BROADCAST TRANSMITTER AND ANTENNA TUNING AND ADJUSTMENT

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STUDY SCHEDULE NO. 44

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

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BROADCAST TRANSMITTER AND ANTENNA TUNING AND ADJUSTMENT

Meeting FCC Requirements

ROUTINE daily operation of a.m. broadcast stations has been discussed in earlier Lessons. Proper operation of this transmitting equipment over extended periods of time, however, requires a knowledge of the FCC engineering standards for the operation of standard broadcast stations and of the proper adjustments and tuning procedures needed to meet these standards.

A broadcast transmitter and its associated equipment do not stay in adjustment indefinitely. Aging of components (especially tubes) with use will change their characteristics, and variations in the temperature, humidity, and dust content of the air will cause variations in the values of other circuit components. It is necessary, therefore, to check and readjust the entire transmitter system periodically. This includes equalization of the frequency response from the microphone to the antenna, and adjusting and retuning the transmitter, transmission lines, and, possibly, the antenna. Modulation monitors, frequency deviation monitors, peak limiting amplifiers, and monitoring rectifiers, amplifiers, and speakers also must be periodically checked and adjusted.

FCC ENGINEERING STANDARDS

Very few technical specifications are given in the FCC general rules and regulations pertaining to standard a.m. broadcast stations. The FCC has adopted the policy of specifying technical details in a separate publication, "Standards of Good Engineering Practice Concerning Standard Broadcast Stations." Such matters as the maximum frequency deviation, the permissible deviation from the rated power, the distortion permissible for different modulation percentages, and the over-all frequency response are covered in this publication.

A great number of conferences were held by the FCC with radio engineers, manufacturers of radio equipment, and others for the guidance of the Commission in formulating the Standards of Good Engineering Practice. These Standards necessarily change as progress in the art of broadcasting is made, so revisions are made from time to time. It is well for any broadcast operator to keep on hand the latest copies of the FCC Standards, which may be obtained from the FCC. As you will see in a moment, many of the Standards cover subjects that fall outside the operating engineer's scope of authority; nevertheless, he should be familiar with them so that he may have a more thorough understanding of the work he participates in. Many of the Standards that pertain to the regular operator's duties have already been discussed; others will be taken up in this Lesson.

Matters Covered. We shall not attempt to quote all the Standards word for word in this Lesson. It is worth while, however, to list the section headings so you can see what is covered by the FCC specifications.

The first several sections pertain to the station frequency allocation, location, and construction. This information is generally used only by the consulting engineering firm hired to set up the station initially, but it is of general interest to all radio broadcast technicians.

(1) Engineering Standards of Allocation.

(2) Field Intensity Measurements in Allocation.

(3) Data Required with Applications Involving Directional Antenna Systems.

(4) Locations of Transmitters of Standard Broadcast Stations.

(5) Minimum Antenna Heights of Field Intensity Requirements.

(6) Standard Lamps and Paints.

The next several sections deal with specifications regarding the transmitter itself. If you become an operator, you should be particularly familiar with these sections.

(7) Further Requirements for Direct Measurements of Power.

(8) Power Rating of Vacuum Tubes.

(9) Requirements for the Approval of the Power Rating of Vacuum Tubes.

(10) Plate Efficiency of Last Radio Stage.

(11) Operating Power Tolerance.

(12) Construction, General Operation, and Safety of Life Requirements.

(13) Indicating Instruments Pursuant to Section 3.58.

(14) Requirements for Approval of Broadcast Transmitters and Automatic Frequency Control Equipments.

(15) Requirements for Approval of Frequency Monitors.

(16) Requirements for Approval of Modulation Monitors.

(17) Use of Low Temperature Coefficient Crystals by Broadcast Stations.

The last sections are of more immediate value to the chief engineer than to the operator. An operator will benefit by becoming familiar with them, however.

(18) Money Required to Construct and Complete Electrical Tests of Stations of Different Classes and Powers.

(19) Use of Common Antenna by Standard Broadcast Stations or Another Radio Station.

(20) Use of Frequency and Modulation Monitors at Auxiliary Transmitter.

(21) Approved Frequency Monitors.

(22) Approved Modulation Monitors.

(23) Approved Equipment.

(24) Standard Broadcast Application Forms.

(25) Field Offices of the Commission.

(26) Average Sunset Time.

The remainder of this Lesson is devoted to showing you how to keep a transmitter and its associated equipment in proper adjustment to meet these FCC Standards. We will start with the audio equipment.

Adjustment of Audio Equipment

If the line between the studio and the transmitter is of any considerable length, the incoming audio signal at the transmitter end must be raised in level to overcome the losses in the line and to drive the first audio stage of the transmitter. This requires the use of a line amplifier, and in nearly all installations today this amplifier is of the limiting type. This type of amplifier has already been discussed; its proper adjustment will now be outlined.

Review of Operation. There are several different makes of limiting amplifiers for broadcast use, but their general installation, operation, and adjustment procedures are almost identical. Their primary function is to limit the audio signal to a certain pre-determined level, which is governed by the audio level required to drive the speech input stage of the transmitter itself. Limiting is produced by a circuit arrangement that automatically reduces the gain in the first stage of the limiting amplifier by an amount that is approximately proportional to the excess of input signal above the pre-determined level. This limiting action prevents over-modulation, which produces distortion and adjacent-channel interference.

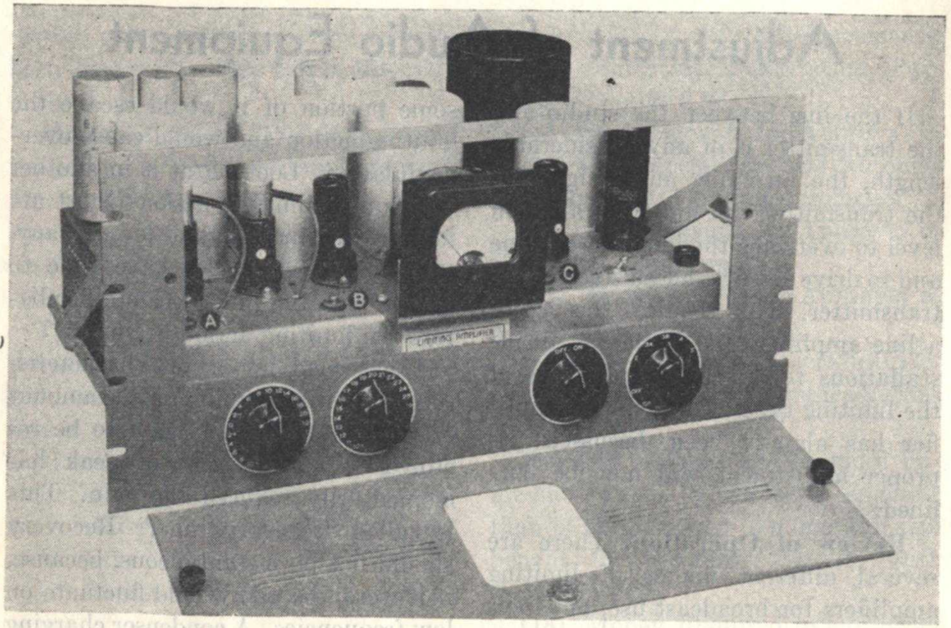
Since this type of amplifier must compress sudden peaks occurring in signal level, the circuits are arranged to reduce the gain in about 0.001 seconds. This "attack" time is fixed in nearly all limiting amplifiers. It must be an almost instantaneous action, because, if the duration of a peak were short compared to the attack time, some portion of it would escape the limiting action and would cause over-modulation. Looking at it in another way, quick limiting action (short attack time) means that few, if any, over-modulated cycles have time to get through the limiting amplifier before the limiting action begins.

The second important characteristic of a limiting amplifier is the amount of time taken for the gain to be restored to normal after a peak has momentarily reduced the gain. This is called "recovery time." Recovery should not be instantaneous, because, if it were, the gain would fluctuate on low frequencies. A condenser charging and discharging circuit governs the recovery time. In some makes of amplifiers, the constants of this circuit must be changed physically to alter the recovery time. In the WE 1126 amplifier (which you studied in an earlier Lesson), this recovery time can be conveniently adjusted from the front panel in five 0.2-second steps from 0.2 second to 1.0 second. Some manufacturers have delay circuits up to 5 seconds duration for restoring gain, but the optimum recovery time has been found to lie between 0.6 second and 1.0 second.

LIMITER ADJUSTMENT

To illustrate the adjustments of a typical limiter amplifier, the RCA 86A will be discussed. A front view of this unit with the panel removed is shown in Fig. 1.

Controls. All limiting amplifiers have two volume controls on the front panel (in this case, the two knobs



Courtesy RCA

FIG. 1. A front view of the RCA 86A Limiting Amplifier showing how a portion of the panel may be removed to permit access to the screwdriver adjustments. A is the HUM control, B the LIMITED LEVEL, and C the ZERO ADJ control.

on the left side of the panel). Since the normal input level available may vary widely in different installations, an "input control" is provided that permits adjustment of the input level at which compression of the signal begins. In this limiter, the input can be varied from +10 to —30 db. The approximate level to which the output is limited when normal compression is occuring can be adjusted through an "output control." The level can be varied from +10 to +30 db in this example.

To adjust a limiting amplifier, turn it on and allow it to warm up for about 10 minutes. Turn the meter selector switch (at the right side of the panel in Fig. 1) to the GR (gain reduction) position so that the meter indicates the amount of limiting action. This should read zero (that is, nearly full scale deflection) when there is no input signal. If this is not so, adjust the screwdriver control C (marked "ZERO ADJ") until the meter deflection is correct.

After the amplifier has warmed up, check the various plate currents and voltages by switching the meter-position knob located at the right of the panel.

Dynamic Balance. The dynamic balance of the push-pull input tubes is a very important item for this amplifier. Most of these amplifiers provide a means of checking this dynamic balance with the tubes in their normal positions on the chassis. This is usually accomplished by turning the meter switch to the proper position and noting the meter reading. In the RCA 86A, a portion of the meter scale is marked to show where the reading

should be if the tubes are matched properly. If the meter deflection is not within this range, you must change the tubes to obtain a matched pair.

If your limiter has no provision to check dynamic balance, you must order the balanced tubes in pairs with the stipulation that they must be dynamically matched tubes. Most manufacturers of limiting amplifiers furnish properly matched input tubes, which they sell in pairs specifically for this purpose. These tubes can be gotten simply by ordering under a certain stock number specified by each manufacturer. At least one spare pair, plainly marked to show their intended use, should be kept in the spare tube rack at the transmitter location at all times.

Hum Control. There is usually a hum control in the filament circuit of this push-pull input stage. (In Fig. 1, this control is a screwdriver adjustment marked A.) It consists of a potentiometer connected across the filaments; the adjustable contact is connected to ground to balance the currents flowing through the filaments. To adjust this control, disconnect the input terminals of the limiter amplifier from the line and connect a 500-ohm resistor across them. Then feed the output of the limiting amplifier to the input of another amplifier having a gain of about 60 db. This latter may be either a spare line amplifier or the monitor amplifier. (The inputs and outputs of the limiting, line, and spare amplifiers are generally terminated on the patch panel, so you can use patch cords to make the connections.) Listen to the output of the second amplifier with headphones, and with both amplifiers turned on, and with the input and output controls of the limiting amplifier in normal position, adjust the hum potentiometer for minimum hum. You will find that the potentiometer may be turned through a considerable arc at the center of its travel without introducing appreciable hum in the headphones; turn it in each direction to a position at which the hum is just noticeable, then reset it at a point midway between these two positions. This procedure should be carried out not only after the initial installation, but whenever a new pair of tubes is installed in the input stage.

Limited Level. Another screwdriver adjustment control on the chassis of this amplifier is the "limited level" (B in Fig. 1). This is a vernier control for close adjustment of the level at which limiting action takes place. This level may vary when tubes are changed.

To make this adjustment, apply a sine-wave audio input signal whose level is +10 db to the input of the limiting amplifier with both the input and output level controls set to +10 db. Adjust the "limited level" control until the meter scale indicates 0.1 db gain reduction. This completes the adjustment. The limiting characteristic of this amplifier is shown in Fig. 2. A similar curve can be obtained, if desired, by increasing the input above +10 db and noting the output level.

After this adjustment is made, set the input and output level controls to give whatever values are necessary to operate the transmitter properly.

Adjusting for Program Signals. The amount of program compression, or the amount and frequency with which gain reduction takes place because of program peaks, are deter-

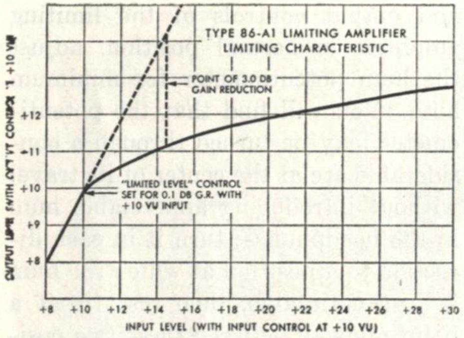


FIG. 2. Typical limiting characteristics of the RCA type 86A limiting amplifier.

mined by the input program level, the setting of the "input control," and the dynamic character of the program. Remember that the peak factor of ordinary program waves that are made up of the complex components of speech or music is much higher than the peak factor of a sine-wave generated by an audio oscillator. Therefore, after the above test has been made with a sine-wave signal, you must lower the gain adjustments 10 to 15 db to obtain 100% modulation on program peaks. This is best done by applying speech or music signals to the amplifier and adjusting the input and output controls to give the correct amount of compression and output level on the peaks of the signal waves.

This amplifier has a control on the front panel that permits the limiting action to be switched out. The amplifier can then be used as a regular audio amplifier.

