M/Sgt. W.F. Pudlin

PHILCO

TECHREP DIVISION BULLETIN

JULY, 1951

MINITURE Voltage Reg.

GRINDING XTALS

BULLETIN
open to
ARMED FORCES CONTRIBUTORS

In view of the large number of military personnel now receiving this magazine, and in view of the close relationship between Philco field-engineer activities and those of the military, we have decided to accept contributions from members of the Armed Forces.

We believe that by thus increasing the scope of the BULLETIN, we can insure that it will continue to supply technical information of the greatest value to both Philco and military personnel, and that the articles we publish will continue to be of the highest quality.

All inquiries or manuscripts should be addressed to the Philco TechRep Division BULLETIN, 22nd and Lehigh Avenue, Philadelphia 32, Pennsylvania.

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PHILCO
TECHREP DIVISION BULLETIN

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Letters to the Editor

The comments and letters which appear in this column are typical of the more than 500 letters and cards we have received since the release of the May and June issues of the BULLETIN. We are very much pleased with the reception this new magazine is receiving, and we greatly appreciate the suggestions which have been made for new articles and features. Many of your ideas will be incorporated into future issues.

The following excerpts are from letters written to us by Philco Field Engineers, by members of other companies of the electronics industry, and by personnel of the Armed Forces:

•

"Tech Reps from other companies are amazed with our publications. This latest addition is tops." Walter J. Conner, Philco Field Engineer, SAC.

•

"This Tech Rep BULLETIN is hot! About the best thing that has hit the field-engineer program since profit-sharing. Three of the Wing Officers are highly desirous of receiving regular copies of these little gems, and I would appreciate it if the enclosed names could be added to your mailing list.

"The Directorate of Materiel has requested permission to reprint the article on Polar Relays, which was contained in the second issue of the BULLETIN." Jack B. Cunningham, Former AACS Pacific Area Supervisor.

•

"Personnel at this base are very enthusiastic over the new magazine. In fact, I am hounded for all back issues. If possible, I would like five copies sent every month, including back issues." Emil J. Voigt, Philco Field Engineer, EADF.

•

"I have received the three copies of your Tech Rep BULLETIN, and many thanks for your kindness.

"One article in particular, in your first number (February), 'Handling of Radioactive Tubes,' was very valuable indeed, as we have been handling a lot of the cold-cathode tubes made by Western Electric, Westinghouse, and General Electric, and had not realized that they could be dangerous if the glass were broken, permitting the radioactive gas to escape.

"I certainly appreciate the data you have sent me, and I want to tell you how very interesting and valuable the articles are to radio engineers." A. M. Stevens, Federal Telephone and Radio Corp., Clifton, New Jersey.

•

"I notice that not only the Tech Reps—but the people with whom they work—are reading the BULLETIN." Philip R. Zimmerman, Philco Field Engineer, Headquarters, FEAF.

•

"It's good to read a magazine that isn't 70% advertising." Russell Wolfram, Philco Field Engineer, WADF.

•

"Everyone here is enthusiastic about the TechRep Division BULLETIN, and I know of several prospective articles in the process of preparation for submission to the editors. The Directorate of Materiel has asked permission to reprint excerpts in the FEAMCOM monthly Materiel Bulletin, which has FEAF-wide distribution. The article on TR tubes was the first to be reprinted in this Materiel publication." John McMenomey, Philco Group Supervisor, FEAMCOM.

•

"I would like to see more of the problems such as the one concerning the 'non-conducting resistor.' They are very instrumental in promoting discussion among maintenance personnel." Walter C. Hinds, Jr., Philco Field Engineer, ADC.

•

"Please allow me to congratulate you on your new magazine, 'Philco TechRep Division BULLETIN.' It is a most interesting and informative publication.

"The article 'CRT Screen Characteristics,' in the May issue, is of extreme interest to me, and is indeed timely, inasmuch as I have been searching for just such material for lectures." Howard L. Coleman, Gough Industries, Inc., Los Angeles, Calif.

(Continued on page 36)

Editorial

SELECTION OF MANUSCRIPTS FOR PUBLICATION

By Robert L. Gish
Associate Editor

A number of potential BULLETIN contributors have requested that we publish a summary of the standards used in the selection of manuscripts for publication. Our editorial policy in this respect can be simply stated: We plan to publish every article we can obtain which is pertinent to the electronics industry, and of interest and value to the Philco field-engineering program.

Certain articles we publish do not apply directly to the activities of all Philco Field Engineers, but, instead, are of particular interest and immediate value to relatively small groups. In a program as diversified as the present one, with Philco men assigned to almost every branch of the Armed Forces, such a situation is to be expected. However, we are attempting to include a wide variety of articles in each issue, so that the BULLETIN will be of maximum value to all Philco Field Engineers, and to the military personnel with whom they work.

Acceptable material may range from the how-to-build-it type of articles (several of which we have already published) to an occasional highly technical discussion of the type usually found only in "Proceedings of the I.R.E." We believe that the wide range of engineering backgrounds and professional interests represented by the readers of the BULLETIN justifies this policy. As in past issues, we plan to continue placing major emphasis on material which deals directly with current field problems; however, we will accept articles which discuss interesting scientific discoveries or engineering achievements, depending upon the applicability of the subjects discussed.

Although the point has been stated in previous issues, we wish to emphasize again that we are primarily interested in the technical accuracy of contributions submitted to us, rather than in the degree of literary perfection. We are prepared to polish the material, and even rewrite it when necessary, if the technical quality of the article meets BULLETIN requirements.

A Trigger-Delay UNIT for RADAR RANGE-ZERO ADJUSTMENTS

By C. H. Boyd

Philco Field Engineer

Theory and circuit details of a device which allows radar range-zero adjustments to be made using a synchroscope without a built-in signal-delay feature.

(Editor's Note: Since the publication of the article, "Improvising a Spectrum Analyzer," in the May, 1951 issue, we have received a considerable number of field requests for other articles dealing with similar methods of increasing the usefulness of existing test equipment. The following article certainly falls into this category.)

Whenever it becomes necessary to adjust or check the accuracy of the range-measuring circuits of most radar equipments, a reference point which represents zero range must be established. This is accomplished by introducing range marks from an external source, and aligning one of these marks with the leading edge of the magnetron pulse. All measurements are made with respect to this point.

In most radars, the range calibration unit which supplies the range marks also supplies a trigger pulse which is a submultiple of the range-mark frequency. This trigger pulse synchronizes the firing of the magnetron with the occurrence of the range marks. The phase of the range marks is continuously variable to facilitate aligning one of these marks with the leading edge of the magnetron pulse.

To make the range-zero adjustment, the video information is presented on a synchroscope which is triggered by the same pulse that fires the magnetron. The phasing control on the range unit is adjusted to align a range mark with the leading edge of the magnetron pulse.

If the synchroscope sweep circuits contain an appreciable delay, the leading edge of the magnetron pulse may not

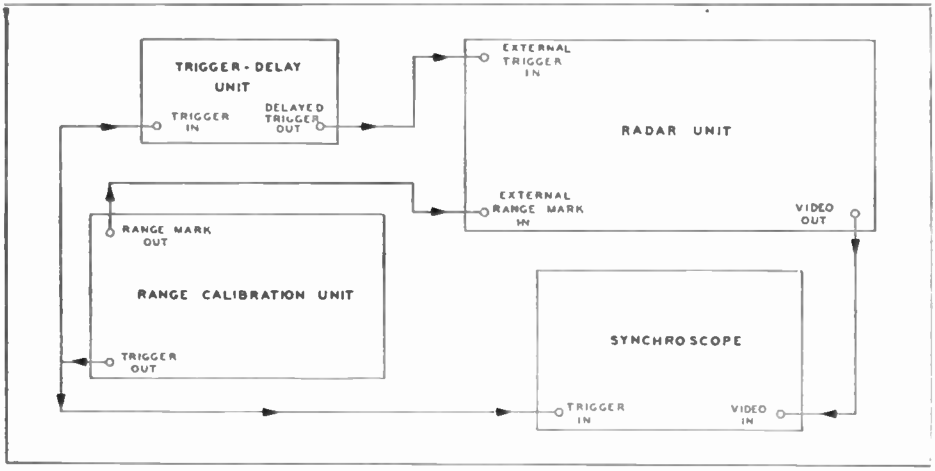

Figure 1. Block Diagram Showing Method of Interconnecting Units for Range-Zero Measurements

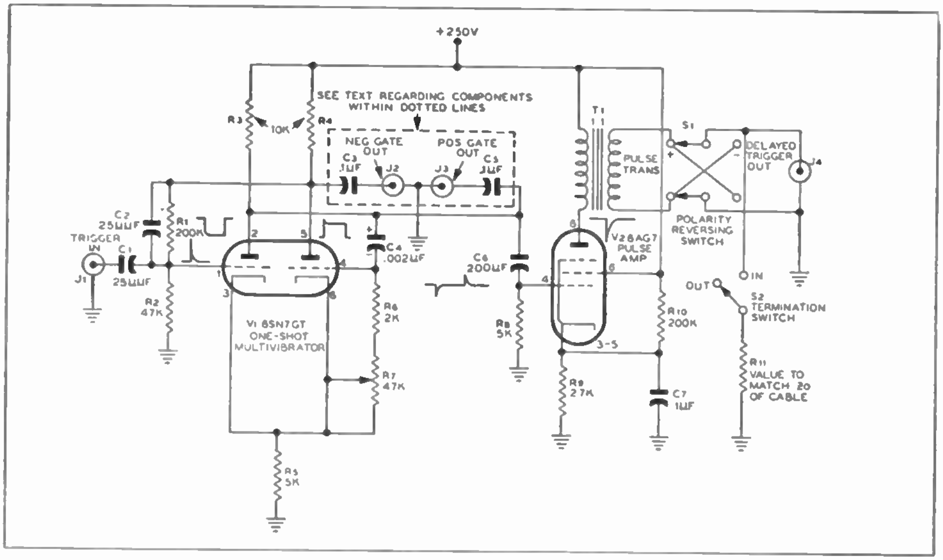

Figure 2. Schematic Diagram of Trigger-Delay Unit

be seen. This makes it very difficult to establish an accurate range-zero point. Some synchroscopes have a delay line provided in the signal channel to compensate for the time required to initiate the sweep. Others contain no provision for this correction.

When only the latter type of synchroscope is available, some external means must be provided to insure that the magnetron pulse is not applied to the synchroscope until the sweep has started. One method would be to use an external signal-delay line. This device is generally unobtainable, and is not easily fabricated in the field. Another method would be to supply an advance trigger to the synchroscope, to allow the sweep to start before the magnetron is fired. However, the range calibration unit in most radars cannot be easily modified to supply such a trigger.

THE SOLUTION

The method found by the writer to be the most satisfactory is to delay the magnetron trigger by means of an auxiliary trigger-delay unit. The delayed pulse is obtained by triggering a one-shot multivibrator, differentiating its output, and amplifying the pulse derived from the trailing edge of the multivibrator plate waveform. (The pulse amplifier is necessary to obtain enough amplitude to trigger the modulator.)

The block diagram of figure 1 indicates the method of interconnecting the various units used. Figure 2 shows the complete circuit of the trigger-delay unit.

When a positive trigger pulse of proper amplitude is applied through J_1, the one-shot multivibrator (V_1) goes through a complete cycle of operation. The output waveforms of voltage at the two plates of V_1 are essentially square waves of opposite polarity. The negative-going square wave appearing at plate 2 is applied to an RC circuit (C_6 and R_8), which differentiates the square wave, producing negative and positive pulses corresponding to the leading and trailing edges of the square wave.

The 6AG7 pulse amplifier is biased to cutoff by voltage divider R_9, R_{10}, so the negative pulse (which corresponds in time to the input trigger) has no effect on the stage. However, the positive pulse (the differentiated trailing edge of the waveform at plate 2 of V_1) drives the grid of V_2 well above cutoff, producing a negative output pulse of high amplitude at the plate of V_2.

The time delay between the input and output trigger pulses is determined by the time required for C_4 to discharge. This is controlled by varying the value of R_7, a part of the discharge path for C_4. With the values shown, delays up to 30 μsec. can be obtained. When the amount of delay for a particular synchroscope has been determined, the variable resistor (R_7) can be replaced with a suitable resistor of fixed value.

A polarity-reversing switch is provided to permit either a positive or a negative trigger to be taken from the output. S_2 provides a means of switching a cable-terminating resistor into or out of the output circuit.

CONSTRUCTION FEATURES

It is possible to build the trigger-delay unit into the range calibration unit of most radars if miniature parts are used; it is also possible to build it into most synchroscopes. No power supply is shown in the schematic diagram, since the device can be powered from existing circuits.

If a self-contained power supply and the parts shown within the dotted lines of figure 2 are added, the trigger-delay unit can be expanded into a more useful laboratory instrument. (The addition of C_3 and C_5 allows either a positive or a negative gate to be taken from the one-shot multivibrator, if a sine-wave or other suitable input is used.)

IN COMING ISSUES

CONTINUING our policy of publishing articles of immediate practical value to field men, we plan to include, in the August issue, an article titled "An Interference Blanking System for MTI-Modified Radars," by James B. Hangsteffer. The article discusses a system developed and tested by the author about a year ago, in Europe. We think that all readers will enjoy the article, regardless of their specialized fields, and that heavy-ground-radar men will find it particularly useful.

