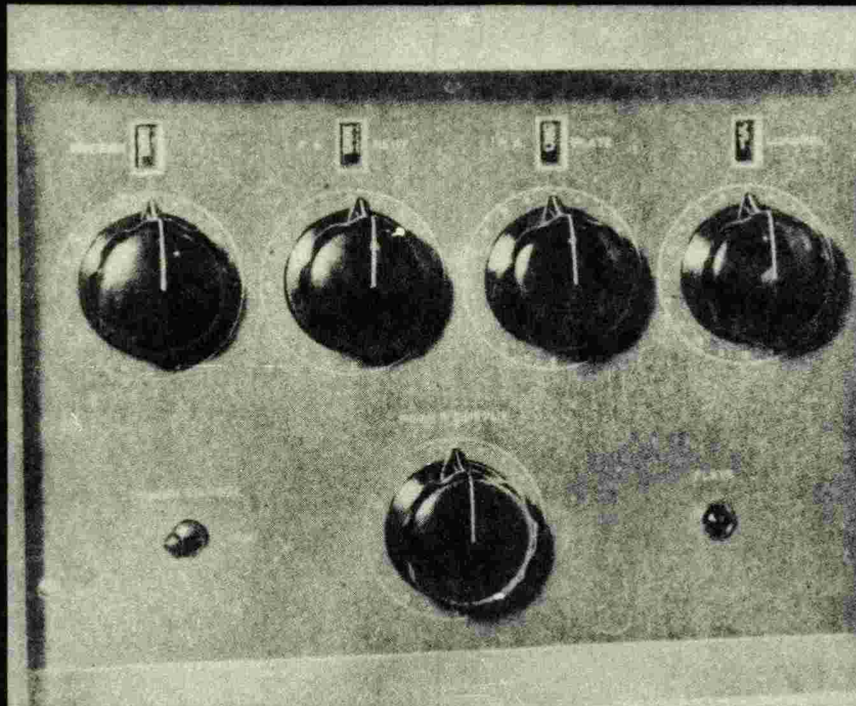

LESSON
68 RA-1

BROADCAST TRANSMITTERS AND TRANSMITTER TROUBLES

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In order that a minimum amount of interference be produced by and a maximum amount of benefit be obtained from all classes of broadcast stations, we will find that the Federal Communications Commission has established certain minimum requirements for their operation. The most important requirements are: the percentage of modulation, spurious emission, interference, antenna currents, frequency drift and power output.

Modulation: The maximum percentage of modulation must be maintained at as high level as practicable without causing the production of undue audio frequency harmonics; that is, they must not be in excess of 10 percent when operating with 85 percent modulation.

Spurious Emission: Spurious emissions, including radio frequency harmonics and audio frequency harmonics, must be maintained at as low a level as practicable at all times and in accordance with good engineering practice.

Interference: In the event interference is caused to other stations modulating frequencies in excess of 7,500 cycles or spurious emissions, including radio and audio frequency harmonics outside the frequency band plus or minus 7,500 cycles of the authorized carrier frequency then adjustments must be made to limit the emissions to within this band or to such an extent above 7,500 cycles to reduce the interference to where it is no longer objectionable.

Power: The operating power of a broadcast transmitter must be maintained within the limits of 5 percent above and 10 percent below the authorized operating power output and must be maintained as near as practicable to the authorized operating power.

Antenna Currents: Broadcast stations employing directional antenna systems must maintain the ratio of the currents in the various elements of the antenna array within 5 percent of the values specified in the license.

Frequency Drift: In the case of excessive frequency drift in the operating frequency during warm-up periods, the crystal oscillator must be operated continuously. That is, the automatic temperature control circuits should be operated continuously under all circumstances. The permissible frequency drift is limited to plus or minus 20 cycles.

It is therefore very evident that there are specific requirements to be met in the operation and maintenance of a standard broadcast station. This is why Federal Communications Commission requires that an applicant show that it is financially qualified to construct and operate a proposed broadcast station. The money below is the minimum required for a satisfactory installation, including the transmitter, antenna system, monitoring equipment and equipment for one large and one small studio of average dimensions, and equipment including microphones, input equipment, and usual acoustical treatment, but exclusive of the cost of land, buildings, organization and development costs in the more elaborate installations including directional antenna which would increase the cost accordingly.