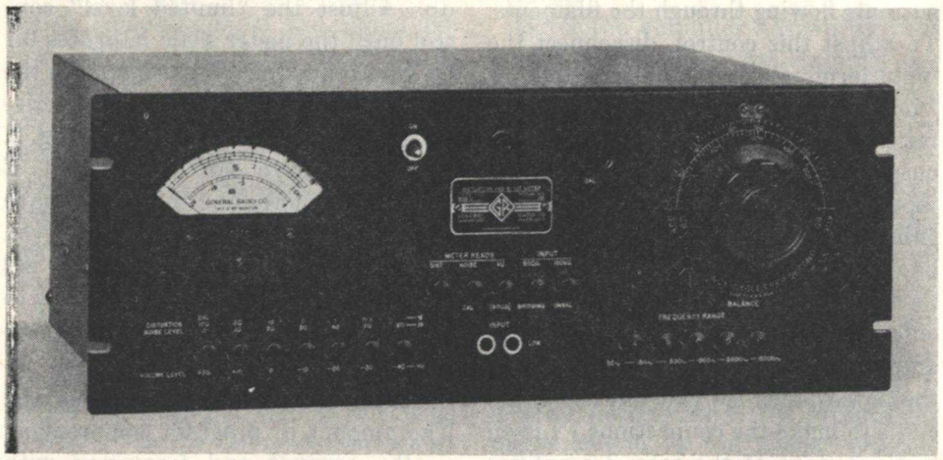
LINE AMPLIFIERS

The controls on a regular line amplifier (which is commonly used in a transmitter installation as a substitute for the limiter in emergencies) are less numerous and simpler to adjust.

A hum control is generally used; this is adjusted in the same manner as is that of a limiter amplifier. The only other control is a gain control. Once this is properly adjusted, the amplifier is ready for operation.

NOISE AND DISTORTION MEASUREMENTS

Included in the proper operation of a broadcast transmitter system is the



Courtesy General Radio Co.

FIG. 3. Front view of the GR 1932-A Distortion and Noise Meter, which is used by broadcast stations in checking station performance. This instrument is capable of measuring distortion from 0.1% to 100%, noise levels to —80 db, from +20 to —60 VU.

maintaining of the noise and distortion levels below certain levels specified by the FCC. Let us study typical equipment and methods used in measuring the noise and distortion in any portion of a broadcast system.

The General Radio type 1932-A shown in Fig. 3 is a typical distortion and noise measuring instrument for broadcast work.

Basically, as shown in Fig. 4 (the schematic of the GR 1932-A), this distortion and noise meter consists of a high-gain amplifier, a calibrated attenuator, a variable audio frequency band reject filter, and a diode voltmeter that permits the measurement of a large range of hum, noise, or distortion levels. Let us first observe its action for measuring noise or hum.

The input signal can be supplied either by a 600-ohm line or by a high-impedance source. The two right-hand Input push buttons just below the name plate in Fig. 3 select the proper input impedance.

When the Noise button (the middle one of the other three beneath the name plate) is depressed, the signal is fed directly to amplifier VT_4 in Fig. 4 and then to the calibrated potentiometer. This permits an amplifier gain variation from 0-60 db in 10 db steps. The steps are selected by the 7 meter range push buttons under the meter in Fig. 3. The output signal is applied to the v.t.v.m. amplifiers (VT_5 and VT_6 of Fig. 4), then rectified by VT_7. Its level is indicated on M_1. Since the scale can be read to 20 db below the full scale value, noise levels from 0 to —80 db with respect to 1 mw. (dbm) may be read.

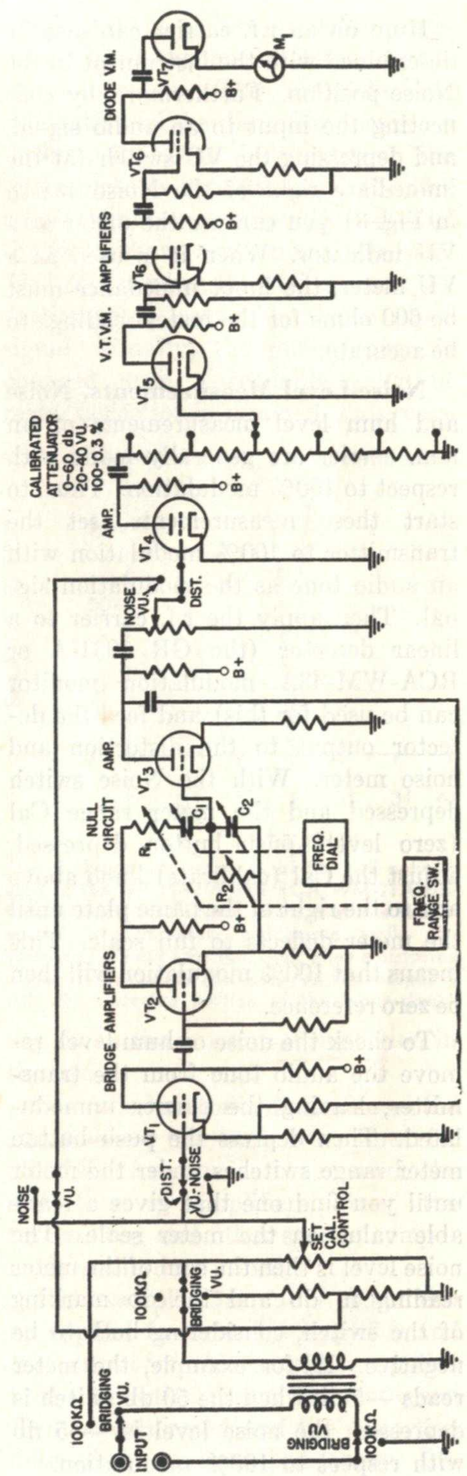


FIG. 4. Simplified schematic of the General Radio Type 1932-A Distortion and Noise Meter.

Hum on an r.f. carrier can also be determined with the instrument in the Noise position. Furthermore, by connecting the input to an audio signal, and depressing the VU switch (at the immediate right of the Noise switch in Fig. 3) you can use the meter as a VU indicator. When it is used as a VU meter, the input impedance must be 600 ohms for the meter readings to be accurate.

Noise-Level Measurements. Noise and hum level measurements of an a.m. carrier are generally made with respect to 100% modulation. Thus, to start these measurements, set the transmitter to 100% modulation with an audio tone as the modulation signal. Then apply the r.f. carrier to a linear detector (the GR 1931-A or RCA-WM-43A modulation monitor can be used for this) and feed the detector output to the distortion and noise meter. With the Noise switch depressed and the meter range Cal (zero level) push button depressed, adjust the Cal (calibrate) knob above and to the right of the name plate until the meter deflects to full scale. This means that 100% modulation will then be zero reference.

To check the noise or hum level, remove the audio tone from the transmitter, leaving the carrier unmodulated. Then depress the push button meter range switches under the meter until you find one that gives a readable value on the meter scale. The noise level is then the sum of the meter reading in db and the db marking of the switch, considering both to be negative. If, for example, the meter reads —5 db when the 50 db switch is depressed, the noise level is —55 db with respect to 100% modulation.

Distortion Measurements. Before we study how distortion is measured, let us first review some basic facts about amplitude distortion.

An undistorted signal consists of a sine wave of only one frequency. When a signal is distorted, however, it consists not only of the fundamental frequency but also of its harmonics. Thus, an amplitude-distorted 400-cycle note will contain a 400-cycle signal plus signals of 800, 1200, 1600, etc., cycles. The number of harmonics present, and their amplitudes and phase relationships, depend on the distortion present. It is this fact that permits us to measure distortion. *If the fundamental component is removed from a distorted signal, the amplitude of the other components present, expressed as a percentage of the amplitude of the original, is a measure of the distortion in the circuit.*

In this distortion meter, as shown in Fig. 4, the distorted signal is amplified by the bridge amplifiers (VT_1 and VT_2) and applied to an RC null circuit R_1-R_2-C_1-C_2. The response of this RC band-reject null circuit is shown in Fig. 5. Notice that the output at frequency F is zero, but that the harmonics of F (2F, 3F, etc.) are not attenuated. The null frequency (F) is determined by the values of R_1-R_2-C_1-C_2. For fixed values of R_1 and R_2, the null point can be changed by varying C_1 and C_2, which are ganged together. These two condensers are controlled by the calibrated knob at the right of the panel in Fig. 3, which is marked directly in frequency. In the schematic of Fig. 4, this is labelled Freq Dial. However, this control is labelled Balance, in Fig. 3, since it is normally adjusted to balance out

the fundamental component of a distorted audio signal. To adjust this null point over a wide range of frequencies, 50 to 15,000 cycles, the resistors R_1 and R_2 are adjustable in steps and controlled by the Frequency Range push button switches below the frequency dial.

When the instrument is used to measure the distortion in, say, a 400-cycle signal, the frequency dial is adjusted to 400 cycles. This removes the 400-cycle fundamental from the signal. The meter reading then indicates the amount of harmonic components (800-cycle, 1200-cycle, etc.) present, and thus gives a measure of the distortion in the signal.

Operating the Distortion Meter. All distortion measurements are made with a sine-wave generator as the audio signal source. For best results, this reference source should have low harmonic output (that is, have only slight distortion). Many types of audio signal generators are available for this purpose; the outputs of most of them, however, contain harmonics, the extent of which must be determined before the generator can be used for distortion measurements. Let us see how the GR 1932-A or WM-71A is used to measure the distortion in an audio-signal generator.

Since distortion is measured with respect to amplitude of the fundamental signal, and since in a low-distortion generator the output is practically all fundamental signal, the generator output is used as a reference in calibrating the distortion meter. To do this, the Cal button under the name plate and the Cal button at the left of the meter range buttons are depressed. Then the audio signal is applied to the input, and the calibration knob is adjusted until the meter shows a full-scale deflection. This completes the calibration of the distortion meter.

Next, the Dist. button under the name plate is depressed and the frequency dial is carefully adjusted until the meter shows a minimum deflection. This occurs when the dial is set at the fundamental frequency of the input signal. Finally, the meter range is changed until a readable value of meter deflection is obtained. This read-

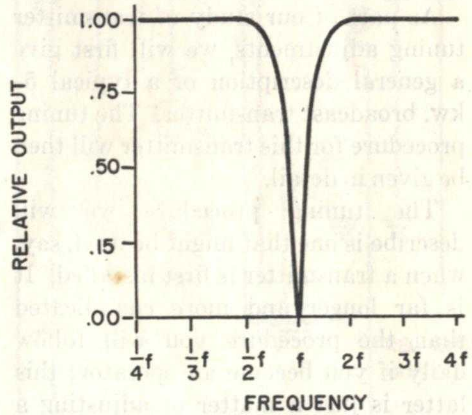


FIG. 5. Frequency response of the null network used in the GR 1932-A and RCA WM-71A Distortion and Noise Meter. Note that the fundamental is completely suppressed while the harmonics are not affected. Thus, when a distorted signal is applied to this network, the output is only the distorted portion of the input signal.

ing shows the amount of distortion in the signal.

Once the harmonic distortion of the audio source has been determined for all audio frequencies to be used, the distortion of amplifiers, lines, the transmitter, and other system components can be determined.

For example, the audio signal can be applied to an audio amplifier and the output of this amplifier applied to the distortion meter. The meter can then be calibrated and the distortion determined as described above. Remember, however, that the value of distortion obtained includes not only the amplifier distortion but that of the audio source as well. The source distortion, which has already been measured, must be subtracted from this measurement to find the distortion caused by the audio amplifier.

The distortion in a broadcast can be measured by using the audio sine-wave source to modulate the transmitter, demodulating the output with a linear r.f. detector, and applying the demodulated signal to the input of the distortion meter. In this case, the distortion measured will include that in the source and that in the r.f. detector as well as that in the transmitter itself.

Transmitter Adjustments

As part of our study of transmitter tuning adjustments, we will first give a general description of a typical 5-kw. broadcast transmitter. The tuning procedure for this transmitter will then be given in detail.

The tuning procedure we will describe is one that might be used, say, when a transmitter is first installed. It is far longer and more complicated than the procedure you will follow daily if you become an operator; this latter is just a matter of adjusting a few dials. Don't worry, therefore, if this tuning process appears complex; probably you will never have to do such a complete job—although, of course, it is well for you to know how it is done.

Figs. 6, 7, 8, and 9 show a simplified schematic diagram of the various stages in the RCA 5D air-cooled 5-kw. broadcast transmitter. This set has a class C r.f. final amplifier and uses high-level class B modulation.

GENERAL DESCRIPTION

The crystal oscillator (Fig. 6) located in the exciter unit uses an 802 pentode tube with a crystal connected between the control grid and the screen grid to provide isolation from the output plate circuit. The crystal itself is mounted in a holder in which are heater units to maintain correct operating temperature of the crystal. A spare oscillator, complete with crystal, heater unit, and tube, is part of the equipment; this spare oscillator may be switched into the circuit, when and if it is needed, by means of a switch on the panel of the exciter unit. The oscillators have an individual power supply using a 5Z3 rectifier.

The buffer amplifier (Fig. 6) consists of an 802 tube with a tank circuit that provides grid excitation and neutralizing voltages for the following stage. The buffer obtains plate and screen voltages from the "low-voltage" rectifiers (two 866's).

The next stage (Fig. 6) is the first intermediate stage, and uses an 805 tube. Taps are provided on the tank coil of this stage to supply the r.f. voltage necessary for the station's frequency monitor. Plate voltage is supplied by the "high-voltage" rectifiers (four 866's).