Of equal interest is a well-illustrated article on "Microwave Waveguides and Components," by Gail W. Woodward, of the Technical Publications Department. Far from being the usual dry re-hash of standard explanations of waveguide operation, this article is one of the most fascinating practical discussions of the subject we have ever read. In addition, the author has arranged his illustrations so that three types of information are presented: (1) a cutaway view of the r-f component or element under discussion; (2) the conventional schematic equivalent of the component; and (3) the new RMA symbol for the component.

Theory of A MOVING TARGET INDICATOR SYSTEM

By Edward Crossland
Hq. Technical Staff

A general discussion of the principles involved in one currently used MTI system.

As it exists in most installations, radar has one major disadvantage in the detection of aircraft. This is its inability to differentiate between echoes from those targets which are moving and those which are fixed. In some cases, operators become very familiar with the pattern of echoes from fixed targets around a station, and can readily determine the presence of an aircraft echo among the fixed echoes. Nevertheless, if an aircraft is flying directly over a fixed target, it is impossible for any operator to detect the aircraft's presence.

For several years there existed a need for a workable system of Moving Target Indication. Much work has been done experimentally, but only very recently have workable systems been available for use in the field.

There are several possible methods of differentiating between echoes from moving targets and those from fixed targets. This article discusses one method which has been generally accepted as suitable for field installations.

In any MTI system there are two problems to be solved: (1) The returns from moving targets must be made to differ, in some manner, from those of fixed targets. (2) Some means must be provided for eliminating the returns from the fixed targets before the moving-target information is displayed on the indicators.

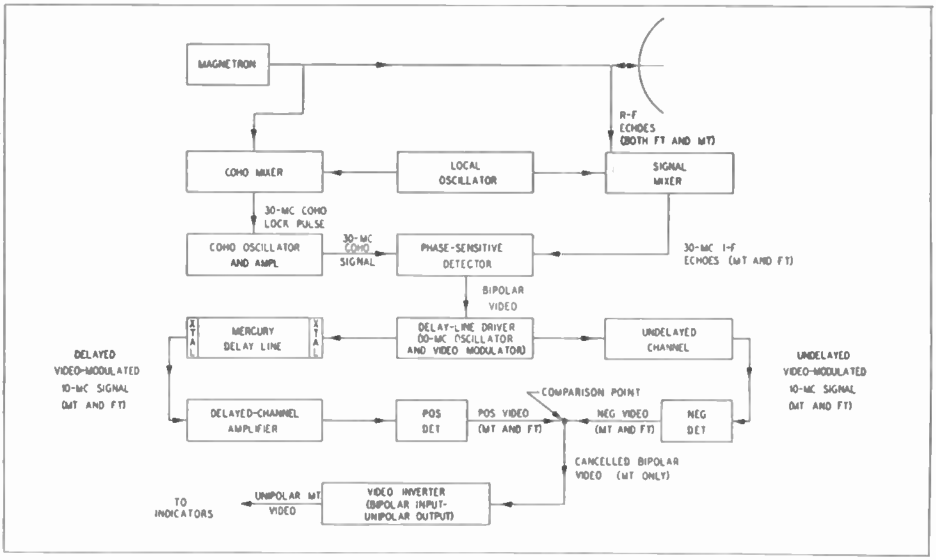

Figure 1. Simplified Block Diagram of a Typical MTI System

The first problem is solved by taking advantage of the Doppler effect produced when moving objects reflect radiated energy. If an r-f signal of fixed frequency is radiated into space and strikes a fixed object, it will be returned to the source with no change in frequency. However, if it strikes an object which has radial motion with respect to the source, the energy reflected and returned to the source will exhibit an effective change in frequency. The shift is to a higher frequency if the object is moving toward the source, and to a lower frequency if the object is moving away. It is possible to detect this frequency change, and thus differentiate between fixed and moving targets. The frequency change may be considered as a phase shift from one pulse to the next.

THE COHERENT OSCILLATOR

To compare the phase of the returned signal with the transmitted signal, some reference signal which always bears the same phase relationship with the transmitted signal during every pulse period, must be supplied. In currently used equipments, this reference signal is generated by a device known as a coherent oscillator, or coho.

The coho is locked in phase with the transmitter signal by means of a pulse obtained by extracting a portion of the transmitted energy from the system, and mixing it with the radar-local-oscillator signal. The result is an i-f locking pulse which is in phase with the transmitted signal, and which has the same time duration. This i-f pulse is usually called the *coho lock pulse*. Each time the transmitter fires, the coho lock pulse is applied to the coherent oscillator to lock it in phase with the transmitter. The coho operates at the i.f. of the radar, and has just sufficient feedback to produce oscillations when shocked by the coho lock pulse. It is turned off by a negative gate voltage after a proper time interval (during which echo signals are received), so that it can be rephased by the coho lock pulse at the start of each pulse period.

(Note: Since the frequency of the magnetron is much higher than that of the coho, strictly speaking, the magnetron and coho are not actually in phase; however, because of the action of the coho lock pulse, the two output signals do bear the same phase relationships during each pulse period.)

PHASE-SHIFT DETECTOR

The comparison between the reference signal (which is "locked in phase" relative to the transmitter) and the returned echo signals takes place in a phase-sensitive detector, which provides, at its output, signals of various amplitudes for different amounts of phase difference between the returned signal and the reference signal. There are many variations in the design of phase-sensitive detectors; this discussion is limited to the crystal-detector type shown in figure 2.

It is necessary that the coho and echo signals applied to the crystal-detector circuit be of the same amplitude. This requirement is easily met by controlling the gain of the amplifier stages. The echo signal is applied to the tuned LC circuit, which is resonant at the i-f signal frequency. Since the center-tap of L is returned to ground. two signals 180 degrees out of phase appear across the coil. These two signals are applied to two crystals which are connected with opposite polarity. The load of crystal 1 is R_1, R_3, and R_4. and the load of crystal 2 is R_2, R_3, and R_4. Since the crystals have R_3 and R_4 as a common load, any current flow through either crystal will cause a change in the voltage across the common load. The coho signal is applied to the load side of both crystals. Figure 3 shows the relationships between the signal and coho voltages for echoes returning from various positions relative to the radar.

Consider the case where the coho and echo signals are in phase. No current flows through crystal 1 during the first

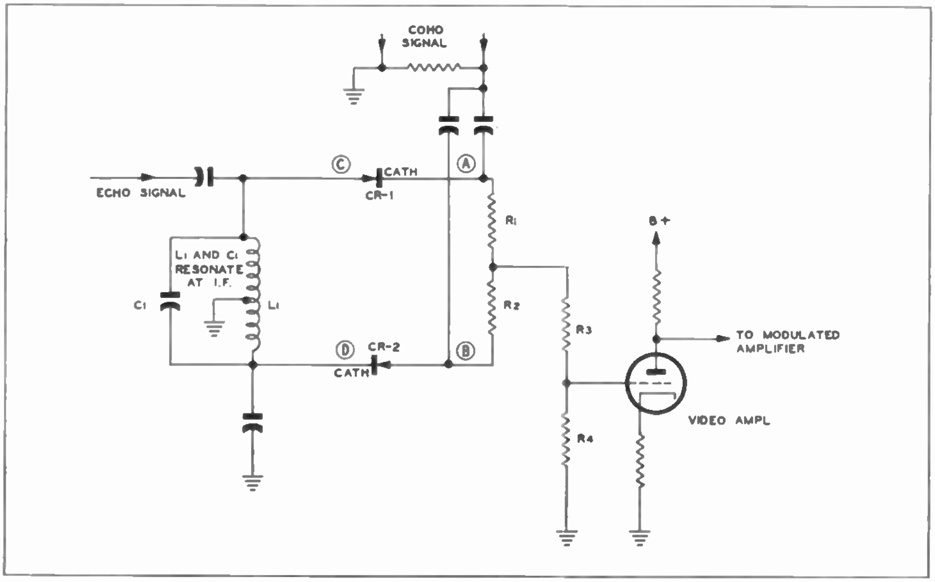

Figure 2. Simplified Schematic Diagram of One Type of Phase-Sensitive Detector

half-cycle of operation, because both voltages are positive and no difference of potential exists. But current flows through crystal 2 during this time, because the coho voltage is positive and the signal voltage is negative. This current flow develops a negative voltage across the common load, R_3 and R_4. During the second half-cycle, crystal 1 does not conduct, because both voltages are negative. Crystal 2 has a difference of potential across it during this time, but does not conduct, because of its polarity. Thus, if the coho and echo signals are in phase, crystal 2 conducts during the first half of each cycle and develops a negative voltage across R_3 and R_4.

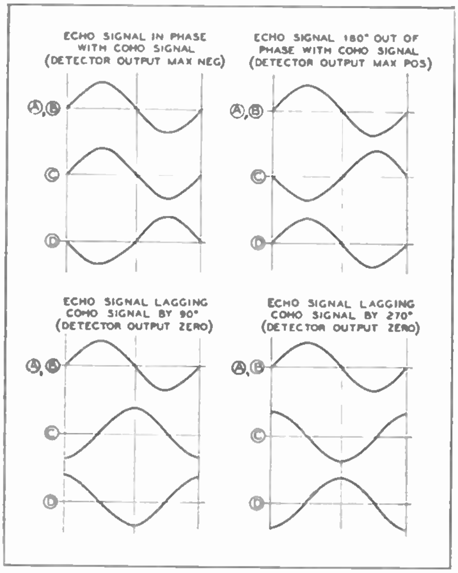

Figure 3. Relationships between Signal Voltage and Coho Voltage for Echoes Returning from Various Positions Relative to the Radar

Now consider the case where the applied coho and echo signals are 180 degrees out of phase. During the first half-cycle of operation crystal 1 has a difference of potential across it, but does not conduct, because of its polarity. Crystal 2 does not conduct, because there is no difference of potential. During the second half-cycle, crystal 1 conducts, and therefore develops a positive voltage across R_3 and R_4. Crystal 2 does not conduct, because there is no difference in potential. Thus, if the coho and echo signals are 180 degrees out of phase, crystal 1 conducts during the second half of each cycle, and develops a positive voltage across R_3 and R_4.

By the same type of reasoning, it can be shown that when the phase difference between the echo signal voltage and the reference voltage is either 90 degrees or 270 degrees, each of the diodes will conduct for a period of time equal to one-half cycle during each cycle of applied input voltage. But, since the diodes are connected in opposite directions in the circuit, the voltage developed across R_3 and R_4 by the current through crystal 1 will be equal in amplitude but opposite in polarity to that produced by the current through crystal 2. Therefore, these voltages cancel, and no output results from the phase detector when the echo signal voltage and the reference voltage are displaced either 90° or 270° in phase.

It can thus be seen that the voltage developed in the common load resistors is proportional in amplitude and polarity to the amount and direction of phase difference between the echo signal voltage and the reference voltage. When the phase difference is zero degrees, the detector output is maximum negative. As the phase difference goes to 90°, the detector output rises linearly to zero, then continues linearly to maximum positive at 180° phase difference. The output decreases to zero again at 270°, and returns to maximum negative output at 360° (or 0°) phase displacement.

Figure 4 shows the output characteristic curve of the phase detector. For a fixed target, the echo signal will produce an output pulse which is either always positive or always negative, at some constant amplitude during every pulse period, or non-existent, if the target is positioned relative to the radar so that its echo arrives at the phase detector 90° or 270° displaced from the coho signal. For a moving target, however, the output of the phase detector will vary continuously

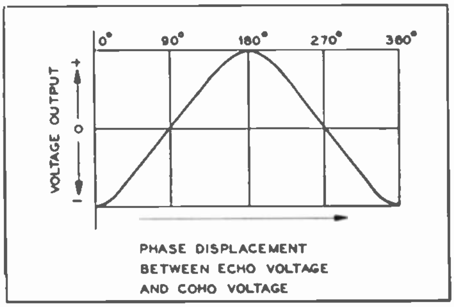

Figure 4. Output Characteristic Curve of Phase-Sensitive Detector

along the curve shown in figure 4, at a rate determined by the radial velocity of the aircraft.

It is evident that there will be certain radial velocities at which aircraft can travel relative to the radar, which will produce identical outputs from the phase detector on successive sweeps. In these cases the echo will appear as an echo from a fixed target; i.e., the returned echo from each transmitter pulse will produce identical output pulses from the phase sensitive detector. Speeds at which this occurs are known as blind speeds, and represent radial motion of the aircraft for a distance equal to any multiple of one-half of an r-f wavelength per pulse period. However, it is impossible for an aircraft to maintain its speed absolutely constant over more than a few pulse periods, and even if that were possible, any tangential component of motion would affect the radial velocity. Therefore, over any given period the radial velocity of an aircraft relative to the radar will vary, thus producing varying outputs from the phase-sensitive detector.

The output from a phase-sensitive detector is bipolar video, since it varies both above and below the reference potential. If the bipolar video from each sweep is retained for one pulse period, and compared with the bipolar video from the next sweep, the fixed-target echoes (which maintain a constant amount of phase shift relative to the reference coho signal) will be equal in amplitude, and, if added in phase opposition, will cancel. On the other hand, those returns from moving targets will be of different amplitudes on two successive sweeps, and will not entirely cancel. The only remaining target echoes after cancellation are those from moving targets.

