to supply the transmitter needs for medium aircraft in the executive and feeder line classes.

As a further aid in the experimental operations and also for demonstration purposes, a 75 hp Ercoupe has recently been acquired by the Flightweight sales group.

Morgan Studying Bendix Products

HOWARD K. MORGAN, newly appointed member of the engineering staff, has been assigned to the office of the Director of Engineering and Research to make a complete study of present Bendix Radio products and to formulate an over-all development program for future equipment, including broadcast receivers.

Mr. Morgan has exceptional qualifications for the task. A Bachelor of Science in E. E. from the University of California, he acquired extensive experience at General Electric, Radio Corporation of America and Pilot Radio.

For the past thirteen years he has been associated with Transcontinental & Western Airways, Inc., starting out as aircraft receiver engineer. In 1939 he was promoted to Superintendent of Communications and in 1944 was made Director of Engineering. Interest in acoustics as related to radio receiver development has kept him abreast of technical developments in sound recording and high fidelity reproduction.

Conferees Discuss Aircraft Control

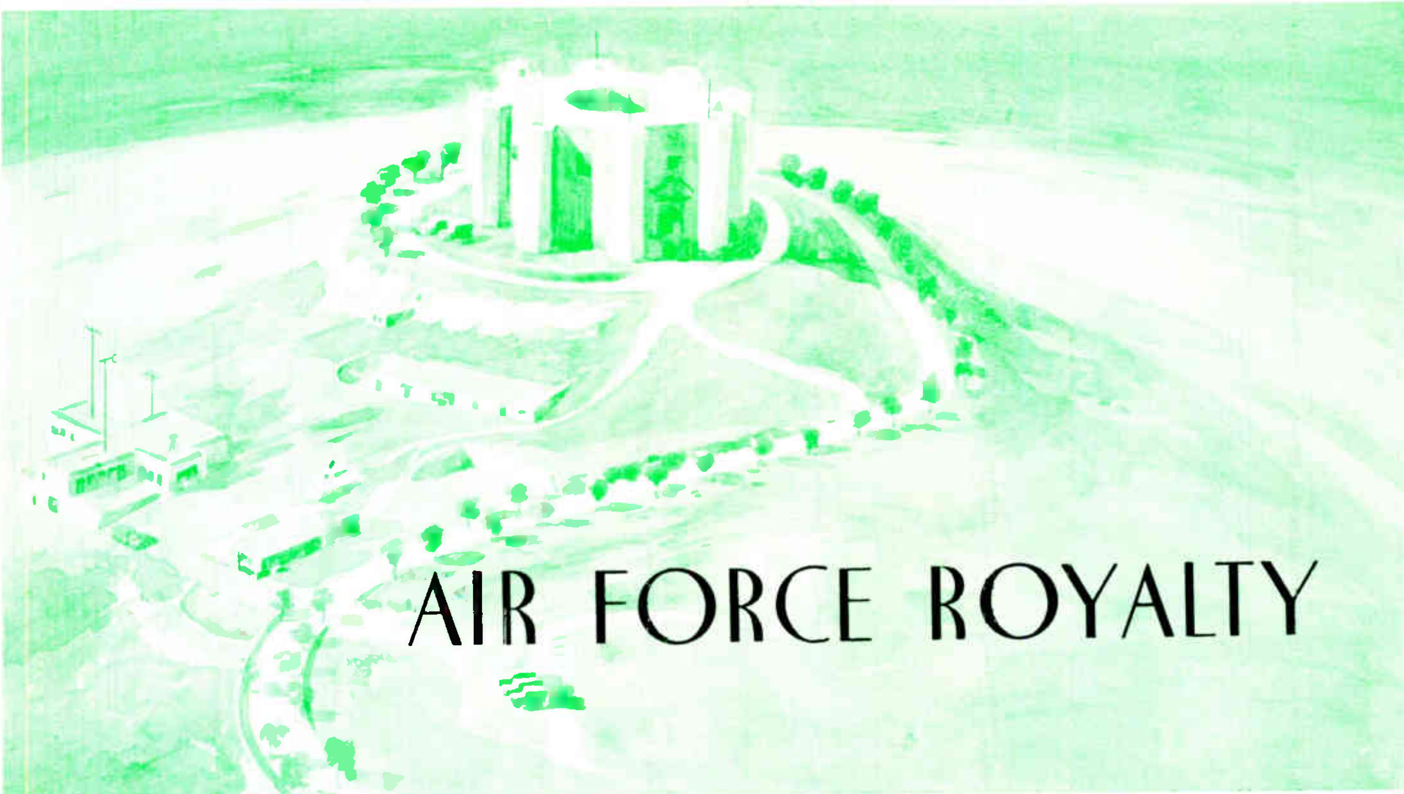
BENDIX RADIO WAS AMONG the industrial corporations invited to participate in a special conference sponsored by the Army Air Forces, Flight Operations Division, during the week of February 4. The meeting was called to discuss all known electronic systems for the navigation and control of aircraft.