The second intermediate power amplifier (Fig. 7) (which is the exciter "final" power amplifier when this set is used as a separate 250-watt transmitter) uses a pair of 805's, with plate voltage supplied by the four 866 rectifier tubes comprising the high-voltage power supply. The degree of

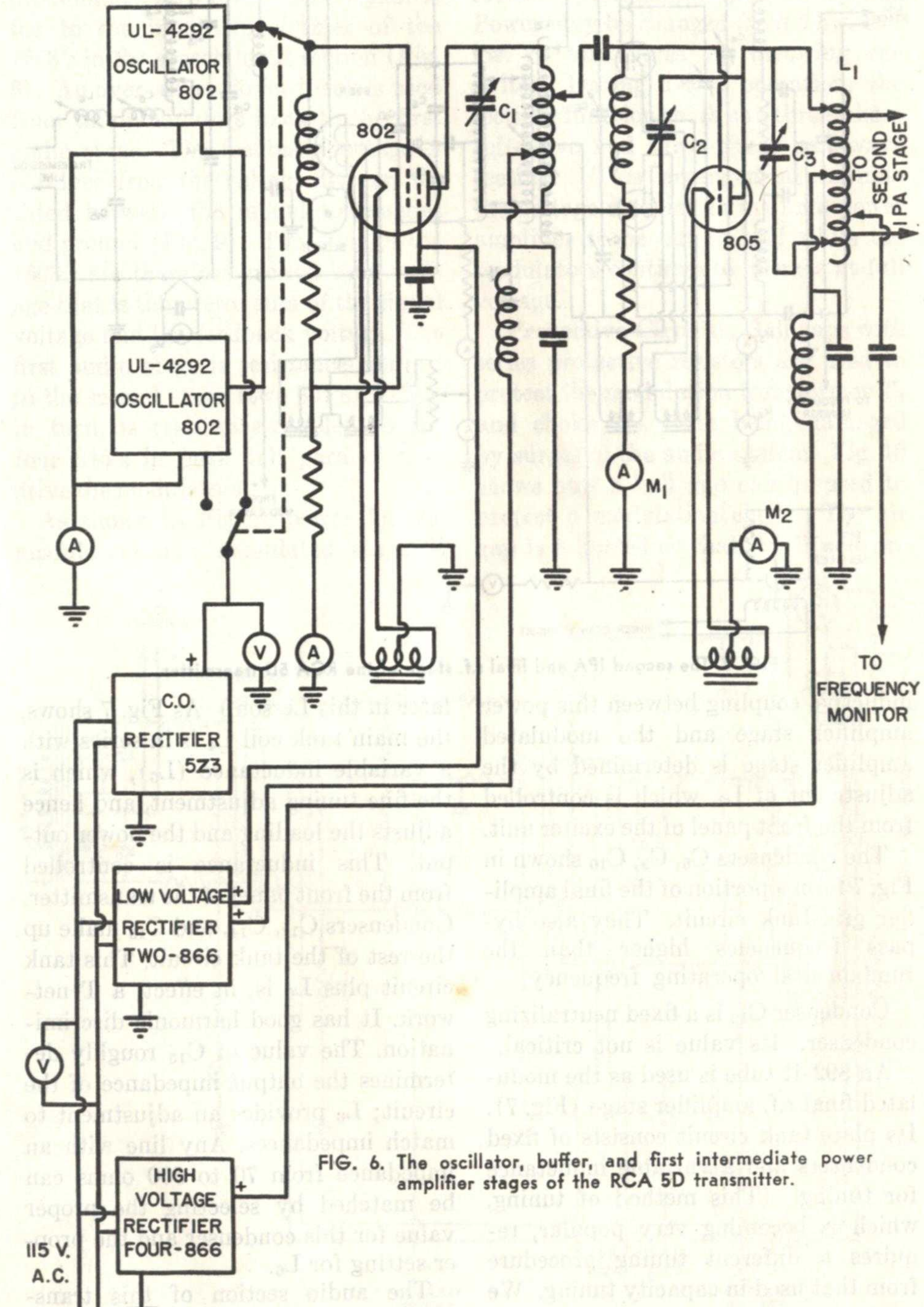


FIG. 6. The oscillator, buffer, and first intermediate power amplifier stages of the RCA 5D transmitter.

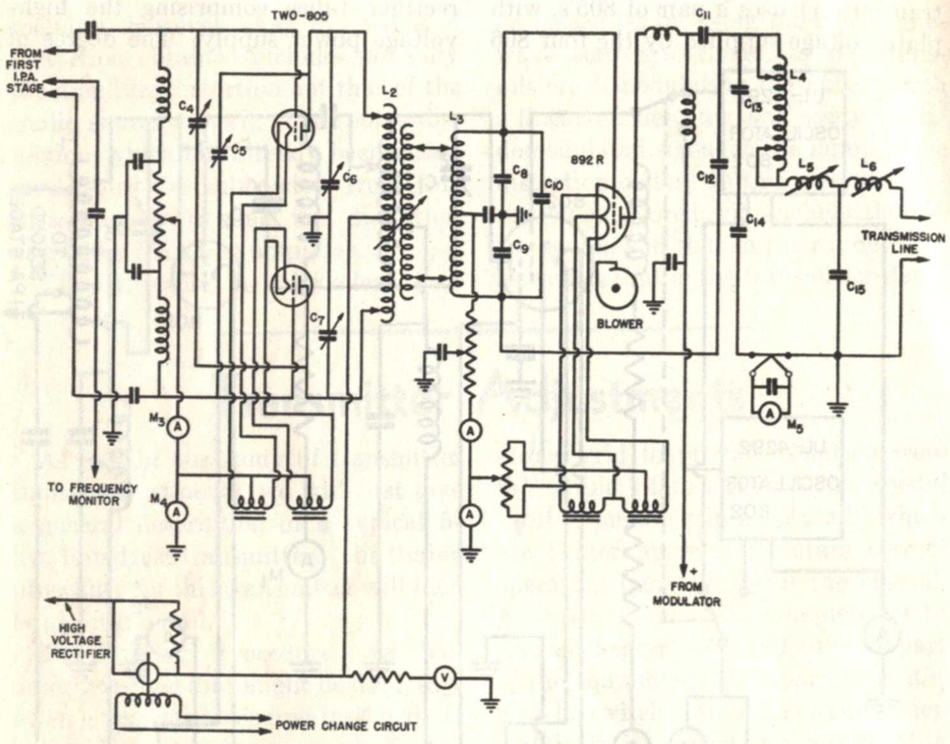


FIG. 7. The second IPA and final r.f. stage of the RCA 5D transmitter.

inductive coupling between this power amplifier stage and the modulated amplifier stage is determined by the adjustment of L_2, which is controlled from the front panel of the exciter unit.

The condensers C_8, C_9, C_{10} shown in Fig. 7 form a portion of the final amplifier grid-tank circuit. They also bypass frequencies higher than the fundamental operating frequency.

Condenser C_{12} is a fixed neutralizing condenser. Its value is not critical.

An 892-R tube is used as the modulated final r.f. amplifier stage (Fig. 7). Its plate tank circuit consists of fixed condensers and a variable inductance for tuning. (This method of tuning, which is becoming very popular, requires a different tuning procedure from that used in capacity tuning. We will discuss inductance tuning a little later in this Lesson.) As Fig. 7 shows, the main tank coil L_4 is in series with a variable inductance (L_5), which is the fine tuning adjustment, and hence adjusts the loading and the power output. This inductance is controlled from the front panel of the transmitter. Condensers C_{13}, C_{14}, and C_{15} make up the rest of the tank circuit. This tank circuit plus L_6 is, in effect, a T network. It has good harmonic discrimination. The value of C_{15} roughly determines the output impedance of the circuit; L_6 provides an adjustment to match impedances. Any line with an impedance from 70 to 500 ohms can be matched by selecting the proper value for this condenser and the proper setting for L_6.

The audio section of this transmitter, shown in Figs. 8 and 9, takes

its input from the line amplifier at approximately zero level. This signal is fed to the input transformer of the 1603's in the speech input section (Fig. 8). An over-all audio feedback is used from the modulators back to the first audio stage. The feedback voltage is obtained from the voltage dividers located between the modulator anodes and ground (Fig. 9). The grids of the 1603's are therefore excited by a voltage that is the vector sum of the signal voltage and the feedback voltage. The first audio stage is resistance-coupled to the second stage (two 807's) which, in turn, is resistance-coupled to the four 845's in push-pull parallel that drive the modulators.

As shown in Fig. 9, power for the modulators and modulated stage is furnished by a three-phase full-wave rectifier system made up of six 872-A's. Power may be changed from 5 kw. to 1 kw. or vice versa by throwing one switch. During 1-kw. operation, the rectifier functions both as a three-phase full-wave and three-phase half-wave rectifier. This arrangement permits the voltage supplied to the final power amplifier to be cut in half while the modulators continue to operate at full voltage.

Protective Circuits. Ball gaps with series protective resistors are used to protect the modulation transformer T_1 and choke L_{10} from being damaged by surges in the audio system. Fig. 10 shows how a ball gap can be used to protect a modulation choke. The air gap is adjusted so that it will not arc

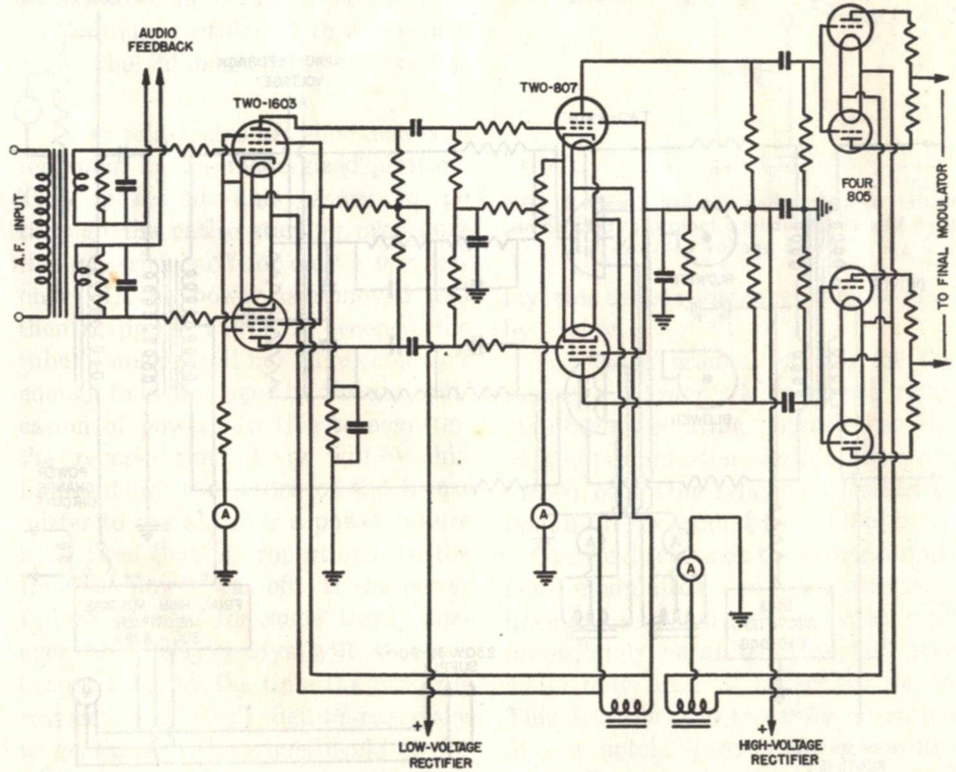


FIG. 8. The audio input, amplifier, and driver stages of the RCA 5D broadcast transmitter.

over on normal modulation peaks, but will do so if a voltage in excess of these peaks appears across the choke. Breakdown of the gap connects the protective resistor into the circuit. Adding this load to the circuit will usually protect the choke against internal arcing and damage. The resistor is necessary; if the gap were used without it, the sudden increase in current would itself cause damage to the transformer or choke to be protected.

Ball gaps on modulation transformers and modulation reactors should be cleaned, polished, and carefully adjusted for correct spacing. An excessively large gap is dangerous, for it does not give sufficient protection against modulation surges, which occur often with telephone-line transmission. The gap spacings for the modulation transformer and the modulation reactor in this particular 5-kw. transmitter are as follows:

Modulation transformer, each gap, 3/32″ (.094″) max.

Modulation reactor, ⅛″ to 3/16″ (0.125″ to 0.187″).

Each time a ball gap is inspected, the resistor mounted in series with it should be checked for continuity.

The gap on the main filter reactor should not be set to exceed ¼″.

Time-Delay Circuits. A time-delay relay in the exciter unit of this transmitter prevents application of plate potential for 20 to 30 seconds after application of filament power.

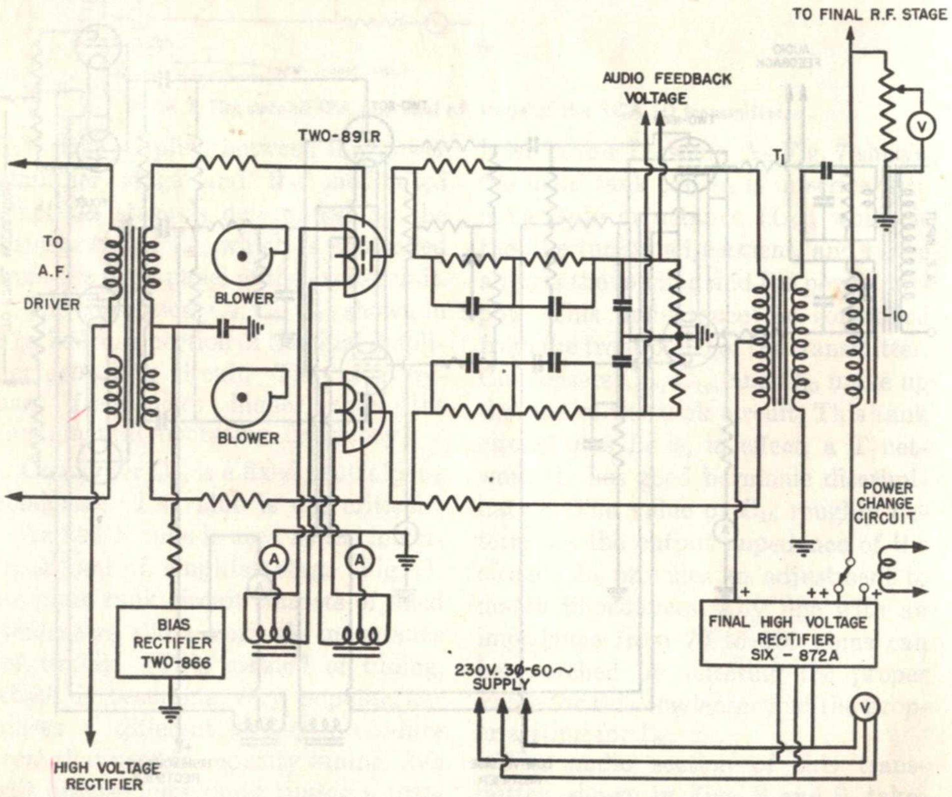


FIG. 9. The modulator stage of the RCA 5D broadcast transmitter.