For video cancellation, the delayed signals are normally presented as positive voltages, and the undelayed signals as negative voltages. Thus, at the cancellation point the fixed-target echoes (which have equal amplitudes on successive sweeps) cancel, leaving only the moving-target returns.

VIDEO DELAY SYSTEMS

There are many possible methods of delaying the signals from one sweep until the signals from the following sweep have returned. Experiments have been carried out with several types of delay lines, but those selected for general use today are those of the mercury type.

One of the characteristics of mercury is that supersonic mechanical vibrations in the 5-mc. to 30-mc. range travel through it at a speed of 4700 ft./sec. For this reason, frequencies in this band are normally used to transmit the signals through the delay line. There are several factors to consider in the selection of the exact carrier frequency: First, the free-space frictional attenuation of the energy in the mercury is directly proportional to the frequency used. At a frequency of 10 mc., this amounts to approximately 0.11 db/in. Second, the attenuation due to the wall effects of the mercury container varies inversely as the diameter of the tube, and directly as the square root of the frequency. At a frequency of 10 mc., this amounts to approximately 0.1 db/in.

It is evident that as the frequency increases, the attenuation increases. This might lead one to believe that the lowest frequency would prove to be the best, but this is not entirely true. The carrier must be amplitude-modulated by the bipolar video signals in order to transmit these video signals along the delay line. It is necessary, then, to choose a carrier frequency high enough to give faithful reproduction of the video at the detection point. In this case, the higher the frequency, the better the reproduction. Therefore, a compromise must be made, and it has been found that mercury delay lines will operate well with a carrier frequency in the vicinity of 10 mc.

The amplitude-modulated 10-mc. signal is applied to an X-cut quartz crystal which is in physical contact with the mercury at one end of the delay line. The crystal transforms the electrical energy into mechanical vibrations which travel through the delay line as supersonic energy at 4700 ft./sec. At the far end of the mercury column, a second crystal acts as a receiver, changing the vibrations back to electrical energy. A crystal normally acts as an extremely high-Q circuit, but due to the loading effects of the mercury, the Q of these crystals is reduced to approximately one (1).

The energy traveling through the mercury at 4700 ft./sec. experiences a delay of 17.6 μsec/in. Since the delay time must total exactly one pulse period, it is a simple matter to choose a delay line of proper length so that the total delay in all circuits of the delayed-channel path equals exactly one pulse period.

The same modulated 10-mc. signal which is applied to the delay line is also fed to an undelayed channel, which consists of a series of shaping amplifiers. These stages are designed to have the same band-pass characteristics as the mercury line, so that the two signals (delayed and undelayed) will be similar at the comparison point.

The output of the mercury line is fed to several stages of r-f amplification, to raise the amplitude of the delayed signal to the level of the undelayed signal.

VIDEO-SIGNAL CANCELLATION

The output of the delayed channel is fed to a detector circuit which detects the positive half of the video modulation envelope. The output of the undelayed channel is fed to a similar detector, which detects the negative half of the video modulation envelope. These signals are coupled at a comparison point, which may be a direct physical connection or a cathode-follower stage with two inputs.

Since the echoes from fixed targets during two successive pulse periods have the same amplitude, and differ only in polarity through the delayed and undelayed channels, they will completely cancel. The moving targets, however, exhibit different amplitudes for successive sweeps, and will not cancel. Thus, the only signals remaining at the output of the cancellation point are those which represent moving targets.

The moving-target video is bipolar in nature, and, since the indicators are Z-axis-modulated, they will not function with signals of both positive and negative polarity. For this reason it is necessary to provide a stage which will accept signals of either polarity, and provide output signals of only one polarity. A conventional circuit for this use is shown in figure 5. The bipolar video signal is applied to one grid of the twin triode (V_1). The second grid is held at a fixed potential, and the cathodes have a common load resistor, R_3. If a positive pulse is applied to the input grid of V_1, a negative pulse will appear across plate load resistor R_1. CR-1 will conduct and the negative signal will be passed to the next stage. Due to the fixed voltage on the section-two grid of V_1, common cathode resistor R_3 causes a positive input pulse to appear as a positive pulse across plate resistor R_2, but due to its polarity in the circuit, CR-2 will not conduct. If a negative input pulse is applied to V_1, it will appear as a positive pulse across R_1, but CR-1 will not conduct. However, the negative input pulse will appear as a negative pulse across R_2, causing CR-2 to conduct, and again pass a negative signal to the next stage. The circuit thus receives both positive and negative video at its input, and provides at its output only negative video for distribution to the indicators.

SUMMARY

It has been shown that there are two

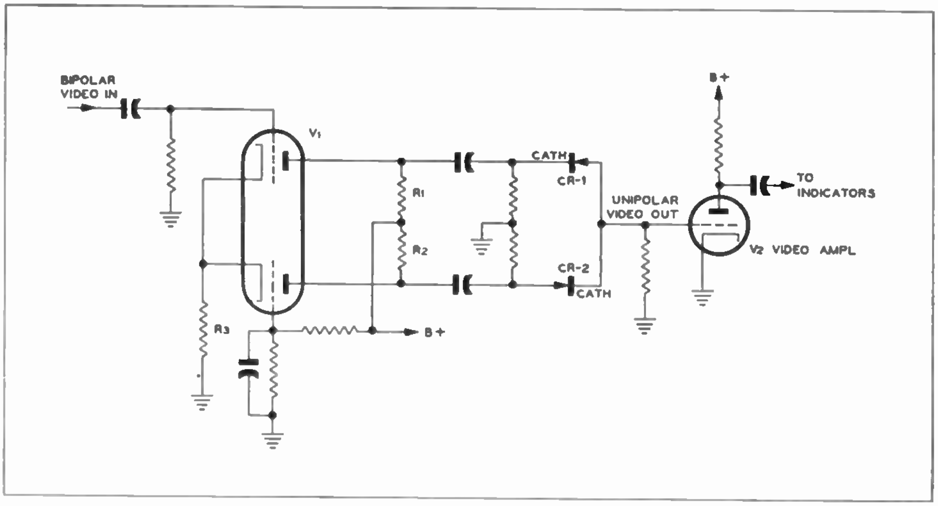

Figure 5. Simplified Schematic Diagram of Circuit to Convert Bipolar Video to Unipolar Video

basic requirements for a practical MTI system: First, the fixed targets must be differentiated from moving targets. This differentiation is accomplished by the phase-sensitive detector, which depends upon the Doppler effect for its operation. Second, the returns from one sweep must be delayed for one pulse period, so that they can be compared with the returns from the next sweep. This delay is accomplished by using a mercury delay line. The outputs from the delayed and undelayed channels are compared, and the fixed-target returns cancel, while the moving-target returns are passed to the amplifier stages. Since the moving-target returns are bipolar, they are changed to unipolar signals before being applied to the indicators.

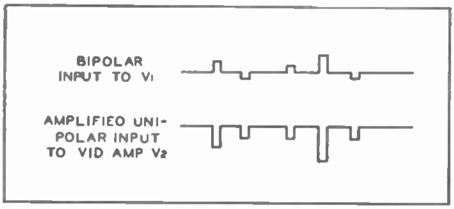

Figure 6. Input and Output Waveforms of Video Inverter Circuit

There are other methods of obtaining Moving Target Indication, such as those which use LinLog and IAVC types of receivers. These systems will be discussed in future articles.

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Solution to . . .

Last Month's "What's Your Answer?"

This problem can be solved easily by Kirchhoff's law of voltages. It is only necessary to obtain expressions for E_1, E_2, and E_3 (in terms of I), and equate the sum of these expressions to the total applied voltage (100 volts).

The voltage across R_1:

$E_1 = IR_1 = 25I$

The voltage across R_2 is given in the problem:

$E_2 = 25$

Since the power dissipated across R_3 is equal to E_3I, and since $P_3 = 25$:

$E_3 = 25/I$

Equating the sum of these expressions to 100 volts:

$100 = 25I + 25 + 25/I$

Transposing, collecting, and multiplying by I to clear of fractions:

$25I^2 - 75I + 25 = 0$

Dividing by 25:

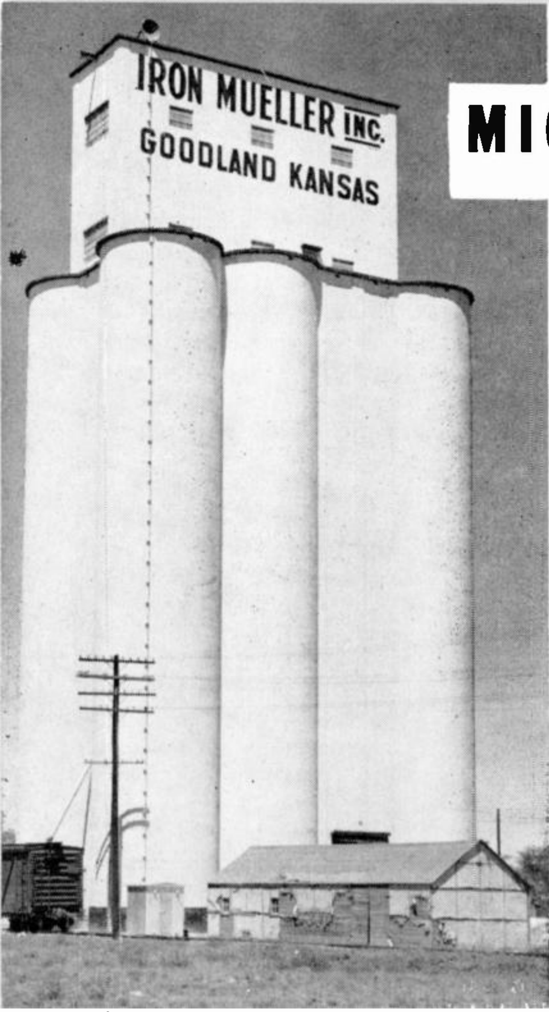
$I^2 - 3I + 1 = 0$

Solving this quadratic equation for I:

I = 2.618 amp. or 0.382 amp.

J.C.D.

MICROWAVE RADIO



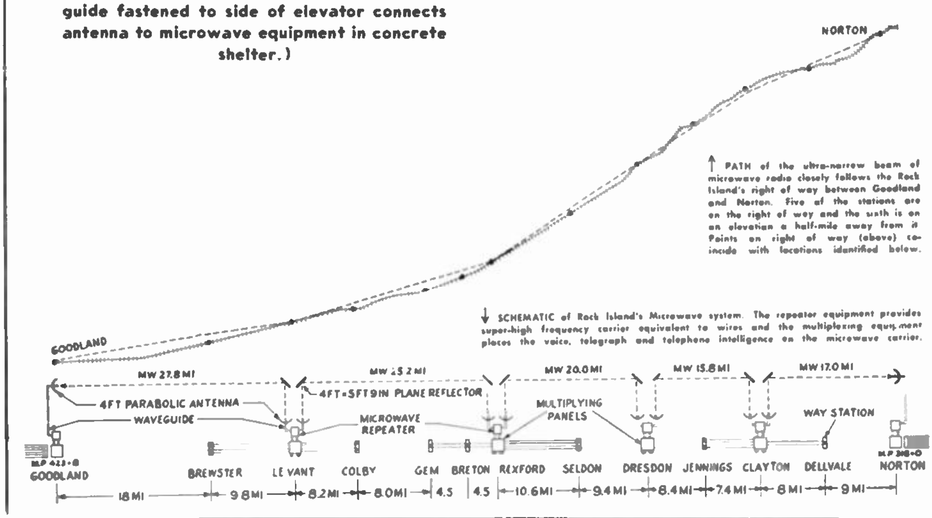
Parabolic Antenna Mounted at Top of Grain Elevator at One Terminal of System (Waveguide fastened to side of elevator connects antenna to microwave equipment in concrete shelter.)

The story of a Philco Microwave Communications System installed over a 105-mile section of the Chicago, Rock Island & Pacific Railroad.

(Editor's Note: This article was originally published in the October, 1950 issue of MODERN RAILROADS, and is reprinted here by special permission.

Since the article was planned and written for a railroad magazine instead of an electronics magazine, the technical aspects of the equipment are treated in less detail than in other articles we publish. However, the material is so interesting, and demonstrates so clearly the superiority of Philco Microwave equipment over pole-line systems, that we feel it will be of great interest to readers of the BULLETIN.)

MICROWAVE radio has now become a practical reality on the railroads. Since initial development of this type of radio, the railroads have experimented with its possibilities for substituting and also possibly eliminating the need for wire lines to carry communications from one point to another. Now the railroads have be-



↑ PATH of the ultra-narrow beam of microwave radio closely follows the Rock Island's right of way between Goodland and Norton. Five of the stations are on the right of way and the sixth is on an elevation a half-mile away from it. Points on right of way (above) coincide with locations identified below.

↓ SCHEMATIC of Rock Island's Microwave system. The repeater equipment provides super-high frequency carrier equivalent to wires and the multiplexing equipment places the voice, telegraph and telephone intelligence on the microwave carrier.