Power (Watts)	Money (Cost)
100	$ 6,500
250	10,000
1,000	25,000
10,000	65,000
50,000	200,000

For the benefit of the owner and operator of a broadcast station, the initial installation requirements of a broadcast transmitter must also provide easy and quick repair of the equipment in case of the failure of a component part. This is why the vertical panel type of mounting is employed as shown in Fig. 1. Note the two doors shown at the rear of the transmitter which, when open, allow the operator to reach all components on the transmitter panel.

The necessary power transformers or filter chokes are shown in the lower section of the transmitter, while the radio frequency amplifier circuits are shown in the upper section.

Inasmuch as broadcast stations must operate over long periods of time, proper servicing and maintenance equipment must be provided. Meters are therefore included

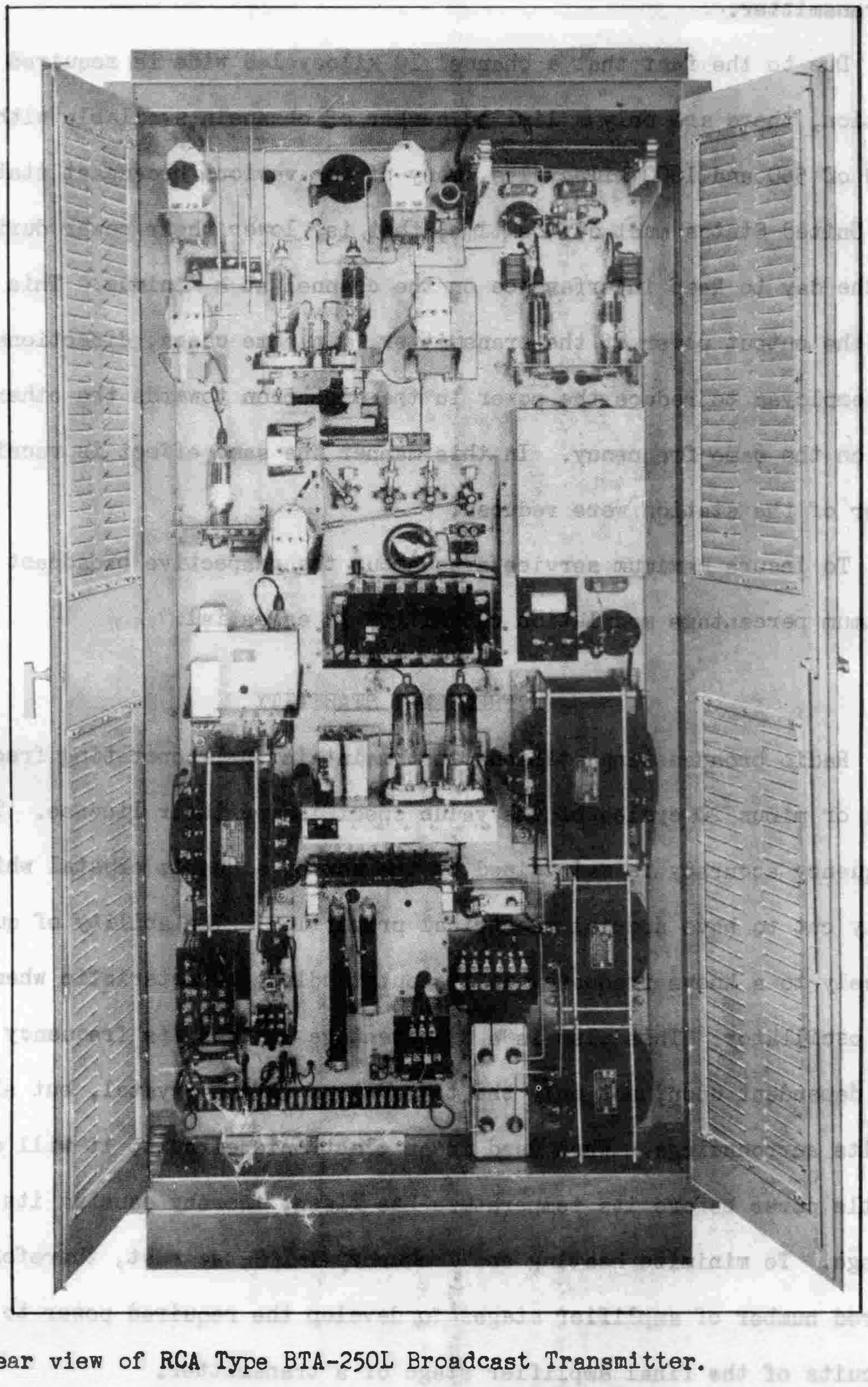

FIG. 1. Rear view of RCA Type BTA-250L Broadcast Transmitter.

in the equipment to indicate to the operator the aging effects upon the tubes employed and furthermore, to insure proper operation of the respective stages within a transmitter.