There is also a filament-delay relay incorporated in this transmitter (and in most other modern transmitters) to protect the filaments of the amplifier and modulator tubes. This circuit prevents immediate application of full filament voltages to these tubes until the filament temperature rises to the normal operating value. This eliminates current surges through the tube filaments which would occur if full voltage were applied to the cold filaments, because their resistance is less when they are cold than when they are at normal operating temperature. Such current surges cause premature filament breakage in large power tubes. This relay should be set for 12 to 15 seconds delay after the main power is applied.

Another time delay is used to turn on the main rectifier 15 to 20 seconds after the filament-delay relay has closed.

These relays also use time delays in returning to the unenergized position. This makes it unnecessary to go through the entire starting procedure if the carrier is off for only a few seconds. If the power is removed and then reapplied within 10 seconds, the tube filaments will not have cooled off enough to be damaged by the re-application of power. In this transmitter, the reverse time delay will, within limits, delay the return of the transmitter to the air after a power failure by a time that is proportional to the time the power was off. If the power failure persists for some time, however, the delay relays will all have dropped out by the time the power is restored, and it will then be necessary to go through the whole cycle of operations to get the transmitter back on the air and operating normally again.

Another protective feature in this transmitter is a method of limiting the surge current flowing through the rectifiers to charge the filter condensers when the power supply is turned on. The high-voltage filter condensers are charged at a low rate through a series resistance when the high voltage is applied. This reduces current surges through the rectifier tubes and thus prolongs their life considerably. After a 1.5 to 3-second delay, this series resistance is shorted out by a relay.

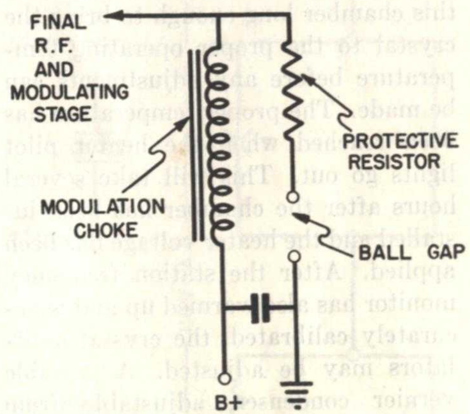


FIG. 10. How a ball gap and protective resistor can be used to protect a modulation choke from excessive voltage surges.

To assure gradual cooling of the tubes, a blower "keep-alive" relay maintains operating potential on the blower motors after the filaments are turned off. This relay is adjusted to remain in for from 4 to 7 minutes.

Overload relays on the power amplifier, modulators, and a.c. rectifier lines are adjusted so they "kick out" immediately on an overload but close again only after a 0.2 second delay. This delay is used to assure operation of the notching relay (which automatically reapplies the power several times in sequence before "kicking out" permanently). It also gives time for any arc to be extinguished before the power is reapplied.

OSCILLATOR ADJUSTMENTS

The two oscillators in this transmitter are each equipped with a crystal mounted within a temperature-controlled chamber. The electrical connections within this chamber are shown in Fig. 11.

The a.c. power must be applied to this chamber long enough to bring the crystal to the proper operating temperature before any adjustments can be made. The proper temperature has been reached when the heater pilot lights go out. This will take several hours after the chamber has been installed and the heater voltage has been applied. After the station frequency monitor has also warmed up and is accurately calibrated, the crystal oscillators may be adjusted. A variable vernier condenser, adjustable from the front panel of the crystal unit in the transmitter, gives fine control of the oscillator frequency; use this to adjust each of the oscillators to the exact operating frequency as indicated by the frequency monitor.

Before tuning the stages following the oscillator, open the rectifier-overload switch so that no plate voltage can be applied, and remove the plate caps from all tubes. Then close the line-voltage switch, and adjust the line voltage by means of the auto-transformer tap switch until the line voltage meter reads 115 volts. Next, close the filament switch and check all filament voltages with a suitable voltmeter. These voltages should be within 2% of their rated values.

Double-check the operation of both crystal oscillators by replacing the plate caps on the oscillator tubes (only) and closing the plate voltage switch. (The crystal oscillator power supply will operate and plate voltage will then be applied to the oscillators, provided that all door interlock switches and contacts of the overload and time-delay relays are closed.) The voltmeter for this stage should indicate an output of 330 volts, plus or minus 10 volts. Check both oscillator circuits by switching from one to the other. The proper grid current on the buffer stage will also indicate that the oscillator circuit is operating correctly.

Remember that closing the plate voltage switch turns on all power supplies in the unit. Since the rectifier tubes may be damaged if they are operated without a load, it is advisable not to replace the plate caps of the rectifier tubes in the power supply for any stage until you have replaced the plate cap on the tube in that stage. This should not be done, however, until you have adjusted the preceding stage. By applying plate voltage to each stage in turn, you make certain that the following stage in each case will be properly excited and will therefore develop sufficient bias to protect it from damage if it is out of resonance. Following this system, you will first adjust the oscillator to resonance with no plate voltage on the buffer and following stages. Then you can safely apply the plate voltage to the buffer, tuning this stage to resonance and providing proper excitation to the intermediate, etc.

Buffer Stage. Next, replace the plate caps on the low-voltage 866 rectifier tubes and the 802 buffer stage (shown in Fig. 6). Close the plate switch to apply plate and screen voltages to the buffer tube, and adjust the buffer tank condenser C_1 for resonance as indicated by minimum plate current. *To avoid tuning to a harmonic of the operating frequency, start tuning with the variable condenser at its maximum value.* Check the screen voltage of this stage with a voltmeter and, if necessary, limit it to 230 volts by adjusting the taps on the voltage divider associated with the screen supply. Because of the characteristic of screen-grid tubes, this buffer stage needs no neutralizing adjustment.

Read the line voltage meter after applying plate voltage to each successive stage, because the line voltage will be lowered by the added current drain through the auto-transformer across the power line. Adjust the voltage to the proper value with the line voltage adjustment knob.

Caution. *Always take extraordinary precautions to avoid contact with high voltage. When the doors are open, always double-check to be sure that the interlock switch system has cut off the high voltage and has discharged the voltage filter.* These automatic switches, which are found in all modern transmitters, are required by the FCC Standards of Good Engineering Practice. In older transmitters where this automatic protection is not used, make sure these condensers are discharged by using a screwdriver with an adequately insulated handle to ground the plate terminal of the tube before touching the plate caps or any component part.

First Intermediate Power Amplifier. To put this first IPA 805 stage (Fig. 6) into operation, replace the plate cap of the 805 tube. (Leave off the caps of the high voltage rectifier for the time being so there will be no d.c. on this stage.)

Next, neutralize the stage by adjusting the associated neutralizing condenser C_2 until M_1 indicates zero or minimum grid current.

Replace the high-voltage rectifier plate caps and tune the stage tank circuit by varying C_3 until M_2 indicates

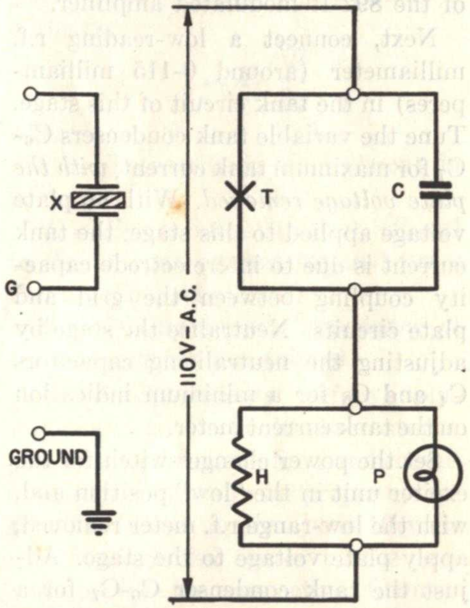


FIG. 11. The crystal oscillator chamber used in the RCA 5D transmitter. The symbols are: X = Crystal, G = grid connection, H = heater winding, C = capacity, T = thermostat, P = pilot light (external).

minimum plate current. Remember again to start tuning at the maximum value of capacity. Next, adjust the plate voltage for this stage to 800 volts by adjusting the connection on the tapped voltage divider resistor.

Second IPA Stage Adjustment. The first step in adjusting this push pull stage (Fig. 7) is to equalize the grid current flow. To do this, first remove each tube in turn and note the grid current indicated by M_3. The two currents should be equal within 10%; if they are not, adjust the grid taps on L_1 (Fig. 6) until measurements show that the currents are this near to being equal.

Next, replace the caps on the push-pull 805 tubes. Adjust the vario-coupler L_2 so that the coils are at right angles to each other, thereby creating minimum coupling to the grid circuit of the 892-R modulated amplifier.

Next, connect a low-reading r.f. milliameter (around 0-115 milliamperes) in the tank circuit of this stage. Tune the variable tank condensers C_6-C_7 for maximum tank current, *with the plate voltage removed.* With no plate voltage applied to this stage, the tank current is due to interelectrode capacity coupling between the grid and plate circuits. Neutralize the stage by adjusting the neutralizing capacitors C_4 and C_5 for a minimum indication on the tank current meter.

Set the power change switch for the exciter unit in the "low" position and, with the low-range r.f. meter removed, apply plate voltage to the stage. Adjust the tank condenser C_6-C_7 for a minimum plate current on M_4.

After this stage has been properly neutralized and tuned, check the individual plate currents of the 805's for balance. The currents of the two tubes should balance within 5%, and should not exceed 210 ma. per tube. This is the maximum plate current rating for an 805 tube.

Modulated Amplifier. The grid and plate circuits of the 892-R output stage use fixed tuning condensers (C_{13}, C_{14}, C_{15}) whose values depend upon the frequency of transmitter operation. The feed line from L_2 taps onto the final grid tank coil L_3 symmetrically. Proper placement of these taps varies from four turns off center at 1600 kc. to six turns off center at 550 kc. This is not a critical adjustment, but simply controls the matching of circuits for maximum efficiency of energy transfer.

You can now vary L_2 to obtain the proper amount of drive for this stage.

Neutralization of this 892-R stage is fixed by C_{12}. Check the neutralization by energizing the exciter unit (with final amplifier *filament* voltage applied) and observing the final tank current on the tank r.f. meter. This meter should not read in excess of approximately 200 ma. with the antenna load connected. If this current is excessive, correct the neutralization by carefully balancing the taps on the grid coil of the final. The symmetry of voltages at this point will determine the accuracy of neutralization.

Since the final power amplifier tank circuit is tuned by adjusting taps on the main tank inductance and by varying two variable inductances in the T network that matches the circuit to the transmission line, let us study the characteristics of inductive tuning before we learn how to make these adjustments.

INDUCTIVE TUNING

Inductive tuning like that used in this typical 5-kw. transmitter has become almost universal for medium and high-power installations. You should, therefore, become familiar with the differences existing between tuning procedures for variable inductance and variable capacitance. *The principal difference is that the frequency at which the tuned circuit has maximum impedance (plate current is a minimum) is not the frequency for which there is a maximum power transfer from the circuit.*

Thus, when a tank circuit is tuned by means of a variable inductance, maximum power transfer to a coupled stage will not occur at the point of minimum current indication. Therefore, you should tune for maximum current in the coupled stage rather than for minimum tank circuit current.

As an example (assuming for the moment that the antenna is properly coupled to the transmission line), you should tune the final stage of this 5-kw. transmitter by varying L_5 through the point of minimum current to where the plate current starts increasing, and read the antenna current to see if it has increased or decreased. If the antenna current is less than it was, turn the inductor knob in the opposite direction through the point of minimum plate current to a point where the current is again increasing. The antenna current will now have increased, showing that the tuning is correct. If the modulated amplifier shows incorrect loading (plate current too great or too small) when this adjustment is made, you can change the loading by changing the coupling capacity C_{15} of the output T circuit. (An increase in this capacity will decrease the loading, for C_{15} will then have less reactance at the operating frequency and therefore less voltage will be dropped across it. Because the power in the transmission line depends upon the voltage drop across C_{15}, less voltage drop will result in less power transfer to the load, decreasing the loading on the final stage.)

If the discrepancy is not too great, you can control the loading by varying L_6 and thus creating a small variation in the apparent impedance of the transmission line.

You can check on the coupling to the transmission line by inserting an ammeter in series with the output of the transmitter coupling and another in series with the input to the antenna coupling. The currents indicated by the two meters should fall within 20% of the value:

$$I = \sqrt{\frac{W}{Z_o}}$$

where:

I = Transmission line current in amperes.

W = Power output (watts). (Equal to the antenna current squared times the antenna resistance.)

Z_o = Characteristic impedance of the transmission line (ohms).

Final Adjustments. Before applying power to the high-power stages, you should check the final and modulator overload relays for proper operation. To do so, apply about 10 volts d.c. between the center of the secondaries of the respective filament transformers and ground. This voltage is sufficient to cause an overload current to flow; the overload relays will kick out if they are operating properly.

The power input of the transmitter may be controlled over a wide range by varying L_5. It is important that this inductance be tuned to the side of minimum plate current indication that gives maximum antenna current. On the correct side of resonance, this inductance may be varied over a wide range to adjust the power input without appreciable affect on the impedance match.