------Invisible Pole Lines

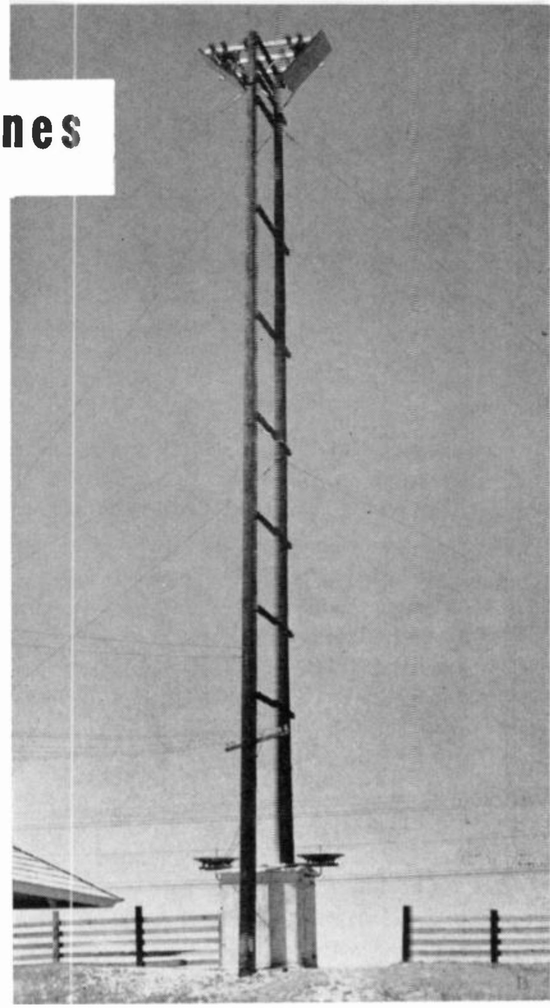
come one of the first major industries to put microwave in regular service.

For a distance of 105.8 miles between Goodland, Kansas, and Norton, Kansas, two terminals and four unattended intermediate repeaters are working day and night, handling telegraph and telephone messages that pass through this part of the Rock Island's main line, as well as messages that originate or terminate there.

The Rock Island microwave installation carries seven intelligence channels on the 6575-6875-megacycle carrier. Two channels are voice, and five are telegraph. The basic voice band is used for the dispatcher's circuit, with dropoffs at each repeater, and the other channels are multiplexed by carrier equipment. Of the five bands for telegraph, one is a local, and four are duplex. However, the system is capable of 32 voice channels.

C. O. Ellis, Rock Island's Superintendent of Communications, views its microwave system as an invisible pole line with a given number of circuits on it. There are two types of equipment: first, the microwave equipment itself, which provides a super high frequency carrier equivalent to wires; second, the multiplexing equipment, which places the intelligence of voice, telegraph, teletype, or other equipment on the microwave carrier. Instead of wires extending from station to station along the right of way, there is an ultra-narrow invisible radio beam over which the messages are transmitted. Because of the confined transmission path of the microwave system, considerable privacy is obtained.

Actually, the propagation characteristics of microwaves are much more similar to light than they are to the broadcast or short-wave bands, or even to the very-high-frequency bands used in train-radio



H-Type, 100-Foot Pole Structure Used at Rock Island Repeater Stations (Parabolic Antennas on roofs of shelters point upward to plane reflectors, which beam signals to and from adjacent stations.)

communication. Microwave transmitting and receiving antennas use either a lens or reflector system to focus energy into a narrow beam. As used by the Rock Island, a 4′ paraboloid antenna, or "dish", concentrates the energy into a pencil beam with a width of 3°.

The microwave system is being used to carry both through and local communications. At Goodland, for example, 14,675 telegrams were handled in June, 1950. This does not, however, include through telegraph messages, wheel reports, car tracing reports, ticket reservations, D&RGW interchange information, etc., carried on through circuits not handled by Goodland at all.

Philco Corporation, whose microwave equipment is used in the installation, has estimated that a basic microwave system would cost approximately $50,000 for 100 miles, and that 24-channel microwave with 100% standby microwave equipment would cost approximately $95,000 for the first 100 miles. By comparison, Philco estimates that adding a single pair of wires to 100 miles of existing pole lines would cost $20,000 and that a new three-pair pole line would cost approximately $120,000.

Norton is manned 16 hours a day, and Goodland 24 hours; but as the system expands, Norton and Goodland may become repeater stations with the terminals of the relay system shifted to coincide with division points.

Although Rock Island's plans for further extension of the microwave system haven't been definitely completed as yet, the economic aspects of the development make it a major factor for use in combination with existing pole lines, particularly where high maintenance costs are involved. In this way it would not only assure continued communications during critical periods when there are line breaks, as has already been indicated by the initial installation, but it would also permit reduction of the number of physical lines. This would have the effect of increasing the load-bearing factor of pole-line cross arms and poles, thereby making it possible for them to better stand up against high winds, and snow and sleet storms.

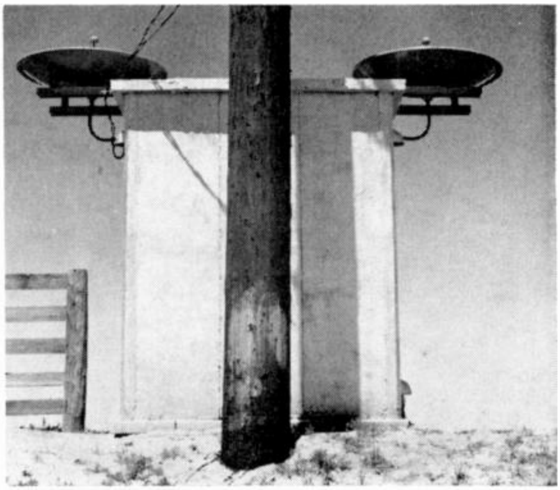
Transmitters and repeaters in the Philco microwave system have been designed so the complete system can be utilized in groups of four-channel units to a maximum of 32 channels. The system can be set up as it is on the Rock Island, to utilize standard carrier equipment, or it can be used with any other multiplexing equipment currently available. The Goodland-Norton installation, for example, superimposes on the microwave carrier the output from carrier equipment supplied by the Federal Telephone and Radio Co. and the Communication Equipment & Engineering Co.

The four microwave repeater stations between Goodland and Norton feed into Philco CLR-5 microwave sets, which are described later. In addition to retransmitting the incoming signals, these sets provide for telegraph and way-station telephone drop-outs for use at the stations where the repeaters are located, and also provide connection into extensions to way-stations located at points other than the actual microwave sites.

In selecting the site of its first major microwave installation, the Rock Island chose one in which the wire circuits had been frequently interrupted, and damage to pole lines by storms and high winds had been considerable. The region thus lends itself very well to microwave experiments. Heavy electrical storms in the summer and constantly changing weather throughout the year produce high static conditions. Also, temperatures range from over 100 degrees in the summer to below zero in the winter.

The high frequency of electrical storms in this area subjects the standby power service to severe tests. Momentary power

Concrete Prefabricated Shelters Used to House Microwave Equipment and Standby Power Generator (Parabolic antennas contain electric heaters to prevent accumulation of snow and ice.)

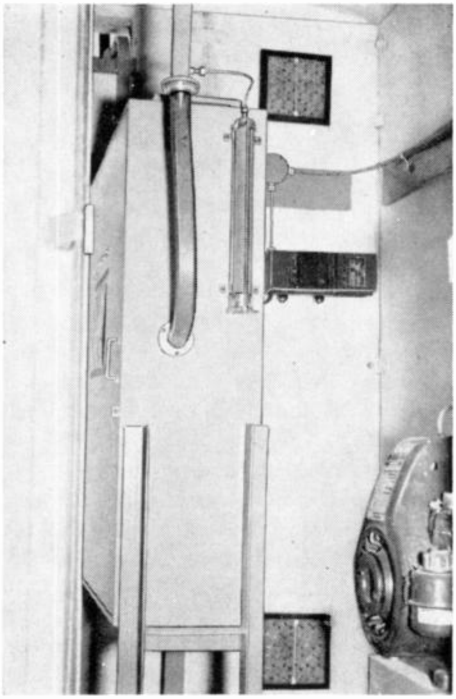


failures, which cause only slight flicker in lights, start up the 1-kw. Onan standby power generator. The Onan plant is set to operate for a minimum of one minute after each start, so there is no chattering when power goes on and off. Since 24 hours rarely passes without an electrical storm, on many days the standby plant operates almost constantly.

Another condition which at first seemed to be favorable for the initial installation was the apparent flatness of the Kansas terrain. Although this eliminated the possibility of mounting the stations on strategic high points, it appeared to help simplify setting up the stations. But it just didn't work out that way, for the terrain, while appearing flat to the eye, had gentle rises which interfered with line-of-sight propagation from a number of locations on the railroad right of way.

The region had never been plotted by the Government, so the profile of the right of way was projected to the curvature of the earth, and the locations of the microwave terminals and repeaters were plotted on the map. After a preliminary survey, it was determined where ground elevation might be satisfactory for mounting the antennas. By using a narrow-beam, 300,000-candlepower transmissometer lamp at night, directed from one tentative location to another, it was possible to confirm whether there was a line-of-sight path between the selected points. In one instance the beam was directed through a valley in order to establish a line-of-sight path to a low-lying station along the right of way.

As a result, five of the stations were located on the right of way, and the sixth was located one-half mile away from the right of way, at right angles, so that it could be situated on top of a hill which gave an altitude gain of 100 feet. Distances between the stations range from 15.8 to 27.8 miles.

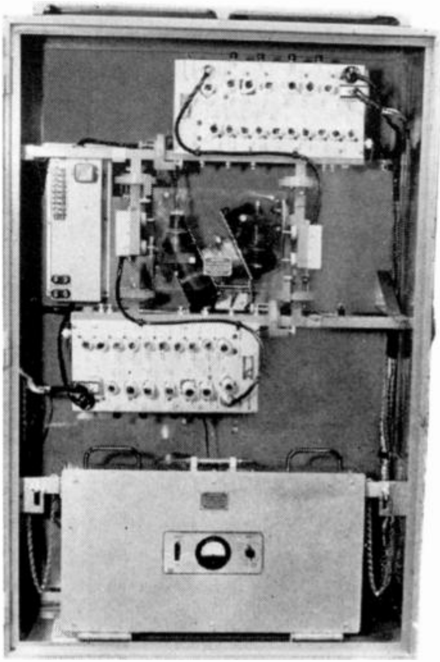


Inside View of Shelter at Repeater Station, Showing CLR-5 Repeater and 1-kw. Power Generator

Four of the stations utilize 100′, H-type pole structures mounting two 4′ x 5′ microwave reflectors which face in opposite directions. The entire plane-reflector assembly is designed so that the reflector can be adjusted to line up with the reflector or paraboloid antenna at the next station.

In the reflector installations, the 4′ parabolic dishes are mounted on the roofs of the concrete houses containing repeater units and power supplies. The radio waves are fed to a radiating element mounted on the end of the waveguide which extends through the center of the dish. The energy is projected back to the dish, which is curved to concentrate the energy into a beam, and cause the 0.4-watt output to be transmitted in the desired direction at a power level equivalent to that which would result if a 1000-watt transmitter were used without a parabolic reflector. At the repeater stations the dishes project the beam vertically, where it is intercepted by the plane reflector, and directed to the next station.

Where the antennas could be mounted on tall structures (160′ grain elevators at Goodland and Rexford), the microwave radiation was fed to the dishes on top of the structures by standard ¾″ x 1½″ brass waveguide, which is dry-air-pressurized. Placing the antenna itself at the top of the structure was more desirable than using a plane reflector, because of the design of the elevator structure. If a plane reflector had been used, it would have been necessary to place the dish at a considerable distance from the base of the structure, so that the beam could be directed to the plane reflector.



Front View of CLR-5 Microwave Repeater

The Rock Island installation utilizes standard Philco CLR-5 microwave equipment. Capable of handling up to 32 two-way voice channels or combinations of voice channels and coded-message channels, this equipment is designed for operation in the 6575-6875-megacycle band.

The two-way repeater units, installed in the Permacrete houses, are enclosed in a single 18″ x 30″ x 42″ metal cabinet. The equipment in the cabinet consists of a pair of feedback repeater assemblies and a regulated power supply. The feedback repeater circuit permits multiple-chain repeats with very little distortion and makes possible the use of only one microwave oscillator tube for both transmitting and receiving with a single-direction repeater. The power consumption of the entire unit is less than 350 watts at 115 volts, 60 cycles. The individual repeater assemblies are easily replaced in the field in a matter of minutes.

The 300—300,000-cycle modulation acceptance bandwidth of the repeater accommodates either frequency-sharing or time-division channelizing equipment for multiplexing. As has been mentioned, standard telephone carrier equipment of the single-sideband suppressed-carrier type and other types may be used to provide a moderate number of voice circuits. Philco type CMT-4 PAM (pulse amplitude-modulated) multiplexing terminals, which are produced in 8, 16, 24, and 32-channel models, are also available. To accommodate telegraph or signalling circuits entering the system at the CMT-4 multiplexing terminals, an appropriate number of voice channels are subdivided by spectrum filtering.

Any or all channels may be dropped off or injected at any repeater without affecting the signal being relayed through the circuit. Party-line operation can also be obtained with the individual channels of a frequency-division, single-sideband system.

As to fading, extensive experiments with Philco microwave equipment have indicated that a usable signal with a 20 to 30-db fading margin can be expected more than 99 percent of the time. Most microwave fading is due to a stagnant condition in the troposphere, or lower atmosphere. Conditions requiring emergency operation, such as storms and floods, are not accompanied by a stagnant atmosphere, and the microwave propagation characteristics are good during such emergencies. Greater freedom from fading can always be achieved by decreasing the hop length, but an economic optimum must be found to secure the reliability required for railroad communications at a reasonable cost.