Major General Curtis E. LeMay, Deputy Chief of Air Staff for Research and Development, opened the sessions which were held in the auditorium of the Pentagon Building. Col. S. A. Mundell, Technical Assistant in the Electronics Sub-Division of the Engineering Division at Wright Field, was presiding chairman.

Representatives of government, civil and military agencies, and of manufacturers engaged in the development of aircraft navigation and control devices were allotted program time to describe equipment currently under development and to give some indication of their thinking on future trends. Among the ideas introduced were some of a definitely revolutionary character while others forecast a gradual, step-by-step development. Although no spot evaluation of the proposals was attempted, it was hoped that the interchange of information would help all interests concerned to direct their immediate and long-range programs to the best advantage to achieve the development of specific all-weather airline equipment.

Bendix Radio was represented by A. C. Omberg, H. K. Morgan and A. S. Robertson, with Omberg as the company's spokesman. His remarks were based on the thesis that adoption of any new system of air navigation and control will tend, as in the past, to follow an orderly progress with gradual improvements and additions to the present system rather than by the overnight introduction of new and revolutionary methods. An illustrated booklet *Toward Automatic Flight*, specially prepared for the occasion by the Technical Publications staff under the direction of W. T. Spicer, was distributed to the assembly. This folder outlined pertinent functions of existing navigational equipment, and indicated how the principles upon which two or more of these equipments operate might be utilized in the design of a device for automatic navigation and flight.

Included among the delegations in attendance were various branches of the Army and Navy, British Air Commission, Civil Aeronautics Administration, Federal Communications Commission, Aeronautical Board, Radio Technical Commission of Aeronautics, Provisional International Civil Aviation Organization, Aeronautical Radio Incorporated, representatives of the major electronic industries, Air Transport and Airline Pilot Associations.



AIR FORCE ROYALTY

Castel del Monte, ancient fortress on the Adriatic coast, was the control center for the Fifteenth Air Force in Italy.

By J. WALTON COLVIN
Service Department

Very high frequency communications and direction-finding equipment is credited in "Radar, A Report on Science at War," official release of the Joint Board on Scientific Information Policy, with playing as big a part in the air defense of Britain as all radar gear combined. This equipment, which proved its worth in 1940, continued in distinguished service throughout the war.

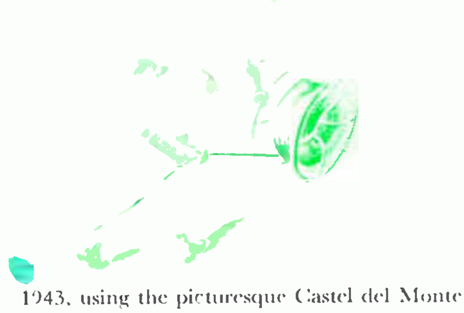
During 18 months of field service in the European, Mediterranean and North African Theaters with the Army Air Forces, I had an opportunity to observe in action both the vhf ground equipment, SCS-2 and SCS-3, familiarly known to Bendix employees as the Queen; and the vhf airborne unit, SCR-522 known as the King George. The SCS-2 and SCS-3 equipments, fixed and mobile communication systems for liaison, direction finding and approach control, are the ground station networks for communication with the 4-channel, crystal controlled airborne liaison transceiver SCR-522.