Due to the fact that a channel 10 kilocycles wide is required for a broadcast station, there are only a limited number of channels available within the broadcast band of 550 and 1600 kilocycles, many of the various broadcast stations throughout the United States must divide time, that is, lower their power during certain hours of the day to keep interference on the channel at a minimum. This is done by reducing the output power of the transmitter. In some cases, directional antenna systems are employed to reduce the power in the direction towards the other stations operating on the same frequency. In this manner the same effect is received as if the power of the station were reduced.

To insure maximum service area about the respective broadcast stations, the maximum percentage modulation capability is essential.

FREQUENCY STABILITY

Radio broadcasting stations must maintain their operating frequencies within plus or minus 20 cycles of the value specified on their license. This degree of frequency accuracy is maintained by the use of a quartz crystal which has been especially cut to have special electrical properties. The ability of quartz to adhere closely to a known frequency is its outstanding characteristic when used in a crystal oscillator. This also is a disadvantage in that its frequency characteristics are dependent upon, not only the temperature of the crystal, but also the temperature of its surroundings. When used in an electronic circuit, it will dissipate very little power before its temperature has risen, thereby causing its frequency to change. To minimize heating and frequency drift, we must, therefore, employ the required number of amplifier stages to develop the required power to excite the grid circuits of the final amplifier stage of a transmitter.

The conventional crystal circuit consists of a quartz crystal placed between two metal plates which are electrostatically coupled to it and are connected between the grid and cathode leads of a tube. The plate circuit of the tube being tuned to the same frequency. The entire circuit functions like a tuned grid-tuned plate oscillator because the quartz crystal is equivalent to a circuit having very high inductance and low distributed capacity. In fact, its distributed capacity is mostly due to the capacity between the two plates of the crystal holder.

If the crystal is made to oscillate too strongly, then the mechanical vibrations of the crystal may be great enough to crack or puncture the quartz. The radio frequency current must therefore be limited to prevent the crystal from cracking. Crystal currents range from 50 to 250 milliamperes.

There are various types of crystal mountings or holders. In general, there are two distinctive types; one which provides a small air-gap between the top plate and the crystal while the other type of holder allows the upper plate to rest on the crystal.

A crystal holder having a heavy metal bottom plate with a large surface exposed to the air is advantageous in that it quickly radiates the heat generated in the center of the crystal thereby reducing rapid temperature changing effects. Different plate sizes and pressures will cause slight changes in frequency and, for this reason, each crystal is ground to its exact frequency using the holder in which it is to be used.

Various types of tubes are used in crystal oscillator circuits. The most popular of these being the tetrode and pentode types. These tubes have the advantage because it is possible to obtain greater power output with less frequency drift. In other words, less power is required to excite a tetrode or pentode tube then that required to excite a triode for the same power output.

Even though a tetrode or pentode tube is used in the oscillator stage, a number of radio frequency amplifier stages are required to develop the amount of power necessary for the efficient transmission of a program. In Fig. 2 is shown three stages of a transmitter. The first stage employs the conventional crystal oscillator circuit using a pentode and filament type tube. The crystal is shunted by the resistor R1 which has a resistance between 25,000 and 100,000 ohms. The filament cathode circuit of the pentode tube is by-passed to ground or chassis by two by-pass condensers C1 and C2. These capacitors have relatively low reactance at the crystal frequency. The resistor R2 is used for the purpose of providing an electrical center tap to the filament voltage and forms the cathode connection. The screen grid electrode is by-passed to chassis by the capacitor C3.

Capacitors which have relatively low reactance to the frequency of operation are referred to as by-pass capacitors. Capacitors used for coupling purposes have somewhat higher reactances than by-pass capacitors as they are used in circuits having greater impedance. Then capacitors used for tuning purposes must have the required capacitance to resonant the tuned circuits to the frequency of operation.