After all adjustments have been made as outlined, one of the crystals should be removed so that the oscillator switch may be thrown to the "dead" crystal circuit. Thus, with low power on the transmitter, the oscillation may be stopped at will for testing. (Of course, this test is made only during the initial adjustment of the transmitter at installation, or when the operation of the transmitter indicates that some r.f. amplifier stage is oscillating. Normally, the crystals are kept in their ovens at all times.) This stopping of oscillation should cause all grid currents and the tank current of the modulated amplifier to return to zero. If they do not, then there is un-

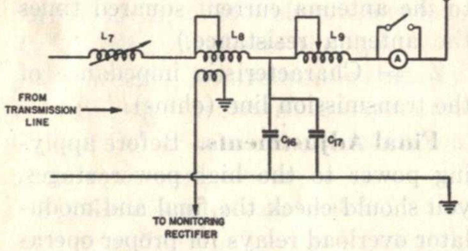


FIG. 12. The antenna coupling unit of the RCA 5D broadcast transmitter.

desired regeneration or oscillation present. If no indication of spurious oscillation results, the same tests should be made with high power applied to the transmitter. Assuming that the circuit operates properly, the transmitter is now ready to be modulated and "go on the air."

ANTENNA COUPLER TUNING

The antenna coupling unit for this transmitter is shown in Fig. 12. The purposes of this T section are: (1) to balance out any reactance in the antenna circuit so that it appears to the transmission line as a pure resistance; and then (2) to make this resistance equal to the characteristic impedance of the line, thereby producing maximum power transfer.

The best way to adjust the coupling unit is to use some impedance measuring device (such as the r.f. bridge, whose use for this application will be discussed later in this Lesson) to measure the input impedance. Then, set L_8 and L_9 and vary L_7 until the antenna reactance is zero and the input impedance is equal to the line impedance. If these conditions cannot be produced with the settings chosen for L_8 and L_9, choose other settings and try again, repeating the process as many times as necessary. (This is not as difficult as it may first appear, since the transmitter manufacturer will tell you approximately what values of inductances to use to couple to usual types of antennas for any fixed frequency.)

Linear Amplifier Adjustments

You have already studied the theory of class B linear r.f. amplifiers, but, to refresh your memory, we will now review it briefly.

The operation of a push-pull linear r.f. amplifier may be represented by the diagram in Fig. 13. As shown, the plate currents drawn by the two tubes A and B are very nearly linear reproductions of the grid-voltage swing. Maximum efficiency of such an amplifier is determined by the output circuit loading. When the output voltage is proportional to the grid-voltage swing, the power output is proportional to the square of the grid swing. Thus, the peak power output is proportional to the square of the grid swing, and the peak power output at 100% modulation will be four times the output when the modulation is zero.

The adjustment of a linear r.f. amplifier will involve finding the correct r.f. excitation, grid bias, plate voltage,

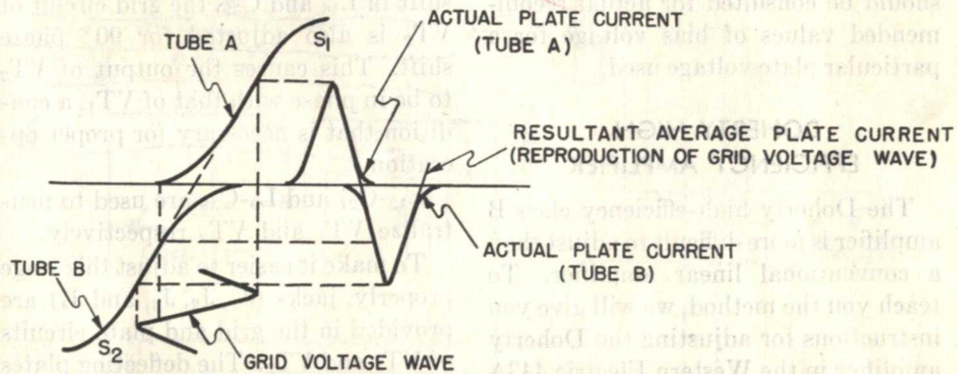


FIG. 13. Curves illustrating the action of a push-pull linear r.f. amplifier.

and load impedance to obtain the desired linearity and efficiency. When ample excitation and voltage is available, the combination of exciting voltage and load impedance that gives full peak output with good linearity can be determined experimentally, as can the bias voltage giving best linearity.

To find the correct setting of taps for best output-tank loading, the grids of the amplifier tubes are saturated with r.f. grid driving power. Then, with one-half the normal plate voltage applied to the linear stage, the amplifier is loaded until it delivers rated carrier power to the antenna. The plate impedance is adjusted so that the efficiency is about 65% or 70%, or equivalent to the plate efficiency of a linear stage under full or 100% modulation. This plate load impedance can be adjusted by changing either the LC ratio of the tank circuit or the coupling between the tank and antenna circuits. Since the LC ratio is usually fixed in commercial installations, the second method is the one most commonly used upon installation or tuning of a commercial transmitter. The tighter (closer) the coupling, the lower will be the plate circuit impedance offered by the tank circuit. The looser the coupling, the higher will be the plate load impedance.

The grid exciting voltage is then reduced by grid-loading resistors until full plate voltage to the amplifier stage gives the same rated carrier power output with a corresponding plate efficiency of about 33-1/3%. This is the plate efficiency for a class B r.f. amplifier as specified by the FCC rules for determining carrier output power by the indirect method.

This method lets you find the grid excitation and the plate load impedance of the linear stage that will give the highest plate efficiency consistent with the desired r.f. power output.

A class B r.f. amplifier is neutralized the same way that a class C stage is.

It is assumed that the correct grid-bias for class B operation has been determined from the amount of plate current to be used. As illustrated in Fig. 13, the optimum grid bias is determined by the point where an extension of the straight portion of the curve intersects the horizontal axis. The grid bias for a class B r.f. amplifier should be approximately the plate supply voltage divided by the tube's amplification factor. Manufacturers' ratings for tubes operating as linear amplifiers should be consulted for actual recommended values of bias voltage for a particular plate voltage used.

DOHERTY HIGH-EFFICIENCY AMPLIFIER

The Doherty high-efficiency class B amplifier is more difficult to adjust than a conventional linear amplifier. To teach you the method, we will give you instructions for adjusting the Doherty amplifier in the Western Electric 443A transmitter.

The circuit diagram of this stage is shown in Fig. 14. Before we learn how to adjust it, let's see how it works.

The unmodulated r.f. voltage is applied through L_3 from the driver stage to VT_1. The C bias, r.f. drive, and load for this stage are adjusted so that (with VT_2 not conducting and with no modulation) its efficiency is about that of a class C amplifier. Its output is coupled through L_{15} to the output network. On negative modulation peaks, the audio output from T_{29} will cause the output of VT_1 to decrease linearly to zero (which corresponds to —100% modulation).

On positive modulation peaks, tube VT_2 will operate and supply power to the load through L_{16}. Because of the 90° phase shift of L_{16} and C_{39}, the load of VT_2 will be inverted, that is, as VT_2 conducts, its resistance will decrease but the load on VT_1 will increase causing VT_1 to deliver more power to the output. On 100% modulation peaks, carrier tube VT_1 and peak tube VT_2 will each be supplying twice carrier power to the output and will be operating at about class C efficiency. The efficiency which the FCC assumes in indirect measurements is 65%.

To compensate for the 90° phase shift in L_{16} and C_{39}, the grid circuit of VT_2 is also adjusted for 90° phase shift. This causes the output of VT_2 to be in phase with that of VT_1, a condition that is necessary for proper operation.

L_{12}-C_{27} and L_9-C_{38} are used to neutralize VT_1 and VT_2 respectively.

To make it easier to adjust this stage properly, jacks (J_1, J_2, J_3, and J_4) are provided in the grid and plate circuits of VT_1 and VT_2. The deflecting plates of an oscilloscope can be connected directly to these points to measure the phase shifts and amounts of voltage in the circuits. The scope thus can be used as a neutralization indicator, for determining when 90° phase shifts are obtained and for determining when the loading is resistive (180° phase shift in an amplifier stage).

In addition to the four jacks mentioned above, a fifth jack (J_5) is provided that has a test clip for connecting to parts of the circuit that have no test jacks.

Neutralization. Neutralization of this stage can be best accomplished by the use of an oscilloscope. To neutralize VT_2, clip the lead provided on the scope test jack to the plate of VT_2 and temporarily ground the plate of VT_1. With switch D_4 open, apply the grid and plate power to the transmitter. Then adjust the neutralizing control C_{38} for minimum indication on the cathode-ray oscilloscope.

The procedure for neutralizing VT_1 is similar. Ground the plate of VT_2, connect the test clip to the plate of VT_1, and adjust the neutralizing control C_{27} for minimum deflection on the cathode-ray tube. After completion of these neutralizing procedures, remove the temporary grounds and close D_4.

Phase Shift Adjustment. The grid circuits of the carrier tube (VT_1) and peak tube (VT_2) must be excited 90° out of phase. The settings of the intergrid coupling capacity C_{28} and the VT_2 grid control C_{37} govern the phase relationship of the grid input voltages. First, set C_{28} to an approximately correct position according to the tuning chart for this transmitter. This chart is shown in Fig. 15. (C_{28} is actually a two-section ganged condenser with both sections in parallel for use to 1400 kc. Above that frequency, however, a link, not shown, is used to disconnect one of these condensers. This is the reason for the break in the curve of Fig. 15.) When this setting is made, you can make further adjustments of the phase relation of the two grid voltages by adjusting C_{37}.

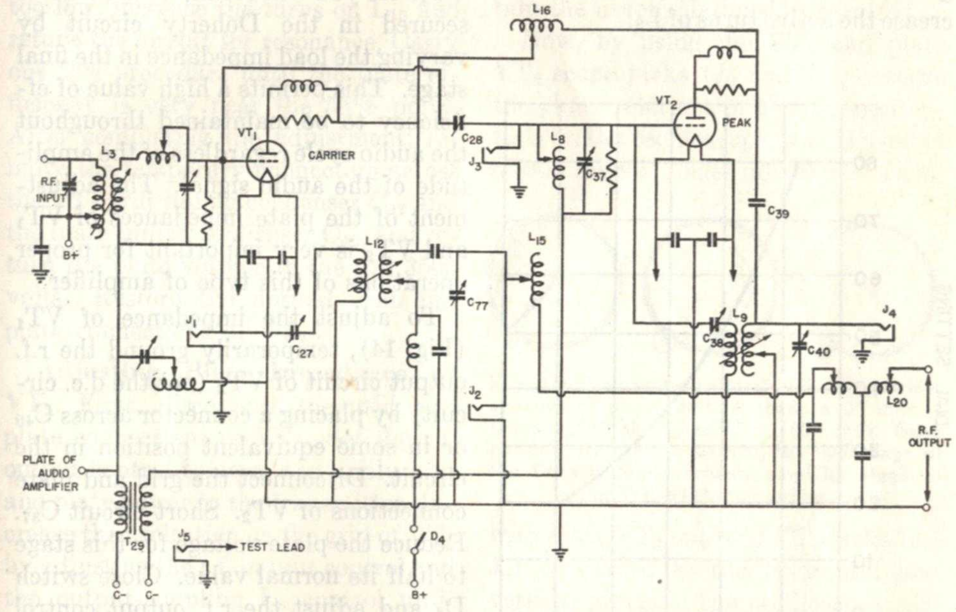


FIG. 14. The final r.f. stage of the Doherty High Efficiency Amplifier used in the Western Electric 443A transmitter.

To use a cathode-ray oscilloscope to check this phase relationship, connect the horizontal and vertical plates of a scope directly to jacks J_1 and J_3 at the grids of VT_1 and VT_2. This will give an elliptical pattern on the cathode ray tube, the character of the pattern depending upon the relative phase of the two voltages involved. Fig. 16

illustrates patterns for three values of phase difference. The proper 90° relationship is indicated by a circle on the cathode-ray tube screen. If you cannot get a circle at any setting of C_{37}, you must change the active turns of inductance L_8. If the most satisfactory tuning is obtained with C_{37} set at minimum, you must reduce the number of active turns in L_8. If, on the other hand, maximum setting of C_{37} gives the best tuning, you must increase the active turns of L_8.

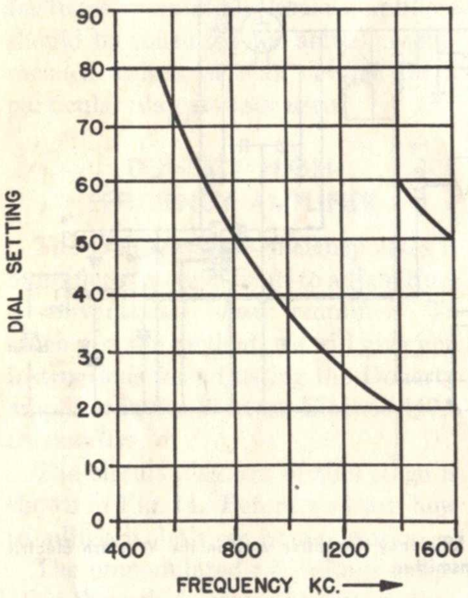


FIG. 15. Tuning chart for condenser C_{28} in the final r.f. stage of the WE 443A transmitter.

Output Circuit Tuning. First, set the coils and condensers in accordance with charts furnished by the manufacturer. Their charts are calculated on the assumption that the transmitter will be operating into a circuit with a series resistance of 65 ohms and a reactance not greater than 20 ohms. When the series reactance of the transmission line or antenna input is greater than 20 ohms, change the turns on L_{20}. If the load into which the transmitter operates has a positive (inductive) reactance, reduce the reactance of L_{20} by decreasing the number of turns. If the load into which the transmitter operates has a negative (capacitive) reactance, increase the reactance of L_{20} (use more turns).

Adjusting the Plate Impedance VT_1. As you will recall, modulation is secured in the Doherty circuit by varying the load impedance in the final stage. This permits a high value of efficiency to be maintained throughout the audio cycle regardless of the amplitude of the audio signal. The adjustment of the plate impedances of VT_1 and VT_2 is very important for proper operations of this type of amplifier.