My job consisted of making the rounds of the different bases to inspect installations, maintenance shop facilities and procedures, to test vhf equipment, to recommend changes that gave greater coverage, and to give lectures and demonstrations on maintenance and tuning procedures to Signal Corps and Air Force classes.

Service By Big Fence

The equipment in battle was efficient and tough. On one occasion a piece of shrapnel penetrated an SCR-522, entering at the bottom and going out the top. It left a hole as big as a half dollar. But the unit still worked.

The vhf radio fixer system of the 15th Air Force, whose call sign was "Big Fence," was set up in Africa in March, 1943. The original control station was located atop a 3600-foot mountain peak in Algeria. This entire complex triangulation system was moved twice during the African campaign without losing a single hour of operation. Big Fence crossed the Mediterranean into Italy on December 10,



1943, using the picturesque Castel del Monte, near Bari, as its center of operations until the conclusion of hostilities. It controlled six D/F units along the Adriatic coast 300 miles north from the Italian heel, and handled an estimated total of 16,000 calls for radio navigational aid.*

The King George equipment was used in many ways by the Air Forces: For air-to-ground and plane-to-plane communications, communication between bombers and fighters, control tower operation, point-to-point communication on the ground to back up telephone lines, radio teletype for ground station installations up to distances of 100 miles, and radiotelephone coverage from different islands to the mainland. One of these radiotelephone installations connected the Isle of Capri with Naples, thus providing telephone facilities between the island where an important rest camp was located, and points throughout Italy. King George sets installed in boats operating out of Naples made it possible for the crews to communicate with the Isle of Capri and with one of the Naples telephone switchboards, using vhf radio over the water and telephone facilities on land. The ground forces installed SCR-522's in some light and medium tanks because these units were found to be more dependable than the FM equipment then available.

Big Fence, like other similar Queen networks, had its special value when a pilot was lost. By taking a fix, operators could direct him to an airfield. It was particularly valuable to fighter planes because they carried only vhf

*All statistics on Big Fence from "Official Communications History of the Fifteenth Air Force."

radio equipment, whereas bombers could often rely on other navigational aids. When a crew, in trouble and forced to ditch or bail out, transmitted the ominous "Mayday" call, Big Fence contacted one of the Air-Sea Rescue

Crews, giving the position from which the plane had last transmitted. This auxiliary service operated amphibious planes, speed boats and regular seaplanes which were equipped with King George units and rescued innumerable crews whose planes were lost in the Mediterranean.

In one off-the-record incident, a control tower operator who for about a year had been hearing another tower 100 miles away, finally succumbed to the temptation to call its operator. While a mission was taking off, he made contact and carried on an interesting conversation. The commanding officer whose job it was to give the offending operator the deserved dressing down, later admitted his reluctance to do his duty, because, being an ex-ham operator himself, he could well understand the irresistible impulse behind the action.

Invasion In The Making

In the Air Forces' communications facilities set up for the invasion of Southern France, the Queen was used far in excess of all other ground communications equipment. Ground installa-

tions which had to be provided were radio beacon stations placed at advantageous points, low and high frequency point-to-point radio stations, emergency vhf homing stations at emergency airfields, and three SCS-3 systems in Corsica tied together in one large system. All vhf installations had to be equipped with crystals to provide special frequencies for the invasion. Air Force personnel had to be trained and briefed on communication procedures and familiarized with regular and emergency navigational facilities. The whole setup had to be coordinated with the facilities of the other Allies.

Every aircraft in this invasion, including many Piper Cubs, was equipped with a King George unit. Weather and photo reconnaissance aircraft had a second unit as a spare tuned to the same frequency. It was routine procedure to check and test every set thoroughly after each mission. It is conservatively estimated that over 75 per cent of all the Air Forces' communications and navigation equipment in this invasion employed vhf, most of which was either manufactured or designed by Bendix Radio.

Long before dawn on the morning of August 15, 1944, the earth trembled with the roar of

thousands of aircraft engines. More than 2000 B-17 and B-24 heavy bombers, over 1000 B-25, B-26, A-20 and A-36 medium bombers and attack planes, over 2000 P-38, P-47 and P-51 fighters, and numerous craft of the other Allies, were heading for a designated point on the mainland between Marseille and Nice. Six thousand planes in all took off with the single purpose of striking at the enemy wherever he should be found in order to clear the way for the invasion fleet carrying veterans of the Tunisian, Sicilian and Italian campaigns who were to make a junction with the Allied Army invading from Normandy.