Microwave repeater stations have the advantage that maintenance is concentrated at a few points, and the repeater stations are designed for unattended operation. This minimizes the number of persons required to man the system, and limits the cost of operation largely to regular and emergency maintenance on the system.

At the frequencies used, the components are small. They include packaged, pretuned tubes, and compact, pretuned transmission-line filters to suppress spurious transmitter oscillations and provide the proper receiver selectivity.

Thus, both systems combine standardized equipment which is only slightly more complicated than conventional radio and carrier circuits, and which requires extremely low power. In fact, the feedback repeater requires fewer components than the equivalent VHF equipment, and is more analogous to a telephone carrier repeater, as far as volume and cost of equipment are concerned. The Philco CLR-5 repeater and associated power supplies use two klystron oscillator tubes and 61 receiving-type tubes.

In the short time it has been operating, the Rock Island's system between Goodland and Norton, Kansas, indicates that microwave radio is entirely feasible for handling voice, telephone, and telegraph messages. Present plans are to expand microwave radio, both in this territory and in other areas, particularly where the weather or new-wire costs warrant it.

In view of the success of microwave equipment in the Rock Island communications system, it is apparent that microwave radio is the answer to the communications problems of other railroads, and that it promises to supplement, and eventually to replace, wire lines on all railroads.

ERRATA—June issue, pages 13 and 15, "Nomography": The cuts for figures 2 and 3 are reversed. The captions and tables are properly positioned. (Yes, our faces *are* red!)

Same issue, page 22, second column: The third line should read "ungrounded" instead of "undergrounded."

CRYSTAL GRINDING

By Herbert Lee
Philco Field Engineer

Techniques for shifting the operating frequency of quartz-crystal slabs.

THIS discussion is confined to AT and BT cuts in the region of 3 mc. to 10 mc., since these are the crystals most commonly used in the field. As pointed out in H. W. Merrihew's recent article* on crystal theory, they are cuts taken from opposite sides of the Z axis, and at different particular angles of X-axis rotation. Of more interest to the technician are the practical differences, that for a given frequency the BT cut is thicker than the AT, that during grinding the BT cuts are less liable to frequency jumps, and that the AT is usually more active than the BT.

In the frequency range of 3 mc. to 10 mc., oscillations result from thickness vibrations. The resonant frequency varies inversely with the dimension of the crystal, in the direction in which the principal vibration takes place. Mathematically stated,

$$f_0 \text{ (in kc.)} = \frac{k}{\text{thickness}_{\text{(in thousandths of an inch)}}}$$

The constants for this frequency-thickness relationship are:

CUT	k
AT	65.5
BT	98.4
X	112.6
Y	77.3

It is easy to see why a micrometer is so handy in crystal grinding.

CRYSTAL SHAPES

The faces of the crystal should be essentially parallel, with a very slight convexity. They should never be either concave or wedge-shaped. Square or rectangular crystal shapes are good, but other parallelograms are undesirable, because they limit the shear activity. Round, disc-type crystals may also be used. Jagged or uneven edges are a source of chips and cracks, so keep the edges of all crystals smooth and straight.

Since thickness vibrations are utilized, crystals are clamped between electrodes shaped to touch the crystal only at the corners (or on the periphery, if the crystal is circular). The air gap is in the order of a few ten-thousandths of an inch, and the spring clamping pressure is from 3 to 6 pounds.

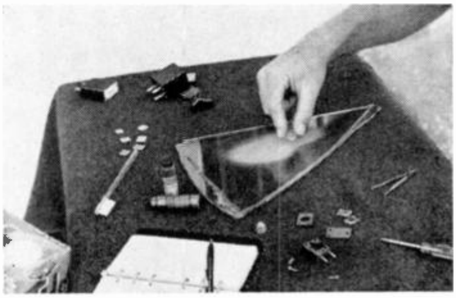
The crystal, electrodes, and holder should be matched so that the crystal fits the holder without binding, and so that the crystal almost covers the lands in the corners of the electrodes. The crystal should never be larger than the electrodes.

GRINDING

A piece of plate glass provides a good grinding surface. For the abrasive, use commercially available medium and fine crystal-grinding compounds, or grades 303 and 304 optical flour, obtainable from an optometrist. Only a few ounces are needed. Use fine abrasive unless the frequency is to be moved a long way, in which case the coarser abrasive should be used until the crystal is nearly up to frequency. A drop of water or a drop of light machine oil will serve as a binder for the abrasive, and will limit the cutting rate.

Equal pressures are applied on diagonally opposite corners of the blank with the thumb and forefinger. Never use one finger pressing in the center, for this will cause a concave face to be developed.

* BULLETIN, May, 1951



Layout of Equipment Necessary For Grinding Quartz Crystals

A figure-of-eight motion is correct. Make several figures of eight, turn the blank 90° so that the thumb has changed to a new corner, make the same number of figures of eight, turn another 90°, make an equal number of strokes, and continue in this manner until the crystal approaches the proper thickness. Use very light pressure, and take your time. If the blank becomes too convex, place one finger in the center and make a few strokes to correct the shape. If a previously ground crystal is being ground to a higher frequency, grind on only one face.

CLEANING

A crystal must be very clean in order to oscillate properly. After grinding, if oil was used with the abrasive, clean with carbon tetrachloride distributed in three cups. The first bath removes most of the residue. The second bath gives the crystal a thorough cleansing (hold the crystal by the edges, and rub it with a pipe-cleaner, cotton, or a cloth soaked in the solvent). The last bath gives an absolutely clean surface. Handle the clean crystal by the edges, or with tweezers (preferably plastic).

If water was used with the abrasive, scrub the crystal well, using a toothbrush and a detergent solution such as Tide and water: then rinse thoroughly in warm or hot water. handling the crystal by the edges, or with tweezers. Air-drying is preferable to using a cloth. Electrodes can be cleaned in the same manner as the crystals.

After the crystal is assembled in the holder, check the frequency. A Pierce circuit provides a good test oscillator. It is handy to note the frequency shift produced by each figure-of-eight motion, so that overshooting of the desired frequency does not occur. Take it slow toward the final frequency; moving just a few cycles at a time is tedious, but rewarding in the end.

INCREASING ACTIVITY

If the activity seems low, try edge-grinding. Work on one edge at a time. Grind at right angles to the faces, or bevel at 45°, but do not grind to a "knife edge." Check the results frequently, and when the activity comes up, try working on another edge. Grind the edges with crocus cloth or a coarse abrasive. Be sure to perform the edge-grinding before bringing the crystal up to the final frequency, because this process will alter the frequency by a few cycles.

Low activity can sometimes be corrected by changing the combinations or the positions of the associated parts. Rotate the crystal in the electrodes 90°, 180°, or 270°, or rotate one electrode relative to the other. If spares are available, try changing the electrodes.

REDUCING FREQUENCY

Be sure to approach the final frequency very slowly, so as not to overshoot. Backing up is a frowned-upon process, but one worth knowing. The writer once moved a crystal more than 2.4 mc. by hand-grinding, but passed the desired frequency. The trick that prevented hysteria was the use of tincture of iodine on the rock. The first application moved the frequency back too far, so some of the iodine was washed off with carbon tetrachloride until the crystal ended up on frequency. Usable, but less desirable than iodine, is india ink or mimeograph ink.

(Note: The reasons for the reduction in operating frequency when these substances are applied to a crystal are, of course, the changes in mass and elasticity produced by the applied substances. Ed.)

VOLTAGE REGULATORS
Vest-Pocket Style

By J. Carl Drumm
Hq. Technical Staff

A discussion of the problems involved in designing a practical miniature voltage regulator, and the methods employed by two members of the Headquarters Technical Staff to overcome these problems.

Within recent years, the voltage regulator has become an indispensable feature of many electronic equipments. By means of this device, oscillators are kept from straying over the spectrum, reference voltages are held constant within rigid limits, and grid biases now have a degree of stability unattainable in the days before voltage regulators.

Tube manufacturers, recognizing the importance of regulating devices, produced a series of voltage-regulator (VR) tubes, including the VR-75, VR-90, VR-105, and VR-150 (later renamed the OA3, OB3, OC3, and OD3, respectively). This line was supplemented recently by the OA2 and OB2 miniatures, which control outputs of 108 and 150 volts, respectively. Unfortunately, VR tubes can be used to regulate the voltage supplied to light loads only. To maintain ionization, approximately 5 ma. must flow through the tube; however, a continuous current of more than 30 ma. will permanently damage the tube. This means that the maximum load current that can be controlled satisfactorily is about 25 ma.; if a heavier load is needed, VR-tube regulation is not recommended.

To supply the demands of heavier equipment, the electronic regulator was developed. It usually contains three tubes:

1. A "pass" tube, which acts as a variable resistance in series with the load current.

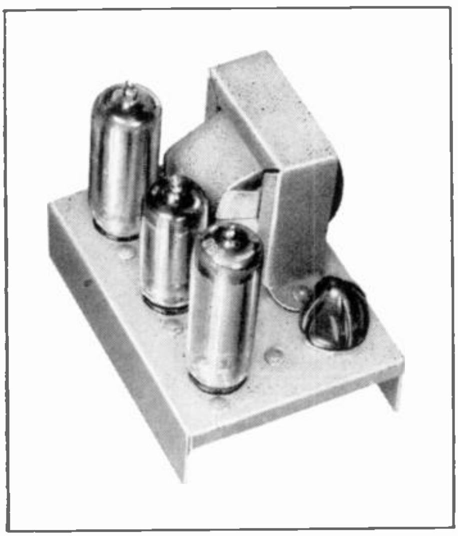
2. A "control" tube (d-c amplifier), which amplifies small changes in the d-c output voltage, and applies this amplified d-c to the control grid of the pass tube, thus changing the plate resistance of that tube, and bringing output voltage back to normal.

3. A VR tube, used to supply a reference voltage for the cathode of the control tube.

The output of the electronic regulator can be held to within a fraction of a volt. A flicker of the voltmeter needle is all that can be expected when a 250-ma. load is connected to and removed from the output terminals of a good heavy-duty regulator. But, although the electronic regulator does its job with extreme accuracy, the use of the circuit introduces new problems: (1) The equipment is bulky. (2) It produces a minimum voltage drop of anywhere from 50 to 150 volts, requiring that the power supply to which it is connected have a higher rating than would be required if no regulator were used. (3) The tubes are often subjected to peak voltages that exceed the ratings of tubes ordinarily used for this type of service especially during the warm-up period.

All of these problems recently confronted a development group in the Television Laboratory at Headquarters. A new type of television demonstration unit was being developed, and the video amplifier exhibited a bad case of motorboating. Suspecting power-supply trouble, Thomas J. Ryan and John L. Marsey, of the Television School staff, began to add filters and VR tubes to the circuit. The motorboating slowed down to a tenth of a cycle per second, but stubbornly refused to be eliminated by this treatment. Careful measurements disclosed that the VR tubes were behaving exactly as the manufacturer had warned that they might—they were allowing the output voltage to vary as much as 2 volts under changing load. When amplified by a high-gain video amplifier, the resulting variations ruined the picture completely.

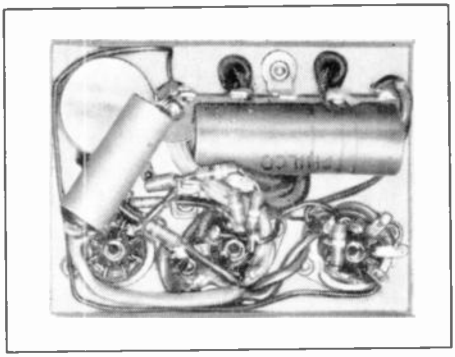
As a last resort, an electronic regulator was used to supply the B+ voltage for the video section; the motorboating promptly disappeared. This was a solution, but it threatened to introduce more problems than it eliminated. For example, all components of the demonstration unit had to be mounted on a 3″ x 7″ chassis; however, it was obviously impractical to mount three octal tubes and their associated circuits in a space that small. Use of miniature tubes was not considered suitable because the voltage



Top View of Miniature Voltage Regulator

ratings of these tubes are generally less conservative than those of octal tubes, and even the octal-tube ratings were being exceeded in the regulated supply that had been built to stop the motorboating. In addition, the demonstration-unit power supply delivered slightly over 300 volts at full load, and nothing short of a 6AS7G would ordinarily be used to produce a 250-volt regulated output from a 300-volt supply. In spite of these difficulties, however, there seemed to be no alternative. So the Headquarters team set about designing a miniature electronic regulator.

As indicated by the accompanying photographs, they were even more suc-



Bottom View of Miniature Voltage Regulator

cessful than they had hoped. The completed chassis is a trifle larger than a pack of cigarettes. It regulates a 50-ma. load at 250 volts, allowing variations of plus or minus $\frac{1}{10}$ volt, and can handle currents up to 75 ma., if necessary. In addition, it produces a 36-db suppression of 120-cycle ripple.