To adjust the impedance of VT_1 (Fig. 14), temporarily ground the r.f. output circuit of VT_2 (not the d.c. circuit) by placing a connector across C_{40} or in some equivalent position in the circuit. Disconnect the grid and plate connections of VT_2. Short-circuit C_{37}. Reduce the plate voltage for this stage to half its normal value. Close switch D_4 and adjust the r.f. output control (this control, which is not shown in Fig. 14, varies the amount of r.f. signal applied to the grid of the first buffer amplifier stage) and the output coupling control L_3 until the total plate current meter reads approximately 0.3 amp. Then adjust the VT_1 plate control (C_{77}) for minimum plate current indication. After proper tuning has been achieved, increase the r.f. output to 0.6 of the normal carrier power. The plate efficiency as determined from the following formula should now be 56±2 per cent:

$$\text{Plate Efficiency} = \frac{(I_{ant})^2 \times (R_{ant})}{E_p \times I_p}$$

Where: I_{ant} = antenna current
R_{ant} = antenna resistance
E_p = plate voltage
I_p = plate current

Should the efficiency be higher than about 58%, reduce the number of active turns on L_{15} and retune the circuit to resonance. This creates a lower L to C ratio, with consequent lowering of plate efficiency. If the efficiency is too low, increase the turns on L_{15} and retune the circuit for resonance. Carry out this procedure until the plate efficiency is very near the 56% point. After completing the adjustment, remove the temporary connectors across the VT_2 grid tuning condenser C_{37} and the plate tuning condenser C_{40}, and return the plate voltage to the full 3500 volts. Restore the normal grid and plate connections of VT_2.

Adjusting Plate Impedance of VT_2. First, disconnect the grid and plate connections of VT_1. Set the r.f. output control to zero, and apply grid and plate power to the transmitter. Increase the excitation on the grid of VT_2 by adjusting the r.f. output control and the output-coupling L_3 control until the total plate current is about 0.2 amp. Adjust the plate VT_2 control C_{40} for minimum plate current. If the capacity of C_{40} is too high to tune for minimum plate current, reduce the number of active turns on L_9. This adjustment does not affect the plate impedance of VT_2, but does affect the capacity required to tune the circuit. After proper tuning has been achieved, increase the r.f. output to 0.6 of normal carrier power. If the plate efficiency is not 62%, change L_{16} (decrease the number of turns if the efficiency is high, increase them if it is low). Each time L_{16} is changed, readjust C_{40} for resonance. After the circuit has been adjusted for proper efficiency, restore the normal grid and plate connections of VT_1.

Final Tuning. With grid and plate power applied, and with the total plate current of the final set at normal, check the 90° grid circuit relationship with an oscilloscope. A slight readjustment of C_{37} may be necessary to obtain the exact relationship required.

Now, by using the VT_1 and plate VT_2 scope jacks (J_2 and J_4), observe the phase relations of the plate potentials on the oscilloscope. C_{77} is used to obtain the 90° phase difference. Then,

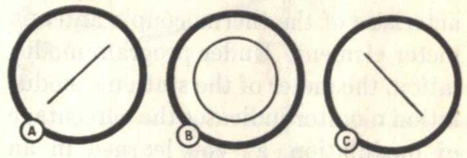


FIG. 16. Three scope patterns indicating various amounts of phase shift. A shows a 0° shift, B shows a 90° shift, and C a 180° shift. These patterns are used in aligning the final stage of the Doherty high-efficiency amplifier stage of the WE 443A transmitter.

with plate VT_2 and grid VT_2 jacks (J_3, J_4) connected to the horizontal and vertical plates of the oscilloscope, adjust C_{40} for a straight line pattern as shown in Fig. 16C. Securing this pattern means that the plate load impedance of VT_2 is a pure resistance, and a 180° phase-reversal is occurring in the tube.

When these adjustments are finished, the two grid potentials are 90° apart, and the two plate potentials are 90° apart. Therefore, the grid and plate potentials of tube VT_1 will be 180° apart. Check this on the oscilloscope, using grid VT_1 and plate VT_2 jacks J_1 and J_4. The pattern on the cathode-ray tube should again be the straight line shown.

Final R.F. Adjustments and Transmitter Modulation. The final stage has now been properly adjusted for correct operating characteristic with an unmodulated carrier output. Your next step is to check the operation *with* modulation.

As you learned in an earlier Lesson, the antenna current should rise 22.5% over the unmodulated value with 100% sinusoidal modulation. This condition prevails only for sinusoidal modulations; under actual program excitation (speech or music), the rise will not be nearly so great because of the great difference of peak-factor in the wave form, and the heating characteristic of the thermocouple antenna meter element. Under program modulation, the meter of the station's modulation monitor indicates the percentage of modulation, as you learned in an earlier Lesson.

The antenna current increase under modulation is governed by the setting of L_3 (Fig. 14) and the plate impedance of VT_1. The required 22.5% antenna current increase for 100% sinusoidal modulation should first be produced by adjusting L_3. Using the station's modulation monitor as a check, raise the output of the audio oscillator until the modulation meter indicates 100% modulation. Adjust L_3 until the antenna current is a maximum (L_3 is then at what is called the position of optimum coupling), then adjust the r.f. output control until the antenna current is 22.5% larger than it was when the carrier was unmodulated. If the current is so large when L_3 is adjusted for optimum coupling that the r.f. output control cannot reduce it to the proper value, decrease the coupling of L_3 and see if the correct value of antenna current can then be secured by adjusting the output control. It will usually be possible to find some setting of L_3 and the r.f. output control that will give the desired antenna current.

If it proves impossible to find such settings, probably the plate impedance of VT_1 is too high. In this case, reduce the number of active turns on L_{15}, and increase the number of active turns on L_{16} by the same amount. Change the turns one at a time until the antenna current is correct. Recheck the phase relations of the plate circuits and adjust the plate controls of VT_2 and VT_1 after this procedure.

Power Measurement in Broadcast Transmitters

There are two general methods of measuring the carrier power output of a broadcast transmitter, the *direct* and the *indirect*. In the direct method, the r.f. current to the antenna, under operating conditions, is measured. Since the antenna resistance has already been accurately determined, the power output can be computed directly from

$$P = I^2R,$$

where I is the antenna current in amps. and R is the antenna resistance in ohms. As an example, if 10 amps. of r.f. power is applied to a 100-ohm antenna system, the power will be 10,000 watts ($10 \times 10 \times 100$).

The indirect method (used, as we will see, in certain cases when there is no accurate means of measuring antenna current or when the antenna resistance is not accurately known) uses the plate power input to the final r.f. stage and an *assumed* operating efficiency.

The efficiency factor is determined by the FCC and presented in a chart for the different types of modulation methods. We will study this chart and the details of the indirect method later.

DIRECT METHOD

The direct method involves the current to the antenna and the resistance of the antenna. The antenna resistance is accurately measured by the consulting engineers responsible for the FCC approval of the original antenna installation or any modifications of it. Let us now review the FCC requirements about determining the resistance and measuring the antenna current.

The FCC does not specify any particular method of making antenna resistance measurements. Measurements made by any standard method will be accepted provided satisfactory evidence is submitted as to the procedure used, accuracy of the instruments, and qualifications of the engineer conducting the measurements.

The resistance variation method, substitution method, and bridge method (to be described in detail later), are acceptable methods for measuring the total antenna resistance.

When the bridge method is used, a low-power r.f. generator to cover the frequency range is necessary. The broadcast transmitter itself is not usually satisfactory for use as this r.f. source, because the maximum power dissipated in the antenna while making measurements should not be over 10% of the power available from the broadcast transmitter.

An accurate determination of the antenna resistance can be made only by taking a series of measurements, each for a different frequency. From 10 to 12 resistance measurements covering a band 40 to 60 kc. wide, with the

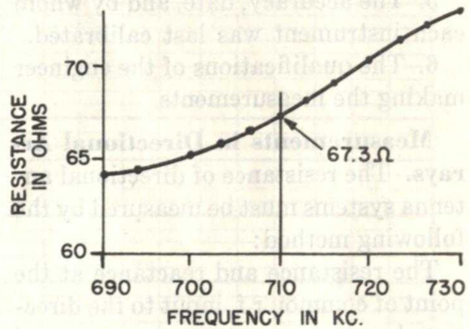


FIG. 17. An example of how an antenna's resistance at 710 kc. is accurately determined by measuring the resistance over a range of about ± 20 kc., and plotting this data to obtain a smooth curve. The intersection of this curve with the 710-kc. line is the antenna resistance (67.3 ohms in this case).

operating frequency near the middle of the band, must be made to give data from which accurate results may be obtained. The values measured must be plotted as shown in the example of Fig. 17 and a smooth curve drawn. The point where this curve crosses the operating frequency gives the value of the antenna resistance.

To satisfy the FCC of the accuracy of the antenna resistance measurements, the following data must be submitted in duplicate to the Commission in affidavit form, accompanied by duplicate copies of FCC Form 306 properly executed:

1. Complete data taken.

2. The graph drawn.

3. Description of the method used to take readings (include schematic circuit diagrams of the measurement circuit and of the antenna system, showing point of measurement and location in circuit of both regular and remote antenna ammeters).

4. The name of the manufacturer of each calibrated instrument used and the rated accuracy of the instrument.

5. The accuracy, date, and by whom each instrument was last calibrated.

6. The qualifications of the engineer making the measurements.

Measurements in Directional Arrays. The resistance of directional antenna systems must be measured by the following method:

The resistance and reactance at the point of common r.f. input to the directional antenna system are measured with the reactance adjusted to or as near zero as possible and with the antenna adjusted for the required pattern. This is done in the same manner as for a single element antenna.

Resistance and reactance measurements at approximately 5, 10, 15, and 20 kc. on each side of the operating frequency are made. The values measured are plotted and the resistance at the operating frequency determined in the same manner as for a single element antenna.

A permanently installed antenna ammeter is placed in each element of the system as well as at the point of measurement of resistance, with the remote-reading ammeters located in the transmitter room. The application for authority to determine power by the direct method must specify not only the current at the point of resistance measurement for the authorized input power but also the current of each element of the system when it is adjusted for the required pattern and for the authorized operating power.

The license for a station with power of 5 kw. or under, which uses a directional antenna and determines the power by the direct method, specifies the antenna resistance as 92.5% of that determined at the point of common input in accordance with the above. The resistance specified for stations of a power over 5 kw. is 95% of that determined at the point of common input.

INDIRECT METHOD

Whenever the antenna current or resistance is not accurately known, the power output of a standard broadcast station must be determined indirectly. This method of measurement is used, for example, when the licensed antenna has been damaged or destroyed by a storm or by some other cause beyond the control of the licensee, or pending changes authorized for the existing antenna system. Making any change in the antenna system or in the antenna current - measuring instruments, or making any other change that may alter the characteristics of the antenna, will also make it necessary to measure power indirectly.

The operating power in the indirect method is determined from the formula:

$$P = E_P \times I_P \times F,$$

where E_P is the plate voltage of the last radio stage, I_P is the plate current of the last radio stage, and F is an efficiency factor that depends on the type