Medium and heavy bombers in the Mediterranean Theater were equipped with approximately 500 AN/ARN-7's and 5000 SCR-269G's. Incidentally, crew members on longer bombing missions used the radio compass to listen to entertainment broadcasts from AES stations and to tune in on "Berlin Sal," who interspersed her high-powered American jazz broadcasts with scripts assiduously but ineffectually aimed at undermining G.I. morale.

Last minute instructions prior to the takeoff were given by special code over the vhf equipment. All Queen operating personnel were constantly on the alert to see that necessary

instructions and orders were passed through without delay. At the height of invasion activities, one fixer net reported giving position fixes to more than 500 aircraft within one hour. When their mission was completed and the craft were homeward bound, many had to make emergency landings using the Queen ground equipment for position fixing and homing.

Anti-Noise Device Installed

Installation of the noise suppressor in the King George receiver section thwarted enemy efforts to jam the vhf frequencies by the use of pulse type signals, and overcame interference from enemy and friendly ground radar installations. By reducing disturbances normally experienced in communications equipment, these new circuits also made it possible to communicate over longer distances because weaker radio signals could be heard.

In a typical weather squadron, a P-38 aircraft equipped with a King George and noise suppressor obtained weather information by vhf to a relay plane flying somewhere between the base and the area. The relay plane transmitted the data back to the base. These planes, flying at an altitude between 15,000 and 25,000 feet, reported numerous instances of excellent two-way communication from plane to plane at a distance of 600 miles, and air-to-ground communication over a distance of 500 to 550 miles, or approximately three times line-of-sight propagation.

Pilots, by the way, were apt to be pretty superstitious. They wouldn't fly without wearing a certain cap or a certain jacket. By the same token if their equipment was giving good results, they were dead set against making any change. I watched many a pilot follow his prized SCR-522 all over the field during checking operations to make certain the same unit was returned to his plane.

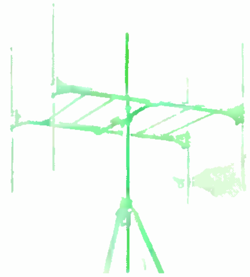
Because of the success of the noise suppressor in vhf airborne units, a similar device was designed for the Queen ground receiver BC-639. A modification which provided all the advantages noted in the SCR-522 was installed in most of the BC-639's in August, 1944, over a year before the Army provided the necessary modification kits for this equipment. In a combat theater, since solution of the communication problems at hand was rated of greater importance than following normal Army procedures, commanding officers could authorize any modification which held promise of contributing to the efficiency of action against the enemy.

J. Walton Colvin

As lone consultant on airborne communication equipment in the Mediterranean Theater when the Italian campaign was most intense, amiable, resourceful J. Walton (Sheriff) Colvin really got around. Communications officers of the 15th Air Force pay enthusiastic tribute to his skill in diagnosing the battle ills of vhf, and his capacity to withstand a gruelling program involving constant travel and long hours of sustained activity. Working also with the 12th, the Desert and the Royal Air Forces, he utilized any available field, tent, theater or school building as his classroom for training groups of from 5 to 200 Air Force personnel in the maintenance, tuning and operation of communications equipment. Though carrying the courtesy rank of a field grade officer, he frequently chose to live with the enlisted men in order to take advantage of every opportunity to talk radio with them. In addition, his daily fare consisted of test and investigation of equipment modifications, advice on supplies and supply procedures, and assistance in planning applications and procedures for radio communications in connection with special missions, notably the invasion of southern France. After V-E Day, he worked with ATC organizations throughout Europe and Africa. A native of historic Orange County, Virginia, he had his own radio and appliance business before coming to Bendix in 1942. With the exception of one year as instructor on Queen equipment at the Bendix Signal Corps School, he has been constantly in the field making installations and trouble shooting for the Sales or the Service Department. Since his return from overseas in October, 1945, he has covered the territory between the Rockies and the Atlantic seaboard, setting up maintenance facilities for Flightweight personal aviation and airline type radio.