In analyzing the oscillator circuit shown in Fig. 2, we must not overlook the

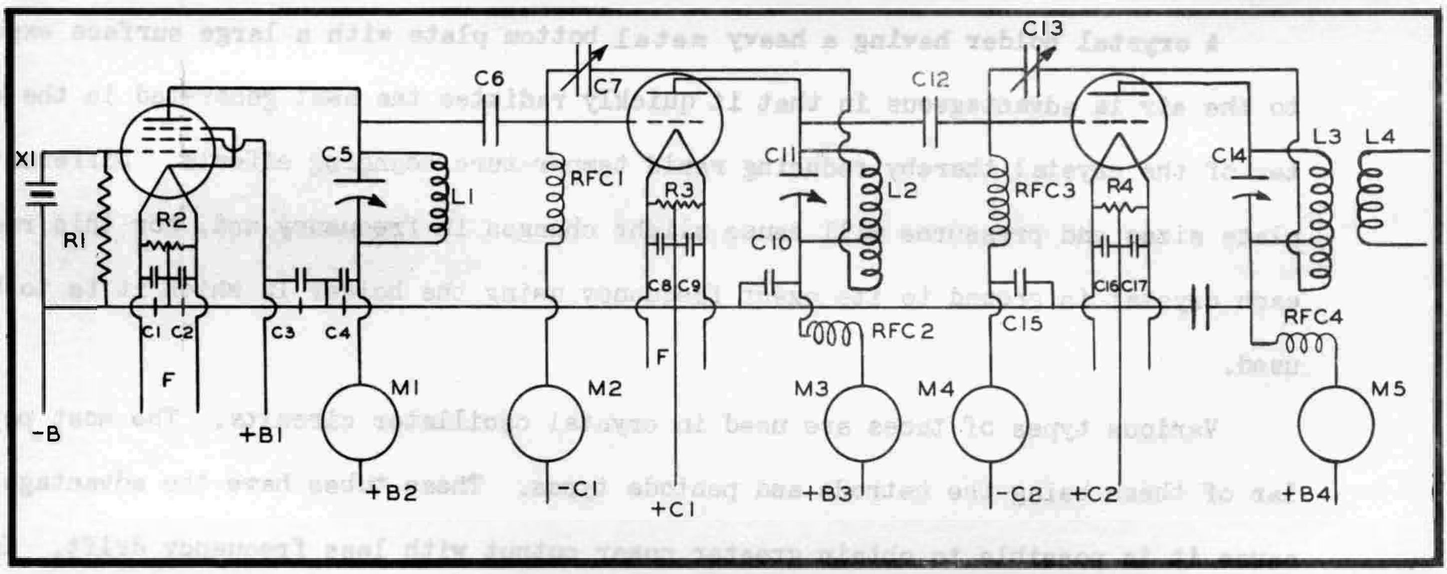

FIG. 2. A schematic diagram of a typical pentode, crystal oscillator and two stages of R. F. Amplification employing triode type tubes.

fact that the control grid, which is connected to the upper plate of the crystal X1 acts as the grid inductance of a tuned grid-tuned plate oscillator circuit. The plate circuit of the pentode is connected to the resonant circuit consisting of C5 and L1. Thevoltage developed across this circuit when in resonance with the crystal frequency is coupled by the capacitor C6 to the grid of the first amplifier tube or stage. The capacitor C4 serves as a by-pass capacitor and completes the plate circuit of the crystal oscillator.

Plate voltage is applied to the oscillator tube through the meter M1 and through the coil L1. This method of feeding power or voltage to a tube element is referred to as the series-fed circuit because the plate current flows through an element of the tuned circuit.

The negative C bias voltage applied to the first R.F. amplifier tube is applied through the meter M2 and the radio frequency choke, RFC1. The first amplifier tube also employs a filament cathode which again requires two separate by-pass capacitors, C8 and C9. The resistor R3 is used for the purpose of dividing the filament voltage to provide the electrical cathode connection. The plate voltage to the first R.F. amplifier tube is supplied through the meter M3, the R.F. choke, RFC2, the upper section of L2 and then the plate lead of the tube. Again, this is a series-fed circuit. The capacitor C10 serves as an R.F. by-pass. Any radio frequency voltage which it does not by-pass is not transmitted to the power supply leads because the R.F. choke, RFC2, is used to provide a high reactance.

The plate resonance circuit of the first R.F. amplifier stage in this transmitter circuit is tuned to resonance by the capacitor C11 and the inductance L2. The R.F. voltage developed across C11 is fed to the grid circuit of the final R.F. amplifier circuit through the capacitor C12. The required negative C bias voltage for this stage is supplied through the radio frequency choke, RFC3, while the capacitor C15 serves as a by-pass for the high frequency voltage in the circuit.