1M 4-48

Day__________ Date__________

W O R

BAMBERGER BROADCASTING SERVICE, Inc.
CARTERET, N. J.
50 KW TRANSMITTER — 710 KC. — W. E. 306A Ser. # 104

MASTER OPERATING LOG

__________ Checked By

__________ Sig. of Person in Charge

I		II	III	IV	V	VI	VII											
NO.	ITEM	OPTIMUM	LOWER LIMIT	TOLERANCE	UPPER LIMIT	UNIT	ENTRIES TO BE MADE IMMEDIATELY AFTER GOING ON AIR & THEREAFTER WITHIN PERIODS INDICATED											
1	LOCAL STANDARD TIME					EST-EDST	12M-2A	2A-4A	4A-6A	6A-8A	8A-10A	10A-12N	12N-2P	2P-4P	4P-6P	6P-8P	8P-10P	10P-12M
2	LOG STARTING TIME					HR-MIN												
3	OUTSIDE TEMPERATURE					°F												
4	WEATHER CONDITIONS					SYMBOL												
5	TOWER AND BEACON LIGHTS					ON-OFF												
6	**M. E. ROOM**—50 KW D. W. EXP. TANK LEVEL		0	4-6	22	INCHES												
7	5 KW D. W. EXPAN. TANK LEVEL		0	1-3	11	INCHES												
8	**CONTROL UNIT**—LINE VOLTAGE PHASE "A"		445	455-475	485	VOLTS												
9	LINE VOLTAGE PHASE "B"		445	455-475	485	VOLTS												
10	LINE VOLTAGE PHASE "C"		445	455-475	485	VOLTS												
11	DISTILLED WATER PRESSURE		38	50-58	70	LBS												
12	DISTILLED WATER TEMPERATURE		40	85-150	180	°F												
13	FILAMENT GENERATOR VOLTAGE		19.5	20.0	20.5	VOLTS												
14	BIAS GENERATOR VOLTAGE	300	290	300	310	VOLTS												
15	RECTIFIER FILAMENT VOLTAGE	408	400	408	420	VOLTS												
16	1600 VOLT RECTIFIER VOLTAGE	1650	1625	1650	1750	VOLTS												
17	17 KV RECTIFIER VOLTAGE		16.5	17.0-18.1	18.6	KVS												
18	**17 KV. RECT. UNIT**—17 KV. RECT. AIR BLAST TEMP.		80	95-105	120	°F												
19	**OSC. MOD. UNIT**—XTAL OSC. SEL. SW. POS'N.					1-2												
20	OSCILLATOR #1 GRID CURRENT		.25	.30-.40	.50	MILS												
21	OSCILLATOR #2 GRID CURRENT		.25	.30-.40	.50	MILS												
22	1-C FREQ. METER OSC. PLATE VOLTAGE	130		130		VOLTS												
23	1-C FREQ. METER OSC. GRID CURRENT		.05	.25-.45	.55	MILS												
24	FREQUENCY DEVIATION		-20	±3	+20	CYCLES												
25	BUFFER AMP. PLATE CURRENT		11	15-30	40	MILS												
26	R. F. AMPLIFIER PLATE CURRENT		40	45-60	75	MILS												
27	R. F. AMPLIFIER OUTPUT CURRENT	210	175	210	250	MILS												
28	MOD. AMP. PLATE CURRENT		65	70-85	90	MILS												
29	MOD. AMP. OUTPUT CURRENT		350	390-475	500	MILS												
30	FEEDBACK CURRENT		7.5	8.0-10.5	12.0	MILS												
31	AUDIO INPUT AMP. PLATE CURRENT		20	25-35	40	MILS												
32	AUDIO POWER AMP. PLATE CURRENT		85	90-115	130	MILS												
33	1ST POWER AMP. INPUT DIVISIONS		28	30-40	60	DIVS												
34	**1ST P.A. UNIT**—1ST P.A. FRONT TUBE PL. CUR.		75	90-140	160	MILS												
35	1ST P. A. REAR TUBE PLATE CURRENT		75	90-140	160	MILS												
36	1ST P. A. LOAD CURRENT		180	200-300	350	MILS												
37	**2ND P. A. UNIT**—2ND P. A. FRONT TUBE PL. CUR.		300	400-700	800	MILS												
38	2ND P. A. REAR TUBE PLATE CURRENT		300	400-700	800	MILS												
39	2ND P. A. LOAD CURRENT		2700	3000-3700	4000	MILS												
40	LEAKAGE CURRENT		0	1-15	25	MILS												
41	**3RD P.A. UNIT**—3RD P.A. FRONT TUBE PL. CUR.		3.0	3.5-5.5	6.0	AMPS												
42	3RD P. A. REAR TUBE PLATE CURRENT		3.0	3.5-5.5	6.0	AMPS												
43	3RD P. A. LOAD CURRENT		20.0	22.0-25.0	26.0	AMPS												
44	3RD P. A. TOTAL CURRENT		6.0	7.0-11.0	12.0	AMPS												
45	LIGHTNING PROTECTIVE DEVICE CUR.		0	0-.2	.5	MILS												
46	**ANT. COUP. RM.**—TR. LINES #1-#2 PRES.		0	10-30	30	LBS												
47	TRANSMISSION LINE #1 CURRENT		15.8	16.5-17.2	17.5	AMPS												
48	TRANSMISSION LINE #2 CURRENT		16.6	17.0-18.0	18.2	AMPS												
49	CLOSED CIRCUIT INDUCT. CURRENT		34.0	35.0-37.0	38.0	AMPS												
50	CLOSED CIRCUIT CAP. CURRENT		30.0	31.0-32.5	33.5	AMPS												
51	MAIN CONCENTRIC LINE #3 PRES.		15	30-50	55	LBS												
52	MAIN CONCENTRIC LINE #3 INPUT CUR.	26.1	24.8	26.1	26.7	AMPS												
53	**3RD P.A. TUNING UNIT**—WEST ANT. CURRENT		17.2	17.8-18.5	19.1	AMPS												
54	CENTER ANTENNA CURRENT		15.2	15.7-16.5	16.9	AMPS												
55	EAST ANTENNA CURRENT		17.0	17.5-18.5	19.0	AMPS												
56	**AUDIO FAC. CONT. RM.**—BUILDING TEMP.		65	75-100	105	°F												
57	81A #1 AMP. PLATE CURRENTS			OPR.COND.		OK-N*												
58	82A #1 AMP. PLATE CURRENTS			OPR.COND.		OK-N*												
59	82A #4 AMP. PLATE CURRENTS			OPR.COND.		OK-N*												
60	1126A AMP. COMPRESSION		0	0-5	7	DB												
61	1126A PLATE CURRENTS			OPR.COND.		OK-N*												
62	82A #2 AMP. PLATE CURRENTS			OPR.COND.		OK-N*												
63	82A #3 AMP. PLATE CURRENTS			OPR.COND.		OK-N*												
64	PROG. PHASED DURING THIS PERIOD			OPR.COND.		OK-N*												
65	**M. E. ROOM**—AVERAGE % MOD. (731A)		50	85-100	100	%												
66	**5 KW OSC. MOD. UNIT**—5 KW XTAL #1 TEMP.		56.5	56.8-57.2	57.5	°C												
67	5 KW XTAL #2 TEMP.		58.0	58.2-58.8	59.0	°C												
68	**BASEMENT**—SWITCH ROOM INSPECTION			OPR.COND.		OK-N*												
69	DIP OIL CIRCUIT BREAKER TEMP.		10	20-45	60	°C												
70	DIST. WATER PUMP OUTPUT PRES.		85	90-100	110	LBS												
71	POND WATER PUMP OUTPUT PRES.		1	2-20	24	LBS												
72	P. W. INTERCOOLER OUTPUT PRES.		1	2-20	24	LBS												
73	POND WATER INTERCOOLER TEMP.		32	40-100	120	°F												
74	DIST. WATER INTER. TEMP. IN-OUT		40	85-150	160	°F												
75	COND. OF MOTORS-GENS.-PUMPS			OPR.COND.		OK-N*												
76	PUMP BEARINGS-GLANDS TEMP.			OPR.COND.		OK-N*												
77	FIL. MOTOR GENERATOR TEMP.		30	40-60	65	°C												
78	BIAS MOTOR GENERATOR TEMP.		30	40-60	65	°C												
79	CIRCULATE VENT. MOTOR #1 TEMP.		25	30-60	65	°C												
80	EXHAUST VENT. MOTOR #2 TEMP.		25	30-60	65	°C												
81	PIP-H. V. PROTECTIVE UNIT TEMP.		30	40-105	120	°F												
82	TRANSF. VAULT VENT. FAN.			OPR.COND.		OK-N*												
83																		
84																		
85	**E. D. G. ROOM**—DRYAIRE DEHYDRATOR		28	32-40	45	LBS												
86	DRYAIRE DEHYDRATOR COLOR	BLUE	P	P-B	B	COLOR												
87	**5 KW TRANS.**—DEHYDRATOR COLOR	BLUE	P	P-B	B	COLOR												
88																		
89																		
90	LOG FINISHING TIME					HR-MIN												

NO.	SIGNATURE OF TECHNICIAN	ON	OFF	NO.	SIGNATURE OF TECHNICIAN	ON	OFF	NO.	SIGNATURE OF TECHNICIAN	ON	OFF
91	SIGNATURE OF TECHNICIAN	ON	OFF	94	SIGNATURE OF TECHNICIAN	ON	OFF	97	SIGNATURE OF TECHNICIAN	ON	OFF
92				95				98			
93				96				99			

MAKE ENTRIES IN INK. PLACE AN ASTERISK (*) AFTER AN ABNORMAL ENTRY, CORRECT SAME WHERE AN ADJUSTMENT IS POSSIBLE

100 SHEET NO. ______

This typical transmitter log shows operating values and permissible range of variations that must be maintained by periodic adjustments in order to conform to good engineering practice.

of output stage used. Efficiency factors for various types of stages are set by the FCC and are shown in Table I.

For example, if the final r.f. plate voltage of a Doherty high efficiency amplifier circuit is 3000 volts and the total plate current is .51 ampere, the power input is 1530 watts. Since the efficiency factor F is .65, the power output by the indirect method is 995 watts; this in an acceptable value for a transmitter whose authorized operating power is 1000 watts.

Broadcast stations permitted to determine the operating power by the indirect method and to use greater daytime power than nighttime power must maintain the same operating efficiency for both daytime and nighttime operation.

OPERATING POWER TOLERANCE

The FCC Rules and Regulations require that, except in cases of emergency beyond the control of licensees, the operating power of each standard broadcast station must be maintained within the prescribed limits of the licensed power.

Each station must be operated at all times as near to the authorized power as practicable: variations of from 5% above to 10% below are the maximum permitted, and these must occur only for periods of short duration.

In addition to maintaining the operating power within the above limitations, broadcast stations using directional antenna systems must maintain the ratio of the antenna currents in the elements of the arrangement within 5% of that specified by the terms of the station license.

As an example of what your duties as an operator will be in relation to the FCC rules for determining power, let us assume that the transmitter where you are employed determines operating power by the indirect method. This means that the power input to the final r.f. amplifier stage is measured and

Table I. Efficiency Factors

Type of Station	Factor
A. Stations using plate modulation in final.	
100-1,000 watts (rated power)	0.70
5,000 watts or higher (rated power)	0.80
B. Stations using low-level modulation.	
Final operated class B	0.35
Final operated class BC (high-efficiency linear amplifier, such as the Doherty)	0.65
C. Stations using grid modulation in final.	
Final stage using 75T, 212-E, 241-B, HK354C, RK-63, 300T, 654, 450TL, 500T, 750TL, 255, 450TH, 1000UHF, 1554, 1500T, 2000T, 3054	0.25
Final stage using 152-TL, 152-TH, 212-E, 242-C, 849-A, 849-H, F-328-A, 228-A, 343-R, 892, 892-R, F-307-A, F-892, F-892-R, WL-895-R	0.35

multiplied by an efficiency factor to find the actual power delivered to the antenna system. Suppose we are concerned with the high-level-modulated 5-kw. transmitter described earlier in this Lesson. The final r.f. amplifier of this transmitter uses an 892-R tube. If we take a typical set of values of operation for this transmitter, we will have 8,500 volts on the plate of the 892-R, with a current of 0.720 ampere. We know that to determine the power input to this stage, we find that the product of E_P times I_P. This gives us:

$$8{,}500 \times 0.720 = 6{,}120 \text{ watts.}$$

The efficiency factor to be used for a plate-modulated transmitter of 5 kw. is 0.80. Therefore, $8{,}500 \times 0.720 \times 0.80 = 4{,}896$ watts. This value is slightly over 2% from the rated power of 5,000 watts. It is therefore, acceptable; the meters used to measure the current and voltage of the final stage can have a combined error of 4%, and any deviation less than 4% can be considered to be all right.

Antenna Measurements

As you learned in previous Lessons, non-resonant transmission lines are generally used to couple the transmitter output to the antenna in broadcast installations. This means that it is necessary to couple the antenna load to the line through a matching network so that the antenna load reflected to the transmission line through the antenna coupler equals the characteristic impedance of the line. Various types of T and π networks composed of reactive elements of inductance and capacitance are used for this purpose. We have already studied the process of adjusting such a coupler.

One part of this problem of coupling transmitter power to an antenna that we have not studied is how the characteristics of the antenna—that is, its exact resistance and impedance at the operating frequency—are obtained. This is generally done by a consulting engineer when the station is built or when any change in the antenna system is necessary. It is, however, of value to you as a broadcast engineer-operator to understand and be able to make these measurements. You can frequently make these measurements yourself and thus save considerably on the charges of the consulting firm.

So you can get a clear picture of antenna measurements, we will describe typical equipment used for this purpose. Since bridge circuits are used for these measurements, let us first briefly review the theory upon which the conventional bridge circuit operates.

Fig. 18 shows a simple bridge, which is just an ordinary series-parallel circuit. R_1 and R_2 are in series, R_3 and R_4 are in series, and the two branches are in parallel across a source of voltage. The circuit is said to be balanced when there is no difference of potential between points b and d. As you have learned, the ratio of R_1 and R_2 equals the ratios of R_3 and R_4 when the bridge is balanced. Setting this up as an algebraic expression:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

which is read: R_1 is to R_2 as R_3 is to R_4.

Knowing the value of any three of these resistances, you can find the unknown value of resistance (such as the radiation resistance of an antenna) by substituting the known values in the

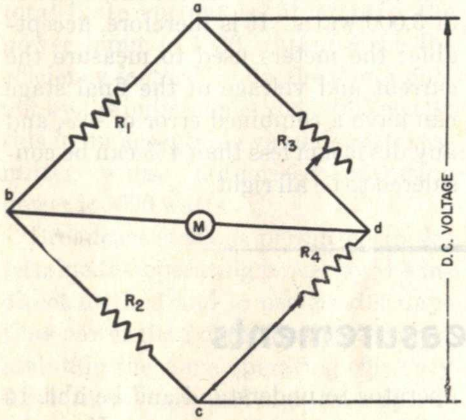


FIG. 18. The basic Wheatstone bridge circuit.

above expression and solving for the unknown after the balance has been obtained.

Such a basic bridge is useful when the unknown to be measured is a pure resistance. When the unknown has a reactive element (that is, is a resistance shunted by a capacitance or inductance), a more complex bridge circuit must be used.

GR 916-A R.F. BRIDGE

The circuit of one of these more complex bridges (known as a series-substitution bridge) is given in Fig. 19. A photograph of the General Radio 916-A r.f. bridge using this circuit is shown in Fig. 20.

Notice that there are two controls, C_A and C_P, shown in the circuit in Fig. 19. C_A is controlled by the large dial and C_P by the small dial shown in Fig. 20. When this bridge is used to measure the characteristics of an antenna, the antenna is connected to the unknown terminals, and C_A and C_P are adjusted until balance is indicated by a null (minimum signal) in the detector. The value of C_A then indicates the value of the antenna resistance, and the value of C_P indicates the reactance (inductive or capacitive) of the antenna.

The Resistance dial reading C_A is independent of frequency. The Reactance dial C_P is directly calibrated in reactance (in ohms) at a frequency of 1 mc. The Reactance dial reading thus increases linearly with frequency. For frequencies other than 1 mc., the Reactance dial reading must therefore be divided by the operating frequency in megacycles. The Resistance dial reads from 0 to 1000 ohms; the Reactance dial reads from 0 to 5000 ohms at 1 mc.