King George to the Rescue

I have reason to entertain a very high regard for the reliability of the King George unit on strictly personal grounds. The fact is, I am indebted to it for getting out of a rather critical situation. During a midnight flight from Paris to Naples—the maiden trip for the plane en route from Scotland—we were caught in a severe storm and pretty soon were lost, knowing only that we were somewhere near Italy. We did not know whether we were over land or sea or in the vicinity of high mountain peaks—an uncomfortable possibility. When all other communication and navigation facilities were used to no effect, the crew turned to the King George. However, attempts to contact a ground station operated by American personnel were fruitless, and hope was waning. Then a call to a ground station operated by the RAF brought an answer. We were immediately given a position fix and a bearing to fly to the airfield. Traversing 200 miles of complete overcast, we were directed to the field and brought down safely through two miles of soup.



A survey which I privately made in the course of maintenance operations affords particular satisfaction to Bendix design engineers. In checking malfunction of the Bendix equipment, I found that over 75 per cent was due to tube failures. This condition improved with the introduction of the practice of testing tubes after 50 hours of service. One-half of the part failures were caused by shorted tubes, and less than 25 per cent by poor material. The balance were attributed to external causes, such as high input voltage. In my overseas experience, I did not encounter a single instance in which Bendix equipment was received poorly soldered or with loose connections. Proper engineering and inspection on the manufacture of precision radio equipment certainly paid good dividends.

Fully equipped with communication radio by Bendix, this new DC-4 was recently flown by its Belgian crew from the Douglas plant to Baltimore en route to Brussels. The standard installation includes two TA2-JB-24 transmitters, two RA-1B receivers, two MN-62A automatic compasses and an MI-32A inter-communication equipment. During the stopover, L. G. Korman (left) and D. K. Jones (right) adjusted the radio compass installation.

Letters on the side of the plane stand for Societe Belge d'Eseploitation de la Navigation Aerienne, a commercial airline serving Europe and South Africa. According to Lieut. John Molle, Chief Radio Operator, the plane will shuttle between Brussels and the Congo under the command of Captain Van Ackere. M. Verniew, Manager of Sabena for Belgium, accompanied the crew on this shakedown cruise of the big ship.

ENGINEERS on the GO

G. A. Exley went to the Philadelphia Division of Bendix Aviation Corp. to inspect machinery and equipment for use in the Model Shop. Exley also attended the annual convention of the American Society of Tool Engineers, resumed after three years, at Cleveland, Ohio.

Pan American Airways Offices in New York were visited by R. K. Frazier, who also went to Wright Field for conferences on Loran and new compass equipments, and visited the Naval Research Laboratories in Washington and the Johns Hopkins Research Laboratories at Silver Spring, Maryland.

F. Schouten visited the Scintilla Division at Sidney, N. Y., concerning mechanical equipment for broadcast receivers.

C. B. Lau, Dr. W. R. Hedeman, and H. A. Cook observed new crystal developments at the Bell Telephone Laboratories at Summit, N. J.

A molding job for Flightweight instruments necessitated a trip by R. J. Streb to the American Insulator Company at New Freedom, Pa.

R. E. Glass flew from Washington to Indianapolis on a Bendix plane to make, en route, experimental field tests of an omnidirectional compass indicator for the CAA. Glass later conferred in Washington with CAA engineers on results of the tests; discussed new equipments to be constructed and tested; and installed Bendix equipment on a CAA plane for tests at the National Airport.

Monthly New York meetings of the Radio Manufacturer's Association subcommittee on Television Relays were attended by Dr. H. Goldberg.

H. Walker made trips to P. R. Mallory and Company in Indianapolis and to the Aircraft Radio Laboratories at Dayton, Ohio.

J. F. Gordon made several trips to the Electronics Department at the Eclipse-Pioneer Division at Teterboro, N. J., to discuss special development work.

Dr. W. R. Hedeman, H. Hemphill, W. L. Webb, M. Taylor, N. Raymond, S. R. Fund, J. T. McNaney, and A. E. Abel visited Wright Field concerning development work on various engineering projects.