The filament circuit for the final R.F. amplifier stage is again by-passed to the chassis by the use of capacitors C16 and C17. The resistor R4 provides the electrical center tap for the filament voltage and the cathode to chassis or ground connection. The plate supply voltage for the final R.F. amplifier is fed through the meter M5, the radio frequency choke, RFC4, the upper section of L3 and the lead to the plate. This is again a series-fed circuit.

Whenever operating a triode as an amplifier, we must provide some means of removing the effects of capacity coupling between the grid and plate electrodes. This is accomplished by employing a neutralizing circuit. This is the reason why the capacitors, C7 and C13, are used in this transmitter circuit. These capacitors are adjusted to supply the exact amount of voltage required to balance out the effects of interelectrode capacity coupling. The R.F. voltage required for the purpose of neutralizing the effects of the grid to plate capacitance between the electrodes must be exactly 180 degrees out of phase with the input voltage to the stage, otherwise these stages will oscillate of their own accord. This phase shift is obtained by providing a few extra turns on the lower ends of the coils L2 and L3. When using tubes having approximately 10 mmfd capacitance, we will find that there will be approximately 25 percent more turns above the tap on the coils L2 and L3 in the respective resonant circuits.

Power is fed to the output load circuit by inductive coupling between L3 and L4. The coupling is adjusted to cause the proper plate load impedance to be reflected into the plate circuit of the final R.F. amplifier tube.

TRANSMITTER TUNING PROCEDURE

The respective grid and plate circuits of many of the stages in a radio transmitter have separate tuning controls to insure proper operation.

The plate circuit of the crystal oscillator tube as shown in Fig. 2 is tuned to resonance by adjusting C5 and by watching the meter M1. The current in this circuit is adjusted for the lowest value of direct current. Under this condition, the resonant circuit formed by C5-L1 will offer the maximum amount of impedance to the R.F. voltage in the plate circuit. The voltage drop across this resonant circuit is applied to the grid circuit of the intermediate amplifier. This stage is oftentimes called a buffer stage because it prevents any reaction back on the oscillator circuit as the final amplifier is modulated.

Although a high negative C bias potential is applied to the grid of the intermediate or buffer amplifier stage, it is possible, upon the application of a strong R.F. signal, to cause grid current to flow on the positive peaks of the R.F. voltage generated. This grid current is indicated by the meter M2. The direct current in this circuit is usually some value between 2 and 10 milliamperes. The proper setting of the neutralizing condenser C7 is indicated when capacitor C11 is rotated without causing an appreciable change in the grid current flowing through the meter M2 when there is no voltage applied to the plate circuit of the tube. Again, the proper setting for C11 will be for the lowest average current flow through the meter M3. When this condition is obtained, maximum voltage will be developed across C11 and L2, the plate circuit of the intermediate amplifier stage. This voltage is transferred to the grid-cathode circuit of the final R.F. amplifier through the coupling condenser C12.

The negative bias voltage applied to the final R.F. amplifier stages of radio transmitters usually is equal to twice the value required to obtain plate current cut-off when there is no R.F. signal applied to the grid of the tube. It is possible even with this high C bias voltage to cause the flow of rectified grid current through M4 on the positive peaks of the R.F. signal.

As in the intermediate amplifier stage, the neutralizing condenser C13 as well as the resonant circuit formed by C14 and L3 must again be adjusted to prevent self-oscillation. Condenser C14 is always adjusted for the lowest average D.C. current flow through meter M5, the coupling between L3 and L4 adjusted to give the required plate current flow in the final amplifier stage.

AMPLITUDE MODULATION

There are two very common ways of obtaining amplitude modulation of the radio frequency carrier developed by a transmitter. These two ways are known as grid and plate modulation. Plate modulation is generally employed because it has certain advantages over the grid modulation methods.

When employing plate modulation, we will find that the impedance of secondary winding of the modulation transformer must be equal to the plate voltage of the final R.F. amplifier divided by the plate current. When employing the circuit shown in Fig. 2, it is important that the reactance of the by-pass capacitor C18 is of a value which will not reduce high frequency modulation. This is true because this capacitor is in shunt with the secondary winding of the modulation transformer.