TUBE SELECTION

One of the most difficult design problems encountered was the selection of a suitable pass tube. The old reliables, the 6B4 and the 6L6, had to be rejected because of their size. Very reluctantly, the 6AS7G was passed over for the same reason. Available miniature tubes promised little, with the possible exception of the 6AS5. The curves of this beam-power miniature suggested that it could be triode-connected and used to pass 75 ma. with a maximum cathode-to-plate drop of 150 volts, and a minimum drop of approximately 50 volts. A trial run yielded results that were even better than those predicted by the tube manual. That solved the pass-tube problem. Next came the control tube, for which a 6AU6 high-gain miniature pentode was chosen. The tube lineup was completed by an OB2 miniature VR tube, which was used to hold the control-tube cathode at a reference level of 108 volts.

DESIGN TROUBLES

Around these three tubes, Ryan and Marsey built a voltage regulator, the schematic of which is shown in figure 1. On the first model, which did not include resistor network R1-R2-R3, the center tap of the heater transformer was returned to the regulated B+ terminal. A few seconds after the power switch was thrown, the 6AU6 burned out. A second trial, with the transformer center tap returned to the control-tube cathode, left the control tube unscathed, but blew out the 6AS5.

These burnouts were obviously due to voltage breakdown between heater and cathode. In order to give a clear picture of what was happening during warm-up, as well as under normal operating conditions, the graph shown in figure 2 was prepared. From this chart, it is evident that the rectifier began to conduct 3 seconds after the power switch was closed, and reached full operating temperature at the end of about 5 seconds. The pass tube and the control tube, however, did not conduct at all until the end of the eighth second. The entire regulator was in operating condition by the end of the twelfth second.

Using this chart as a basis for calculations, it became easy to see why the tubes were burning out. Take first the case where the transformer center tap was returned to regulator B+. During the first 3 seconds, while the rectifier was heating, the cathodes and heaters of the pass tube and the control tube were all at ground

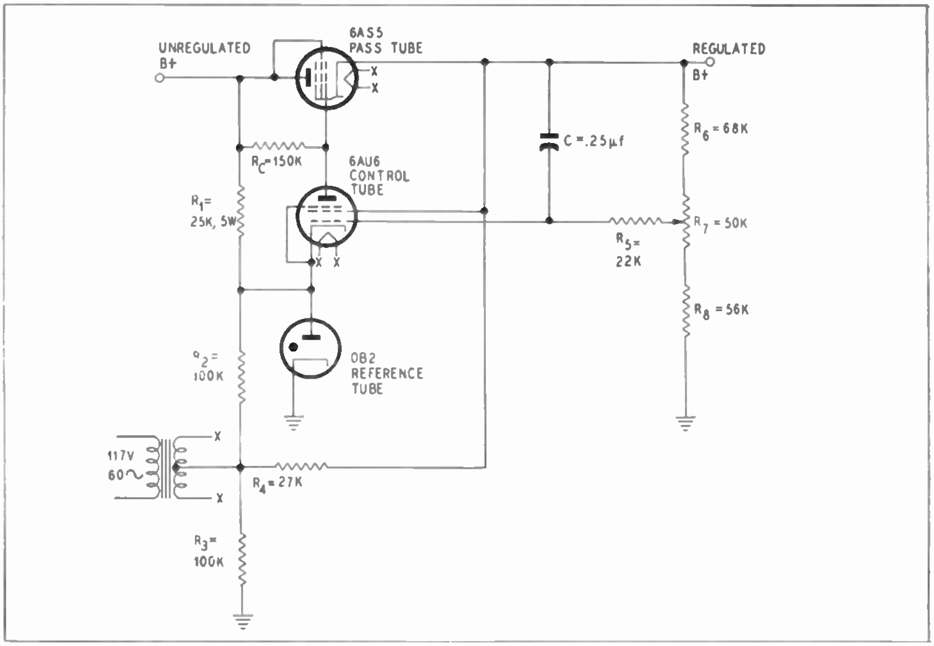


Figure 1. Complete Schematic Diagram of Miniature Voltage Regulator

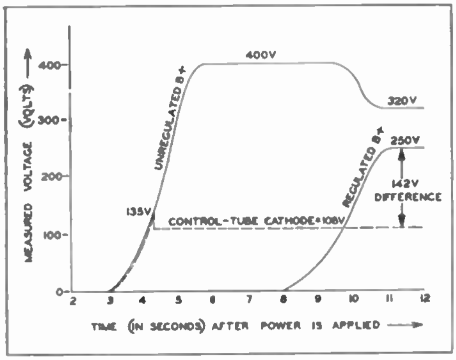


Figure 2. Voltage Variations in Regulator Circuit During Warm-Up (Without Protective Network)

potential, since there was no current flowing anywhere in the regulator circuit. In fact, the heaters remained at ground potential for at least 5 seconds, until the pass tube began to draw current through the bleeder connected across the regulated output. The cathode of the control tube, however, started rising as soon as the rectifier began to conduct (at the end of 3 seconds), and continued to rise until the VR tube fired, which occurred at a potential of about 135 volts. After that, the control-tube cathode was held at 108 volts. By that time, however, the damage had been done; the 135-volt peak had been enough to cause cathode-heater breakdown in the 6AU6, which has a maximum-potential rating of only 90 volts between these elements.

Returning the transformer center tap to the cathode of the control tube did little to improve the situation. The control tube was perfectly safe, because its cathode and heater were connected together. But the pass-tube cathode and heater were now as much as 135 volts apart during warm-up, and 142 volts apart during normal operation (see figure 2). Considering that the maximum cathode-heater rating of the 6AS5 is also 90 volts, a short tube life could be confidently predicted. This condition would be further aggravated if the regulator were adjusted to an output voltage higher than 250 volts.

THEORY OF PROTECTIVE NETWORK

A solution to this problem was found, and was incorporated in the final model. As shown in figure 3, it involves the addition of three half-watt resistors (R2, R3, and R4), and guarantees that neither tube will have a cathode-heater potential of more than 90 volts at any time, even if the regulated output voltage is increased to as much as 288 volts.

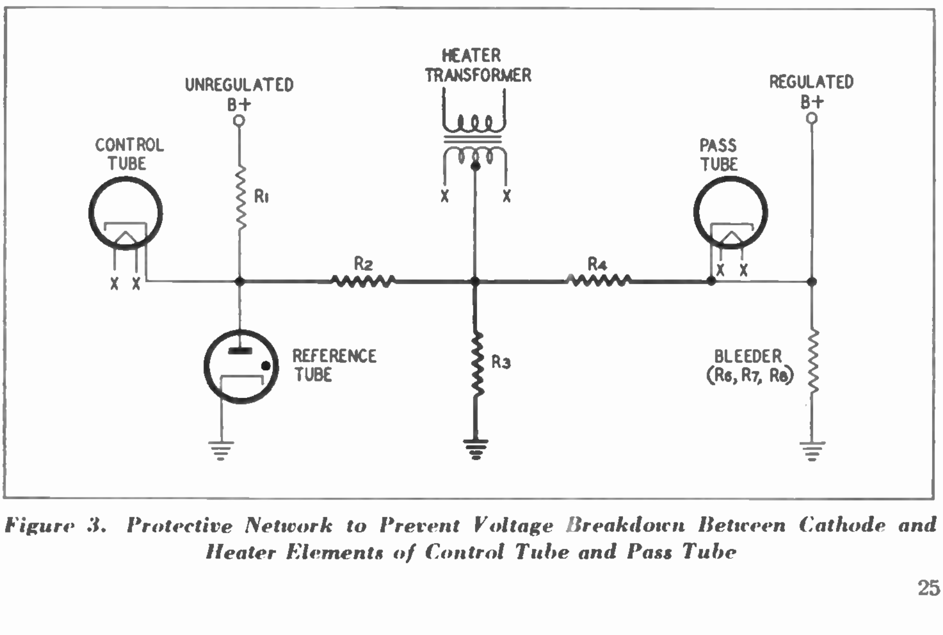


Figure 3. Protective Network to Prevent Voltage Breakdown Between Cathode and Heater Elements of Control Tube and Pass Tube

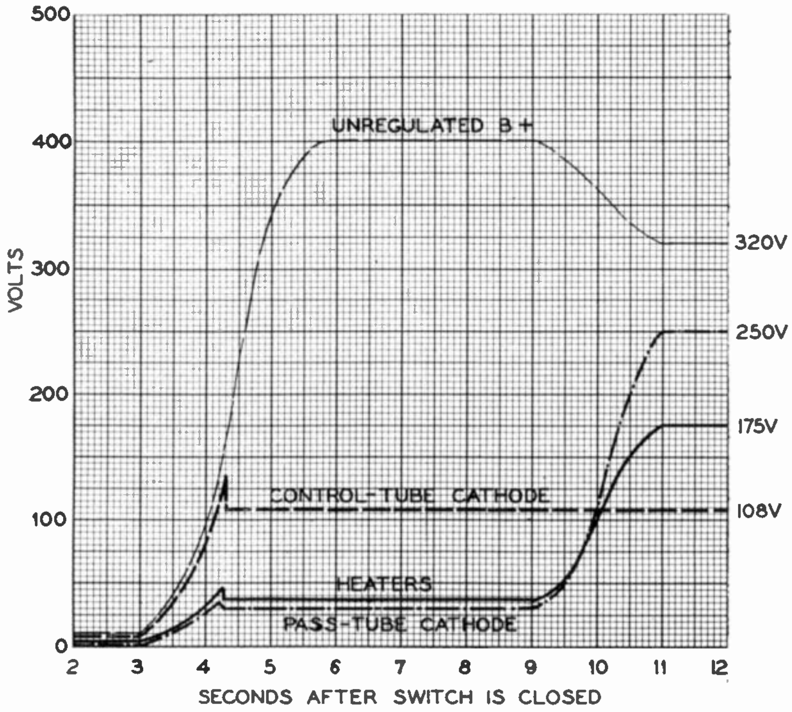


Figure 4. Voltage Variations in Regulator Circuit During Warm-Up (With Protective Network) Note that the protective network holds the heater potentials at values intermediate between the two cathode potentials, thus avoiding breakdown of the pass tube or control tube.

The protective network operates on the following principle: Instead of being connected to regulated B+ or to the cathode of the control tube, the transformer center tap is returned to a voltage divider designed to insure that the heater potential will always fall at some value *between* the voltages of the two cathodes. Referring to figure 4, it can be seen that the heaters are never more than 90 volts higher or lower than either cathode until the system has reached operating temperature. The three potentials then level off, with the cathodes at 250 volts and 108 volts, respectively, and with the heaters at a measured value of 175 volts. Under operating conditions, then, the cathode-heater potential for the pass tube is 75 volts, and for the control tube, 67 volts.

HUM SUPPRESSION

Having whipped the problems of tube selection and voltage overload, the Headquarters team proceeded to the question of hum suppression. In addition to its primary job of holding the B+ voltage constant, in spite of varying load currents and fluctuating input voltage, the electronic regulator also acts as a very efficient filter to suppress hum. A moment's reflection will show that superimposing hum upon a d-c voltage merely changes the amplitude of the voltage at a regular rate. And since the electronic regulator is specifically designed to suppress changes in amplitude, it can be used to supplement the action of the regular power-supply filter.

In order to take full advantage of the hum-suppressing capabilities of a regulator, it is important that any hum voltage present on the regulated B+ line be fed to the grid of the control tube with a minimum of attenuation. Any d-c variations appear on the grid only after passing through a voltage divider consisting of resistors R6, R7, and R8. Assuming that the control potentiometer (R7) is set at the midde of its range, a 10-volt change in d-c voltage at the output of the regulator will appear on the control-tube grid as a 4.5-volt change. This is quite adequate for control of low-frequency changes in output voltage, but an improvement would be possible if the grid of the control tube could be returned directly to the regulated B+ line —an obvious impossibility, considering that the cathode is anchored at 108 volts above ground by the VR tube, and that B+ is 250 volts above ground. The prospect of operating the control grid 142 volts positive with respect to its cathode is too painful for prolonged consideration.

In the case of the hum component, however, no such dilemma exists. The grid can be left connected to its d-c divider, but can be effectively connected to B+ (as far as the hum voltage is concerned) by connecting a .25-µf. capacitor between the grid and B+, as shown in figure 5. The reactance of this capacitor to 120 cycles is approximately 5300 ohms; therefore, a 10-volt hum appearing on the regulated B+ line would be fed to the grid as a 9.5-volt correction voltage, making hum suppression very effective.

After capacitor C was incorporated in the regulator, it was found that the voltage from a moderately "hummy" power supply having a peak ripple of 1.5 volts emerged from the regulator with a peak ripple of only $\frac{1}{40}$ volt. This represents as much suppression as would be expected from an L-section filter employing a 10-henry choke and a 10-µf. capacitor.