F. R. Norton and C. McMullen visited the Electronics Division of Remington Rand at Middletown, Conn., to inspect airborne television cameras and to visit the television camera tube shop.

A Columbia University symposium on servo mechanisms was attended by J. T. McNaney, J. L. Hedeman, T. J. Moran, and W. A. Willis.

R. C. Merryman and A. E. Hayes, Jr., made several trips to the U. S. Patent Office in Washington.

G. R. White went to the Jefferson Transformer and the Thoradson Transformer companies in Chicago concerning transformer measurements. White also discussed air flow measurements with Velnor Instrument Company engineers in Chicago, and r-f power measurements with Bird Engineering Company engineers in Cleveland, Ohio, then attended the IRE convention and exhibits in New York.

H. A. Cook visited Electronics Laboratories and P. R. Mallory and Company in Indianapolis to obtain engineering information on vibrator power supplies for Flightweight and Railroad radio. Cook also attended a New York executive committee meeting of the Transformer Components Standardization Committee of the RMA and was appointed chairman of the Resistor subcommittee which has since been meeting monthly to take action on standardization of resistors.

A. C. Omberg and F. R. Norton attended RMA meetings in New York and Philadelphia and a Federal Communications Commission meeting in Washington.

M. Taylor, A. Hemphill and J. T. McNaney discussed development work on a new compass, loop indicator, and electric tuning methods at Kearfott Engineering Company in New York.

The Naval Research Laboratories in Washington were visited by A. E. Abel.

D. C. Hierath went to the Erie Resistor Corporation at Erie, Penna., concerning plastic molding facilities and manufacturing of components for broadcast receivers.

F. R. Norton discussed television receiver test equipment at National Design Service in New York; met with the RMA Studio Facilities subcommittee of the Television Transmitter Committee; visited the Measurements Corporation at Boonton, N. J., to discuss television test equipment; went to North American Phillips Company plants at Irvington and Dobbs Ferry, N. Y., to discuss tube problems, and to inspect direct viewing and projection television cathode-ray tubes; and visited the American Lens Company in New York to discuss television optical projection problems.

J. E. Trant made trips to the Eclipse-Pioneer Division at Teterboro, N. J., and to the Marine Division in New York.

A. C. Omberg visited the Radiation Laboratory at Massachusetts Institute of Technology, Cambridge, Mass., and conferred with officials at Camp Evans at Belmar, N. J.

Dr. W. R. Hedeman and W. H. Sims, Jr., went to the Watson Laboratories at Eatontown, N. J., concerning specifications for ground station equipment for the Air Forces.

W. L. Webb spent some time at the Bendix Radio West Coast plants; observed a Columbia Broadcasting System technicolor television demonstration in New York; and attended meetings of the RTCA in Washington.

O. L. Peterson visited the Eclipse-Pioneer Division at Newark, N. J.

Engineering problems on component parts necessitated trips by W. R. Strauss and L. G. Zucker to firms in Chicago and Fort Wayne.

H. Becker and F. R. Norton visited the United Transformer Company in New York to discuss special television circuit transformers, deflection yokes, and focusing coils.

A. E. Hayes, Jr., made several trips to the U. S. Patent Office in Richmond, and visited the Radiation Laboratories at MIT in Cambridge.

H. K. Morgan and W. L. Webb visited the Cruft Laboratories at Harvard University concerning research work.

W. H. Sims, Jr., and A. E. Abel inspected models of CAA equipments in Washington, D. C.

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To the Readers of the BENDIX RADIO ENGINEER:

Publication of the BENDIX RADIO ENGINEER as the technical organ of the Bendix Radio Division will be suspended with this issue.

The decision to relinquish our role as publisher of the ENGINEER was made reluctantly; nevertheless, we are proud that we were able to originate and sustain a periodical which has been so well received by the industry.

Any future action taken concerning the magazine will be determined, in a large measure, by your interest, so any comment that you may care to make now regarding the value of the BENDIX RADIO ENGINEER will be indeed welcomed. Your support in the past has been sincerely appreciated.

W. L. Webb

W. L. Webb,
Director of Engineering
and Research

BENDIX RADIO

DIVISION OF BENDIX AVIATION CORPORATION

BALTIMORE, MARYLAND