Let us assume that we have a dc plate voltage of 1,000 volts on the final R.F. amplifier stage. In order to obtain 100 percent modulation, we will find that the peak a.c. output voltage (1.73 X the RMS value) of the modulator transformer must be equal to 1,000 volts. Upon the application of this voltage, we will find that the positive peaks of the audio signal will cause the application of 2,000 volts to the plate circuit of the final R.F. amplifier. Naturally, when we double the plate voltage to this circuit, we will increase the applied power to the antenna four times. This means that the power applied to the antenna system will be four times greater than carrier value. This is the condition for 100 percent modulation and at the time the positive A.F. peak is applied to the plate circuit.

Now let us see what happens when the phase of the A.F. voltage is reversed causing the application of 1,000 volts (negative) to the plate circuit. Again, we shall assume we have a d. c. voltage of 1,000 volts applied to the plate circuit. Naturally, the application of 1,000 volts (negative) to this circuit will cause a complete cancellation and removal of plate voltage. This means that there will be no plate current and the R.F. power output will be zero on the negative peak of the audio signal.

In briefly reviewing the two conditions through which the complete modulation cycle goes we will find that the power output will vary from essentially 0 to 4 times the original carrier value.

In order to obtain maximum undistorted power output using plate modulation, it is essential that the R.F. grid excitation to the modulated stage of the transmitter using plate modulation be sufficient to cause the power output to rise linearly to four times the original carrier value as the plate voltage is doubled.

When employing grid modulation, we will find that the d.c. plate voltage of the modulated stage is maintained at a fixed value. The unmodulated R.F. voltage applied to the grid circuit of this stage is adjusted to cause the output to be approximately 30 percent of the unmodulated power output which is obtained with plate modulation. The negative d.c. bias voltage applied to the grid circuit for grid modulation will be of a value that causes plate current cut-off with no R.F. excitation. This voltage should be well regulated as it is critical and must be carefully checked for the particular tube employed. As previously stated, the R.F. grid excitation must be carefully regulated to give approximately 30 percent power output as mentioned above to provide linear output upon the application of the audio signal voltage to grid cathode circuit of this grid modulated stage.

The secondary winding of the modulator transformer is connected in series with the C bias lead. When employing grid modulation, the A.F. voltage required will usually be 10 percent of the value which would give us efficient plate modulation. The power required is also lower and about the same ratio depending upon the value of the shunting resistor. The reactance of the capacitor C15 must be maintained at a low value so that the higher audio frequencies are not by-passed as this would cause a reduction in high frequency response at the receiver. The reactance of the capacitor C12 should likewise be low because it is also in shunt with the secondary winding of the grid modulation transformer although both of its terminals are at R.F. potentials with respect to ground at all times.

In reviewing the relative merits of plate and grid modulation we come to the conclusion that the modulated power output for the grid modulated system is approximately 1/3 of the value received when using plate modulation. Therefore, if we wish to obtain the same relative modulated R.F. power output we must increase the voltage and power handling ability of the R.F. amplifier tube about three times. In actual practice, this ratio is, for the purpose of keeping distortion at a low value, set at approximately five times. Grid modulation, therefore, reduces the cost of the modulator but increases the cost of the final R.F. amplifier stage. Grid modulation also requires more critical adjustment of the negative C bias voltage applied to the grid circuit of the final R.F. amplifier and also a more critical adjustment of the

R.F. excitation for low distortion.

Radio broadcast transmitters also employ R.F. amplifier stages similar to those used in the early stages of radio receivers; however, the tubes and the relative voltages applied to the electrodes of the tubes used are proportionately greater. In every case, linear R.F. amplification is essential for undistorted amplification