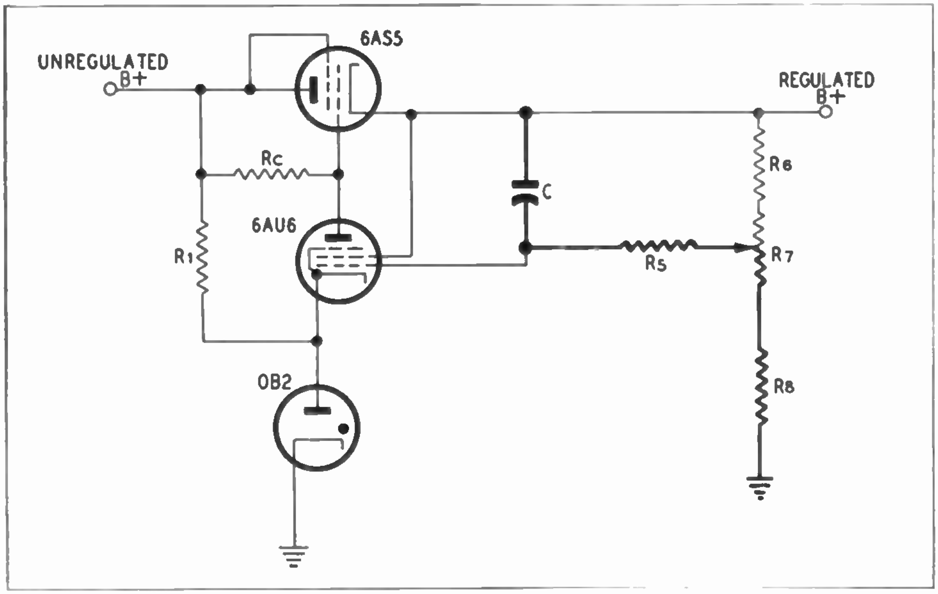


Figure 5. Simplified Schematic Diagram of Regulator, Showing Voltage-Divider Network (Heavy Lines) Used to Improve Hum Suppression

POSSIBLE USES FOR MINIATURE REGULATOR

The complete voltage regulator, shown in figure 1, has been in use in the Television Laboratory for several weeks, and has been found to be completely satisfactory. In addition to the use for which it was originally intended, the midget regulator lends itself to "outboard" mounting on the chassis of equipment not already provided with electronic voltage regulation. The photographs accompanying this article are of an outboard model designed for attachment to existing equipment by means of self-threading metal screws. The small voltage drop across the 6AS5 (as small as 50 volts at 50 ma.) usually makes it possible to use this regulator on existing power supplies without undue drop in the B+ voltage originally supplied to the load.

A number of improvements over the original circuit are now being contemplated. It seems possible to replace the OB2 with a "grain-of-wheat" neon bulb, with a further reduction in cost and size. The range of the control potentiometer can be increased in cases where a wider variation in regulated voltage is desired. (The model shown in the photographs has a range of 230-290 volts under a 50-ma. load.) If a current in excess of 75 ma. is to be regulated, two or more 6AS5 tubes can be connected in parallel, with small resistors in the plate and grid leads, to discourage parasitics and to insure proper division of the load. Just as it stands, however, the midget regulator is finding innumerable uses around the Headquarters laboratories. It is to be incorporated in a new television demonstration unit for use in the Armed Services schools, and tentative plans have been made to include it in future Philco laboratory equipment designed for the use of advanced radio and radar students.

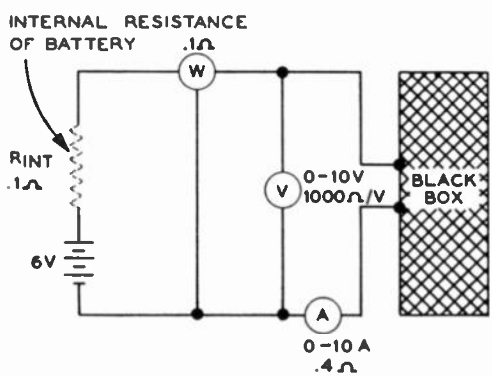
WHAT'S YOUR ANSWER?

By J. Carl Drumm, Hq. Technical Staff

In the figure, the following readings are observed:

Wattmeter—less than 2 milliwatts
Voltmeter—3 volts
Ammeter—5 amperes

What is in the black box? (*Solution next month.*)



CONTRIBUTORS

CHARLES H. BOYD

CHARLES H. BOYD—This writer first learned of the Philco field-engineering program when, as a CONVAIR employee, he rubbed elbows with Philco men stationed at Fort Worth, Texas. While at the bomber plant, Charlie performed maintenance on all types of test instruments used with electronic equipment installed in the B-36. The testimonials of the Philco men assigned to CONVAIR convinced Charlie that he should join the Philco family, so in January, 1951, he did join, and is now serving with the Far Eastern Air Force, in Japan. His first BULLETIN article, "A Trigger-Delay Unit for Radar Range-Zero Adjustment," appears on page 4 of this issue.

A U. S. Navy tour of duty, from 1945 to 1947, gave Charlie an opportunity to study aviation radio operation and radar maintenance in Naval schools at Memphis, Tennessee. He also received Naval Air Instructor training. As a civilian, prior to the War, he obtained academic training at Lee College and Houston University. Increasing public interest in television prompted Charlie to enter the American Television Institute, in Chicago, from 1948 to 1950. Upon graduation, he worked in the television camera laboratories of the Institute for several months before returning to Texas.

Charlie possesses a first-class radio-telephone license, as well as an advanced amateur-radio license. His call is W5RVO, and he operates on the 10-meter phone band.

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EDWARD J. CROSSLAND—While in Europe from 1947 to 1949 as a U. S. Air Force Staff Sergeant, Ed Crossland was associated very closely with the Philco Field Engineers assigned to his unit. At Erding Air Base, Germany, he met Philco men Jim Hangsteffer, Jack Herre, Walt Thornburg, Dick Laferle, and Ed Rogers, and became so imbued with the Philco spirit that he joined the Company himself in January, 1951. He has been a member of the Headquarters Technical staff ever since. In May, Ed was sent on a special field assignment to Warner-Robbins Air Force Base, Macon, Georgia, where he and H. "Bud" Merrihew, a contributor to earlier issues of the BULLETIN, are conducting a training program on heavy ground radar. While in Philadelphia, Ed wrote "Theory of a Moving Target

EDWARD J. CROSSLAND

Indicator System," which appears in this issue, page 7.

Ed's practical experience in electronics began in 1945, with the Public Service Company, of Tulsa, Oklahoma, Ed's home town. A year later Ed donned a uniform, and was sent to Ft. Monmouth, N. J., for duty with the Signal Corps. He attended electronics courses in radar, communications, and electronic control systems. After his training was completed, he was assigned to Europe, with the Air Force. He spent five months at Munich, and the following 14 months at Erding, where he eventually became Section Chief of Radar Maintenance. In 1949, again a civilian, Ed entered the University of Tulsa, where he majored in engineering and physics.

KENNETH L. SEATON

HERBERT M. LEE

KENNETH L. SEATON—Intensive field experience with military communications equipment under actual combat conditions qualified Ken Seaton to write his first BULLETIN article, "Modification of Test Oscillator TS-32(*)/TRC-1 to Furnish 5-MC. Output," appearing on page 31 of this issue. Ken became a Philco Field Engineer last summer, and is stationed in the Korean area.

For three years prior to his employment by Philco, Ken attended the University of Michigan, where he worked toward a Bachelor of Science degree in electrical engineering. He plans to complete the one year of study still required for his degree, in the not-too-distant future.

While in the U. S. Army, Ken was assigned to the Signal Corps, and for 30 months was responsible for the repair of all types of radio receivers and transmitters in the Signal Corps repair shop located in Honolulu. Following this duty, he spend the last eight months of his military career as NCOIC of the repair shop on the island of Hawaii.

Ken has sandwiched radio-repair work into his other activities ever since 1938, and more recently has transferred his talents to television repair. He holds a first-class radiotelephone license.

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J. CARL DRUMM—For a photograph and a brief biography of J. Carl Drumm, see page 13 of the February, 1951, issue of the BULLETIN. Carl's most recent BULLETIN article, "Voltage Regulators—Vest-Pocket Style," appears on page 22 of this (July) issue.

HERBERT M. LEE—This writer's first BULLETIN article is entitled "Crystal Grinding," and appears on page 20. Herb informed us that he was asked so many questions about the subject after H. W. Merrihew's recent article appeared (May, 1951), that he wrote this article to answer some of the same questions for others.

Herb is a Philco Field Engineer who is currently active at Tinker Air Force Base, Oklahoma, where he is engaged in the supervision of maintenance of Air Force technical equipment, and the instruction of personnel in such maintenance. When he joined the TechRep Division, in 1949, Herb was assigned to the Alaskan Air Command in a similar capacity for more than a year.

Herb's first acquaintance with communications gear occurred during a tour of duty in the U. S. Navy, from 1943 to 1946. He attended the Naval Training School at Corpus Christi, Texas, for five months, and until his honorable discharge, was engaged as an aviation electronics technician's mate. His postWar experience includes a one-year assignment with Pan American Airways, followed by a position with Lockheed Aircraft Corporation. Later, he entered Duke University, where he majored in electrical engineering. With almost three years of college work behind him, Herb plans to complete his undergraduate requirements for a degree in the near future.

Modification of TS-32(*)/TRC-1 To Provide 5-MC. Output

By Kenneth L. Seaton
Philco Field Engineer

A simple means of obtaining a 5-mc. signal for field alignment of badly detuned i-f transformers in the R19(*)/TRC-1 receiver.

(Editor's Note: This article was written as a result of a query by Air Force Inspectors for suggestions on improvement of existing test equipment. Mr. Seaton has not yet been informed of whether this modification has been accepted or authorized, but the article provides an excellent example of the way a Philco Field Engineer solves a tricky problem.)

Radio Receiver R-19(*)/TRC-1 is so well constructed that it gives very little trouble from component failures. However, the design is such that trouble is experienced when the 5 mc. i-f transformers are detuned so badly that they cannot be retuned with the TS-32 test oscillator.

The problem arises because the receiver circuit employs a double-conversion system in which the output of the crystal-oscillator harmonic-generator circuits is used as an injection signal for two separate mixer stages. When properly aligned, the high i.f. falls somewhere within the frequency range from 32.5 mc. to 47.45 mc. (depending on the frequency of the r-f signal to be received), while the low i.f. is always 5 mc. Normally, the 5-mc. i-f transformers do not require retuning in the field, except for possible touch-up adjustments during the conventional alignment procedure. But frequently an inexperienced operator detunes the 5-mc. transformers so badly that they cannot be retuned properly without a great deal of trouble (unless, of course, a signal generator capable of providing 5-mc. output is available). In field operating locations, such signal generators are rarely, if ever, provided; therefore, a simple means of providing a 5-mc. signal is highly desirable, if off-the-air time is to be kept to a minimum.

THEORY OF MODIFICATION

The sixth harmonic of the 80-mc. transmit crystal is 5 mc. (833.333 kc. x 6), as is the fifth harmonic of the 90-mc. transmit crystal (1000 kc. x 5);

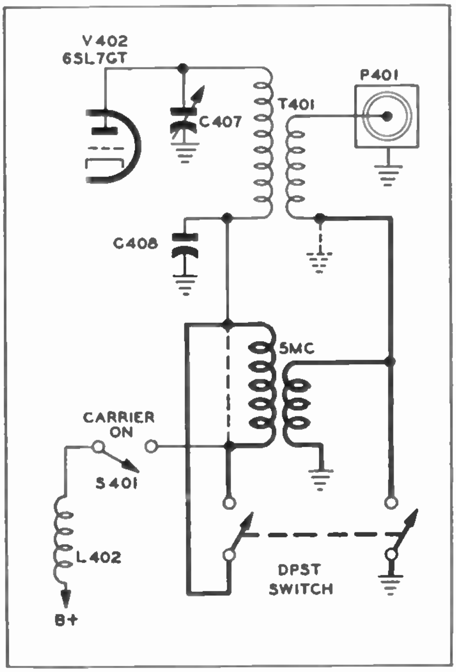

Figure 1. Simplified Schematic Diagram of Modified Output Circuit of TS-32(*)/TRC-1 (Dotted lines show original circuit, and heavy lines show added components.)

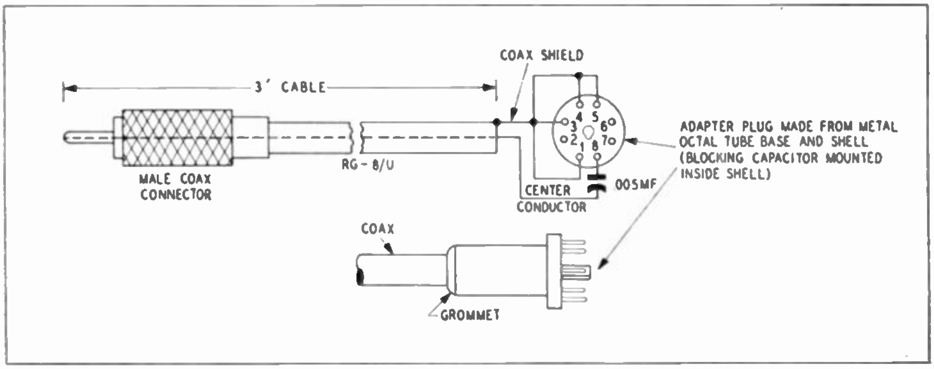

Figure 2. Construction and Wiring Details of Output Cable and Adapter Plug

therefore, if either of these crystals is placed in the TS-32, a 5-mc. harmonic component will exist in the plate current of the frequency-multiplier output stage. To make this 5-mc. signal available, it is necessary only to install a tuned output circuit that is resonant to 5 mc.

Figure 1 shows the changes required in the output stage; the dotted lines indicate the original circuit connections, while the heavy lines show added circuits. When the dpdt switch is open, the 5-mc. coil selects the sixth harmonic of the 80-mc. crystal (or the fifth harmonic of the 96-mc. crystal) previously placed in the usual crystal socket. The coil inductance is adjusted so that it tunes to 5 mc. when capacitor C407 is in the center of its range. Tuning is then not at all critical, and need not be adjusted. When the dpdt switch is in the closed position, the added circuits are shorted out, and the TS-32 operates in the normal manner.