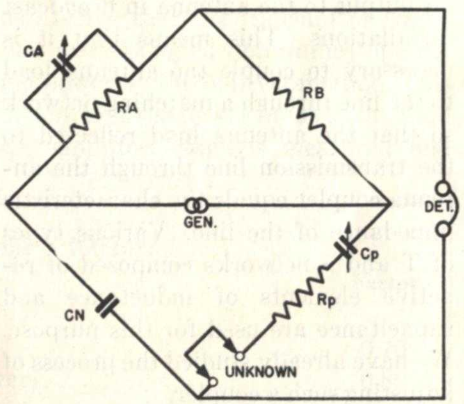
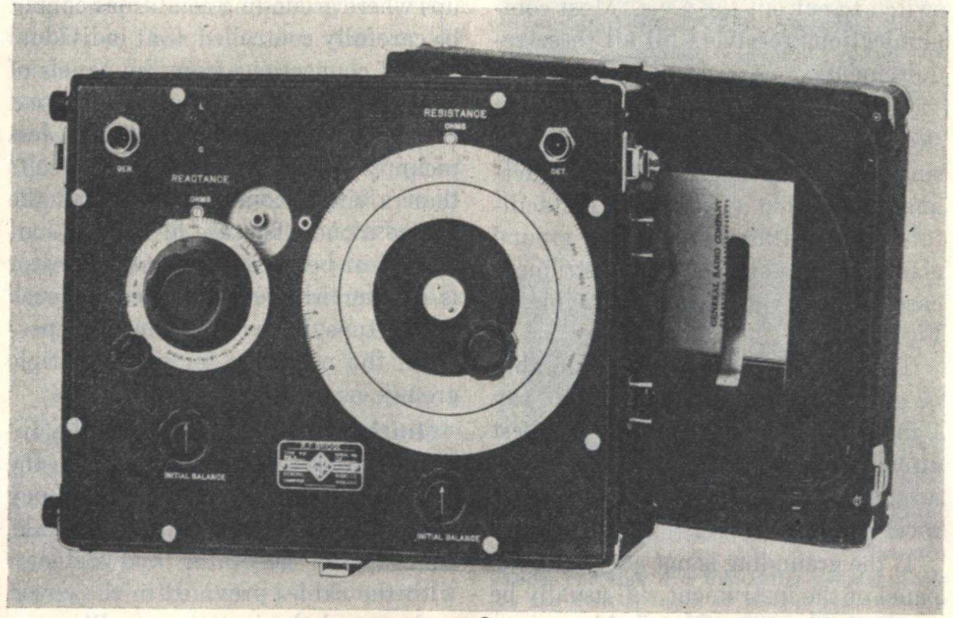


FIG. 19. The bridge circuit of the GR 916-A r.f. bridge which is used for accurately determining the resistance and reactance of antenna systems.

Knobs marked Initial Balance are shown in Fig. 20 under the two dials. These knobs control trimmer condensers that are used to balance the bridge before the antenna is connected to it. In this initial balancing operation, the Unknown terminals are shorted, the Reactance dial is set at either 0 or

5000, and the Resistance dial is set at zero.

A two-position toggle switch located above the Reactance dial is used to establish the initial-balance setting of the Reactance dial at 0 or 5000 ohms. The two positions are marked L and C to indicate that the first is to be used when measuring inductive reactance and the second when measuring capacitive reactance.



Courtesy General Radio Co.

FIG. 20. View of the GR 916-A R.F. Bridge. When a balance is obtained, the resistance for any frequency of the unknown is indicated directly on the large scale and the reactance of the unknown on the small scale. The reactance however must be divided by the operating frequency in mc. to obtain the correct value.

Two coaxial terminals for making the input and output connections to the bridge are marked Gen and Det on the panel. The Gen terminal is connected to the r.f. generator and the Det terminal to the detector.

A binding post for making the ground connection to the unknown impedance is located on the panel just to the left of the Resistance dial. The other connection to the unknown impedance is made to the jack in the center of the circular window, at the left of the ground binding post, through one of two special connecting leads supplied with the instrument. (One of these connecting leads is short, the other, long; each has a plug tip at one end and a clamp connector at the other.)

Two input transformers are supplied with this bridge, one for operation in the 400-kc. and 3-mc. range, the other for the 3-mc. to 60-mc. range. Both are mounted inside the case of the instrument. The proper transformer must be connected into the input circuit (instructions for doing this are furnished by the manufacturer) before this instrument is used.

OPERATION OF THE BRIDGE

Generator. Any well-shielded r.f.

oscillator having an output voltage of the order of 1 to 10 volts and adequate frequency stability will serve as the generator.

Detector. Any well-shielded receiver having a sensitivity of the order of 1 to 10 μv. will serve as the detector. The receiver used should have an adequate r.f. sensitivity control, a local oscillator to give a heterodyne note at the intermediate frequency, and a switch to cut out the a.v.c. Most communications receivers fill all these requirements.

Groundings. The instrument should, in general, be grounded at a single point, through as low a reactance connection as possible. To facilitate making this connection, a ground clamp is provided on the instrument case. (This clamp is not visible in Fig. 20.)

The ground lead should preferably be a short length of copper strip, say 1 inch wide. In field set-ups the best ground is usually found to be some large metal structure, such as a relay rack.

If the grounding is not adequate, the panel of the instrument will usually be at a different potential from your hand. In this case, the balance can be changed by touching the panel; naturally, this will produce erroneous results.

Stray Pickup. If the panel of the instrument is at ground potential, but those of the detector and generator are not, there is probably too much reactance in the connections from the outer conductors of the coaxial leads to those panels. You can check this by removing the detector cable from the panel jack of the bridge. If the detector output indicator shows the detector is then picking up r.f., either the generator is inadequately shielded or energy is being transferred through the power line. If, however, the detector shows no pickup when it is disconnected from the r.f. bridge, you can blame excessive reactance between the panels and the outer conductors of the leads for the difference in potentials of the various panels.

You will sometimes find, in field setups where grounding conditions cannot be carefully controlled, that individual ground connections from the panels of the generator, bridge, and detector to a common ground point will give less pickup and more consistent results than a single common ground to the bridge alone. The use of coaxial connectors at both generator and detector is particularly recommended for such field setups, to avoid, as much as possible, the necessity for such multiple ground connections.

Initial Balance. To place the instrument in operation, install the proper transformer for the frequency at which measurements are to be made, connect the generator and detector with the cables provided in the cover, and ground the instrument. Plug one of the two connecting leads into the panel jack and clip the free end to the ground binding post. This shorts the Unknown terminals.

Set the toggle switch to the L position and the Reactance and Resistance dials to zero. Balance to a null by varying the two Initial Balance knobs. (This is the procedure followed to measure impedances with inductive reactance components. To measure impedances with capacitive reactance components, set the toggle switch to the C position and the Reactance dial to

5000 ohms, than balance with the two Initial Balance knobs.)

The connecting lead has a certain amount of inductive reactance, the exact amount depending on its length. At some higher frequency, therefore, you will find that the initial balance can no longer be obtained at 5000 ohms on the Reactance dial with the toggle switch set to the C position. This shift in the initial balance causes no corresponding error in measurement, since in the series-substitution process, the constant inductive reactance of the connecting lead cancels out. It does, however, reduce the reactance range of the bridge, since the full coverage of the Reactance dial cannot be obtained. This condition can be corrected, if necessary, by inserting a small fixed condenser in series with the connecting lead to neutralize its inductive reactance.

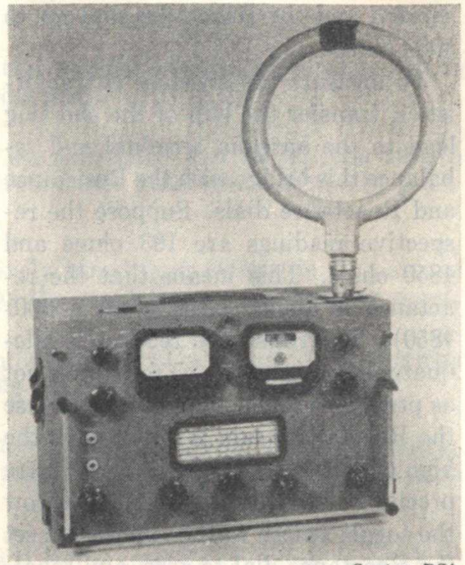
If the short lead is used, the shift is relatively small over the entire frequency range of the instrument at broadcast frequencies; as a matter of fact, it is not ordinarily necessary to use a series condenser at any frequency when the short lead is used.

As we said earlier, the receiver used as a detector should have a good r.f. sensitivity control and a switch to disconnect the a.v.c. If the receiver gain is set too high, there is a tendency for the receiver output to increase as balance is approached; if the resistance balance is not approximately correct in its setting, it becomes quite difficult to find the reactance balance, or vice versa. When the r.f. sensitivity control is set to minimum sensitivity, and the a.v.c. is disconnected, it is not difficult to make the initial balance.

As balance is approached, you can increase the receiver sensitivity to improve the precision of setting. For the first rough balance, the generator signal can be modulated and the receiver beat oscillator can be turned off. The precise balance, however, should be made with the generator signal unmodulated. The a.v.c. should be left disconnected at all times.

If the receiver does not have an adequate r.f. sensitivity control, you can get an accurate balance by reducing the generator output rather than the receiver sensitivity. When you make a precise balance, set the generator output at maximum so that the ratio of useful output to leakage is as great as possible.

Measurement of a Typical Broadcast Antenna. As a typical example of the use of this bridge, let us see how it



Courtesy RCA

Proper operation of a transmitter includes checks on the field strength at various places in the service area. The RCA 308-B Field Intensity Meter shown here is a typical portable instrument for this purpose. Its frequency coverage is 120 kc. to 18 mc. and will indicate field strengths down to 20 microvolts per meter.

is used to determine the characteristics of a broadcast antenna operating on 1170 kc.

Since the antenna in this example is about 0.6 wavelength long, it is reasonable to assume that the impedance has a capacitive reactance component. With the toggle switch set to the C position, and the connecting lead grounded to the rack, get the initial balance with the Unknown terminals shorted and the Reactance dial set to 5000 ohms.

To measure the antenna characteristics, transfer the clip of the shorting lead to the antenna terminal and rebalance this bridge with the Resistance and Reactance dials. Suppose the respective readings are 193 ohms and 4850 ohms. This means that the reactance is about —150 ohms (5000-4850). The resistance reading is adequate, but the reactance reading is not as precise as might be desired, because the Reactance scale is crowded at the high end of the dial. To obtain a more precise reactance measurement, throw the toggle switch to the L position, set the Reactance dial to zero, and rebalance the bridge with the two Initial Balance controls (this is done with the antenna still connected). Next, transfer the clip of the connecting lead to ground and rebalance the bridge with the Resistance and Reactance dials. The Resistance dial should rebalance at zero. The Reactance dial reading, however, will balance at a value at the low end of the scale that will accurately indicate the capacitive reactance of the antenna. In this case, let's say that the value is 160 ohms.

The observed resistance R_o and reactance X_o of this antenna, therefore, are:

$$R = 193 \text{ ohms.}$$

$$X = \frac{-160}{1.17} = -137 \text{ ohms.}$$

Remember that the reactance dial is calibrated to read at 1 megacycle, and, therefore, the reactance value as shown on the Reactance dial must be divided by the operating frequency in megacycles to obtain the actual value of the reactance. Since the operating frequency is 1170 kilocycles, the value of —160 ohms is divided by 1.17 to obtain the true value of —137 ohms in this example. (The minus signs for these reactances merely indicate that they are capacitive rather than inductive.)

To tune the antenna to resonance, a series inductance is needed that will supply the same amount of inductive reactance as the antenna has capacitive reactance. In practice, a coil of greater inductive value is used; it is tapped off at the correct number of turns to obtain the amount of positive reactance needed. The correct number of turns on the coil needed to supply the 137 ohms reactance may be closely calculated for the operating frequency used. The bridge is then used and the exact number of turns varied by means of the tap until the reactance value of the antenna system is as near zero as it can be made.

Lesson Questions

Be sure to number your Answer Sheet 44RC.

Place your Student Number on *every* Answer Sheet.

Most students want to know their grade as soon as possible, so they mail their set of answers immediately. Others, knowing they will finish the next Lesson within a few days, send in two sets of answers at a time. Either practice is acceptable to us. However, don't hold your answers too long; you may lose them. Don't hold answers to send in more than two sets at a time or you may run out of Lessons before new ones can reach you.

1. If the recovery time in a peak limiting amplifier is too short, what will be the effect on amplifier gain at low frequencies?

2. What is the purpose of adjusting the frequency dial of the GR 1932-A Distortion Meter to obtain a minimum meter deflection when making distortion measurements?

3. In an r.f. amplifier with an inductively tuned tank circuit, is the point of minimum plate current the same as the maximum power transfer point?

4. Since the neutralizing condenser C_{12} in the final r.f. stage of the transmitter of Fig. 7 is fixed in value, how is the neutralizing adjustment made?

5. In the general type of "T" coupling network as illustrated by L_5, C_{15}, and L_6 of Fig. 7, which variable inductance, input L_5 or output L_6, has more control of the output power?

6. What are the two purposes of the T type antenna coupling network of Fig. 12?

7. Under what conditions may the indirect method of measuring the operating power of a broadcast station be used?

8. In a standard broadcast station using high level (plate) modulation, if the plate voltage of the final r.f. stage is 2000 volts and the total plate current is 700 ma., what is the operating power by the indirect method?

9. If the antenna current of a broadcasting station is 5 amp., the antenna radiation resistance 10 ohms, the final r.f. plate voltage 1000 volts, and final r.f. plate current .35 amp., what is the operating power of the station?

10. The d.c. input power to the final r.f. stage of a broadcast transmitter is 1500 volts at 700 ma. The antenna radiation resistance is 8.2 ohms and the antenna current is 9 amperes. What is the efficiency of the final r.f. stage?

GETTING AHEAD

We have all heard the old proverb, "If wishes were horses, beggars would ride." This is just another way of saying that if wishing could bring success, all men would be successful.

You need only to look around you to see that wishing is not enough. The world is full of failures. But our common sense tells us that these men are not failures because they did not *wish* to succeed. So what *is* the secret of success?

It is *what we do about our wishes* that makes all the difference. The secret is ACTION. Take two men with equal ability and the one who works harder will get ahead faster than the other man.

If one of the two men has less ability than the other, less education, fewer opportunities—but is energetic, active—does something about his problems—he will be more successful than the man who does nothing but wish for success. The men who get to the top and stay there are men of ACTION.

A certain amount of wishing is necessary and helpful. Wishing can help you chart the road to success—but in order to get anywhere, you have to get out and keep going. Yes, keep going and you will get there.

J. E. SMITH