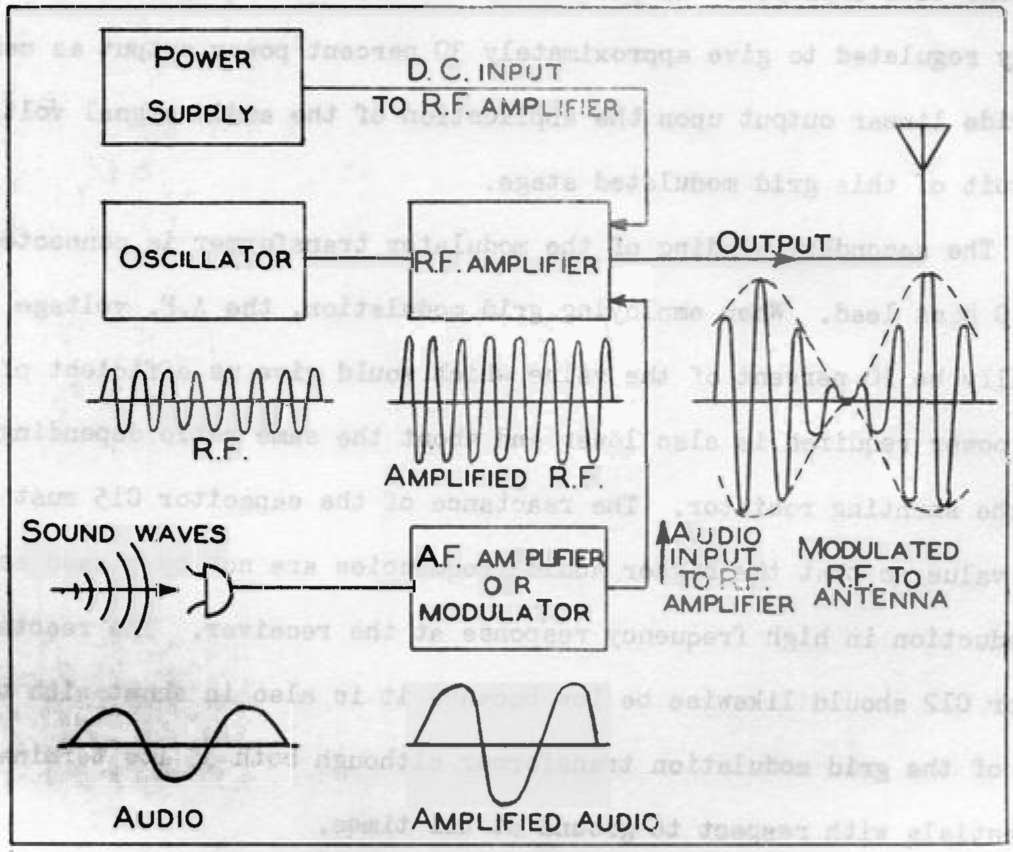

FIG. 3. A block diagram showing how amplitude modulation is obtained.

of the modulated signal. Many of the broadcasting stations employ linear R.F. amplifiers after the modulated stage in their transmitters. Regardless of the method of modulation employed, we find that the relative cost and the merits of either of the systems are debatable, that is, the respective engineers for the various concerns who design and manufacture the transmitters find that both systems have their advantages and disadvantages; however, their relative cost is approximately equal, although the adjustments required for good plate modulation are easier to make.

You will hear of other forms of amplitude modulation all of which will, in general, employ a combination of one or both of the systems described. For example:

Cathode modulation is employed in some low powered transmitters. This system of modulation causes a variation of the grid and plate voltage at the same time, because the A.F. voltage is applied in the filament-cathode to ground lead.

Regardless of the method of obtaining amplitude modulation, the information shown in the block diagram, Fig. 3, applies. Here it can be seen that the modulated R.F. to the antenna varies in accordance with the amplified audio frequency voltage. Note that R.F. voltage generated by the crystal oscillator is also amplified before it is modulated and by the amplified audio voltage received from the microphone.

TRANSMITTER PROBLEMS

Trouble shooting in broadcast and many other types of transmitters is generally easier and quicker to localize than in radio receivers, because each one of the respective stages has the necessary meters or is provided with a selector meter circuit arrangement to assist in finding the defective part or indicating the circuit which is operating improperly. There are several outstanding transmitter problems which are only found in transmitters and these shall, along with their detection and correction, be covered. Some of the rememdies could be applied to the servicing of radio receivers and other electronic devices. The outstanding transmitter problems which will be discussed in detail are:

1. Checking parasitic and spurious oscillations
2. Checking for imperfect neutralization
3. Reneutralization of transmitters
4. Measurement of double frequencies
5. Measurement of harmonic percentage

Although radio engineers design the various circuits of transmitting equipment for satisfactory operation, such operation can only be obtained when the equipment is in satisfactory operation. Such operation can only be obtained when the equipment is in satisfactory operating condition and adjusted for the type of performance required.