The output of the oscillator is coupled to the receiver for 5-mc. i-f alignment by means of an adapter that plugs into the socket of i-f tube V104. Figure 2 shows the wiring and construction details of the adapter plug and cable.

CONSTRUCTION DETAILS

The following parts are required to accomplish the modification and to construct the adapter cable:

QUANTITY	DESCRIPTION
1 ea.	Switch, toggle, dpdt
1 ea.	Capacitor, mica., .005 μf.
1 ea.	Transformer, i-f, 5-mc. (from AN/TRC-1 spare parts)
1 ea.	Connector, coaxial, male
3 ft.	Cable, coaxial RG-8/U
1 ea.	Tube, octal, metal (only the base and metal shell are used)

The 5-mc. output-coil assembly is made from a spare i-f transformer (T-106, T-107, or T-108) found in the AN/TRC-1 spare parts. Since only half of the transformer is used, the porcelain coil form is scored around the middle with a file, then suspended on sharp edges, and broken in half by a sharp blow with an edged tool. The output coupling link is an eight-turn coil, closely coupled to the primary winding. The coil assembly is mounted on the left-rear corner of the chassis, adjacent to the 6SH7 socket, as shown in figure 3.

The .005-μf. capacitor is mounted in the adapter plug, and wired in series with pin 8 to keep receiver B+ voltage out of the cable and output link.

In order to provide room for mounting the dpdt switch on the left end of the TS-32 chassis (see figure 3), it is necessary to move C408 to the opposite side of the 6SL7 socket.

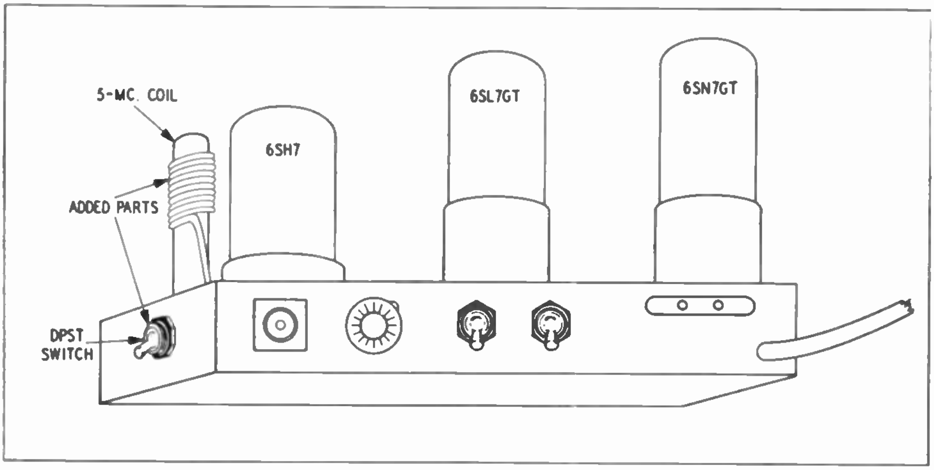

Figure 3. Front View of Modified TS-32(*)/TRC-1, Showing Placement of Added Parts

USE OF THE MODIFIED TEST OSCILLATOR

The 5-mc. output of the TS-32 is connected to the receiver by removing i-f amplifier tube V104, and plugging the adapter into the socket. The 5-mc. i-f trimmers are then tuned to their mid-positions, and the receiver panel meter is switched to position 1. Some reading should then appear on the meter. If a reading appears, all the 5-mc. i-f trimmers are adjusted for maximum meter reading; if no reading appears, the rear trimmer of T-107 is rotated slightly until an indication is obtained, after which the other 5-mc. i-f trimmers are peaked as before. The remaining circuits are then properly adjusted as in the usual i-f alignment, including the limiter and discriminator transformers, after which the adapter is removed, and tube V104 replaced. The adapter cord is removed from the TS-32, the usual output cable is connected, the dpdt switch is thrown to the closed position, and the r-f alignment is completed, using the proper transmit crystal.

Operators very seldom experience difficulty in aligning the r-f circuits of Radio Receiver R-19(*)/TRC-1 when the 5-mc. i-f stages are properly tuned. In numerous demonstrations this modified test oscillator has enabled rapid i-f alignment, even when used for the first time by the operator. The i-f circuits were completely detuned beforehand, a condition very difficult to correct by usual methods. Not a single failure of correct alignment has resulted in any of these demonstrations, and all who have participated in, or viewed, the demonstrations were impressed with the ease and speed of alignment of detuned i-f stages. This method of i-f alignment is not recommended for use when the operating frequency is being changed; it is recommended when the i-f stages have been detuned so badly that normal alignment is difficult.

(Note: Just before this issue went to press, Raymond Dick, Philco Group Supervisor in Korea, stepped into the editorial office and informed us that the modification described in this article has been thoroughly tested under field conditions, and has substantially reduced the amount of off-the-air time experienced on vital communications circuits between Japan and Korea.

He also stated that the modification has been further simplified since the article was submitted. The special output cable can be eliminated by constructing a small spring-clip device to snap onto one end of the standard 30" output cable supplied with the TS-32. Details of the device are not yet available, but the only requirement is a means of connecting the center conductor of the cable to pin 8 of V104 through a .005-µf. capacitor, and the use of a grounding clip for the shield of the cable. Ed.)

PREPARING A GOOD TECHNICAL REPORT

By John E. Voyles
Philco Group Supervisor
and
Douglas C. Dean
Headquarters Staff

Five points to remember in order to improve your reports.

ARE your technical reports adequate? Do they actually convey an accurate description of the job you are doing for the military service? Report requirements of individual military commands vary greatly; however, whatever the exact form of the report you are required to write, you should ask yourself the following questions:

1. Have I kept an accurate record of my activities day by day? If notes on the things that are done each day are kept in a pocket-size notebook, then when the day arrives for writing the technical report, the field engineer will not have to depend on his memory for everything he has accomplished or planned to accomplish since his last report was written.

2. Is my report accurate, brief, and impersonal? When a report is accurate, it gives a true picture of a situation, as found. When a report is brief, it contains only the detail that is absolutely necessary. Writing a report in an impersonal manner avoids excessive use of the word "I", and prevents criticism of any individual or branch of the military service. It is an easy matter to blame a service, such as Supply, and to complain that if parts were available, much more could be accomplished. It may be true that parts are difficult to obtain, but the situation can be corrected much more effectively by listing on each technical report the items ordered, the date they were ordered, the requisition number, and the tracer action taken. In this way it can be brought to the attention of higher commands that the delay in securing the parts has affected your work as a field engineer. The requisition numbers and dates of the orders will help Supply personnel in higher echelons to follow up on requisitions.

3. In being brief, have I left out things that should have been said? "No comment" or "Negative report" repeated too frequently in the technical report indicates to higher headquarters personnel that the field engineer has done very little to write about. (Higher echelons depend upon technical reports for much of their information concerning field-engineer activities.) Briefs of reports on unsatisfactory conditions submitted through prescribed military channels should be included, to indicate that action has been taken. Remember, technical reports are not generally action correspondence, but may contain information that results in action. Comments on types of maintenance performed, types of training conducted, hours spent in training, subjects covered, number of men in training and their backgrounds all give accurate pictures of a field engineer's activities.

4. Have I included extraneous information? Each section of the technical report should include only three phases of the job: work completed, work being done, and work to be done.

5. Have I committed a breach of security? It is the responsibility of the field engineer to check with his immediate superiors and the local Security Officer when in doubt about security, to see that the technical report is properly classified. Security is of utmost importance in all field-engineer activities.

If you give special attention to the five points discussed above, the quality of your future technical reports will improve, and all related field-engineer activities will benefit accordingly.

Wanted—ARTICLES

A recent card-questionnaire survey was conducted by the editorial staff to sample field reactions to the handling of content in the previous issues of this magazine, and to find out what subjects you readers wish discussed in future issues. The following list contains only a few of the suggestions received, but these are the subjects suggested most frequently, and on which information appears to be most desired:

Improvised Test Equipment

Noise Elimination in Receiving Equipment

Power-Equipment Maintenance

Antenna Theory and Construction

Crystal-Mixer Circuits

Screen-Room Construction

Magnetic Amplifiers

New Tubes, Crystals, Etc.

Applications of Thyrite Resistance Material in Armed Forces Equipment

Multiplex Theory

Noise-Diode Measurements

Synchro Systems—Data Transmission

Single-Sideband, Suppressed-Carrier Theory

MTI Features of New Radars

Transistor Theory

Velocity-Modulated Tubes

Effects of Weather on Radar Propagation

Transmission-Line Loading and Antenna Loading at Low Frequencies

Impedance-Matching Devices

Elimination of Radar-Pulse Noise in Communications Receivers

Sonar

Color Television

New UHF Developments

Telemetering

Radar Gun-Sights

New Radio-Compass Developments

Location of Noise Interference in Aircraft

Radar Calibration and Siting

Radio-Teletype Circuits

Field-Strength Measurements

Ground-Conductivity Measurements

Remote Control by FM Radio

Newly Developed Field-Maintenance Techniques

Traveling-Wave Tubes

A few of the above-listed subjects (such as color TV) are not directly related to field-engineering activities; however, the interest in this and similar subjects is so great, and our circulation has grown so far beyond the Philco TechRep Division, that we plan to publish papers on these subjects frequently.

NEW TRAINING MANUAL
on
Philco Microwave Radio Relay Equipment
(CLR-6)

Another in our current series of training manuals is now nearing completion, and will reach the field in September. It covers Philco's new CLR-6 Microwave Radio Relay Equipment, and is the first of a group of three manuals dealing with Philco Microwave Equipment. It will be followed by a manual on the Philco CMT-4 Time Division Multiplex Equipment (used with the CLR-6), and finally, by a comprehensive manual on Microwave Communications Systems.

The CLR-6 manual will be similar in style and format to the recently released "Training Manual on Radio Set AN/TRC-1," and will contain much fundamental information on the new r-f components incorporated into the CLR-6, as well as a complete analysis of all other circuits, and full alignment and trouble-shooting data. All necessary auxiliary information, such as siting data and system layout, will also be included.

Letters to . . .

(Continued from page 2)

"At Yokata I was working primarily on airborne radar, and the articles in the BULLETIN were right down that alley. I received my latest copy about a week before I left, and it looked so good I took it to the shop. It went over big with the Airmen." Robert E. Carter, Former Philco Field Engineer.

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"Perhaps binders for a number of issues could be made available. Often copies are mislaid for lack of a specialized place to put them." Max J. Fuchs, Jr., Philco Field Engineer, FEAF. (We're working on that. Ed.)

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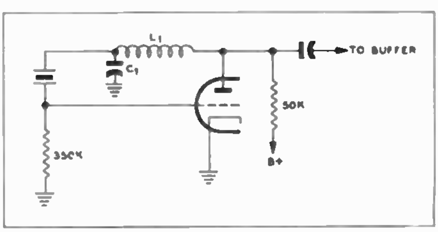
"A copy of your June, 1951 TechRep Division BULLETIN, received in this office and forwarded to our engineers, has elicited much favorable comment from them, and a request to obtain the BULLETIN regularly, if possible. They also would appreciate seeing copies of the first two issues of your BULLETIN, if they are available." Captain N. M. Young, Office of the Chief Signal Officer, Washington, D. C.

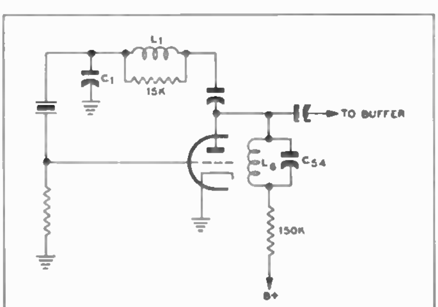
"SHORT CIRCUITS"

THE following problem was submitted by Philco Field Engineer Sidney Weiss, stationed at Fort Knox, Kentucky, and is published here because Headquarters has no information regarding the solution. If any reader has such information, please submit it to "Short Circuits" Editor, Philco TechRep Division BULLETIN, 22nd and Lehigh Avenue, Philadelphia 32, Pa.

"When aligning Receiver R-19/TRC-1 with Test Oscillator TS-32C, a dead spot (in oscillator output) occurs from 83 mc. to 85 mc. This phenomenon also occurs in Transmitter T-14, A, B, and C, but was corrected in the T-14D and T-14E by a change in the value of the plate resistor of the crystal oscillator, and by the addition of a tuned circuit, as illustrated below.



Schematic Diagram of Oscillator Circuit of T-14D and T-14E Before Modification



Same Stage After Modification

"TM 11-2601, page 164, par. 159 discusses this problem and its solution only with regard to the transmitter. The tuning procedure involves extra work when aligning the receiver at these frequencies, because a transmitter must be used as a signal generator.

"The file of Modification Work Orders in the Post Signal Repair Shop at this station contains no information pertaining to changes in the test oscillator. A number of solutions to this problem are possible, but I wonder if some such modification has not already been engineered and authorized. If there is any information available for the correction of this fault in the test oscillator, it will be very welcome."

If any readers have similar problems or solutions to such problems which they have encountered in the past, this column is the place to share them with other field engineers.

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