In Fig. 4 is shown a typical circuit of a modulator of a radiotelephone transmitter employing two tubes in parallel. Notice the two grids and the two plates are connected in parallel as shown by the wide lines. Since the three-electrode vacuum tube is an excellent amplifier, it is possible for two tubes to produce oscillations at extremely high frequencies formed by the high frequency oscillatory circuit. The resonant circuit is formed by the inductance in the connecting wires and the distributed capacity furnished by the elements of the tubes. In effect, we

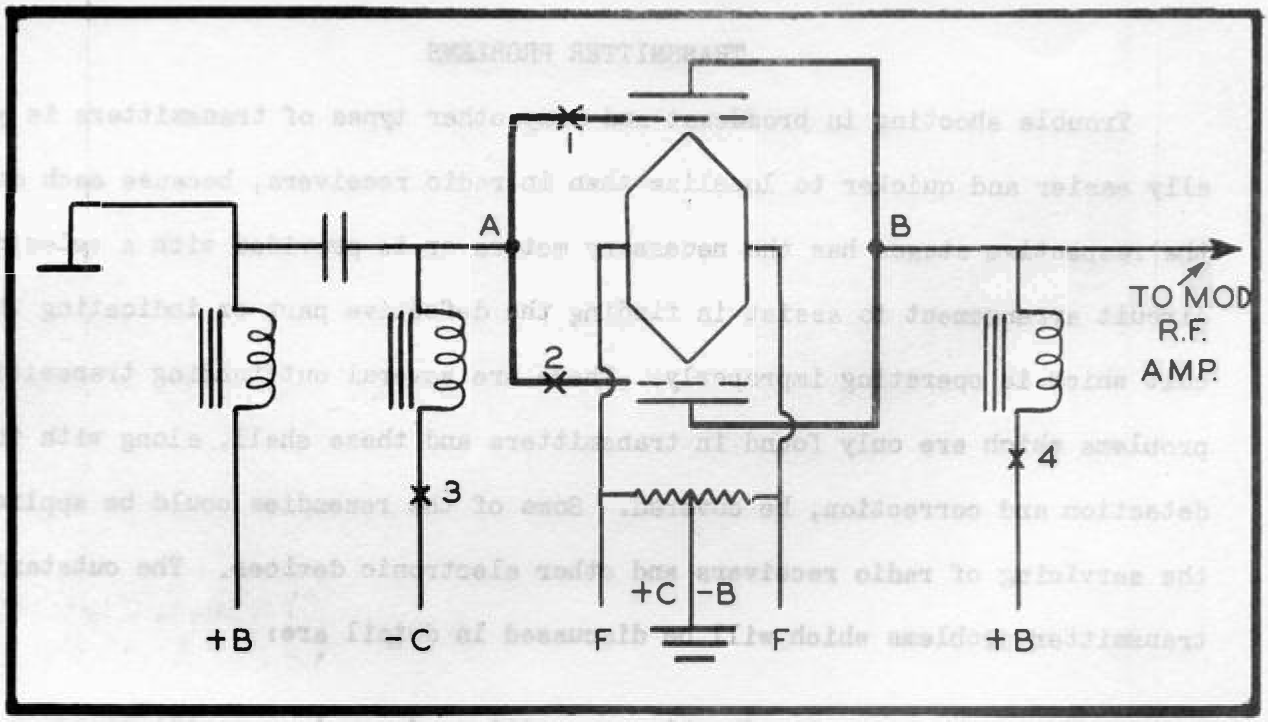

FIG. 4. The wide lines show the leads connecting to the grids and the plates of the two tubes which may form a push-pull radio frequency oscillator.

have a push-pull oscillator circuit with its respective plate and grid voltages. These voltages are applied to the circuit points A and B. High frequency oscillations will cause excessive grid and plate currents, and if they are allowed to continue, they may damage the tubes. Furthermore, the audio frequency voltages will not be amplified to the proper amplitude. We can expect harmonid distortion to be high. The elimination of parasitic oscillations in the circuit shown in Fig. 4 may easily be accomplished by employing non-inductive resistors connected in series with each grid lead. These resistors are sometimes referred to as parasitic suppressors. They should be connected at the socket as indicated at points marked 1 and 2. The grid and plate current meters should read their normal operating value when parasitic resistors are used. For Class A amplification, the grid meter at the point 3 should read zero current at all times. The plate current meter at point 4 will then remain at a constant value. Spurious oscillations are therefore suppressed by connecting parasitic suppressors (resistors) in series with the grid leads of tubes connected in parallel. The value of the resistors employed will vary depending entirely upon the characteristics of the tubes used. In general, 100 ohm non-inductive resistors will eliminate spurious oscillations.

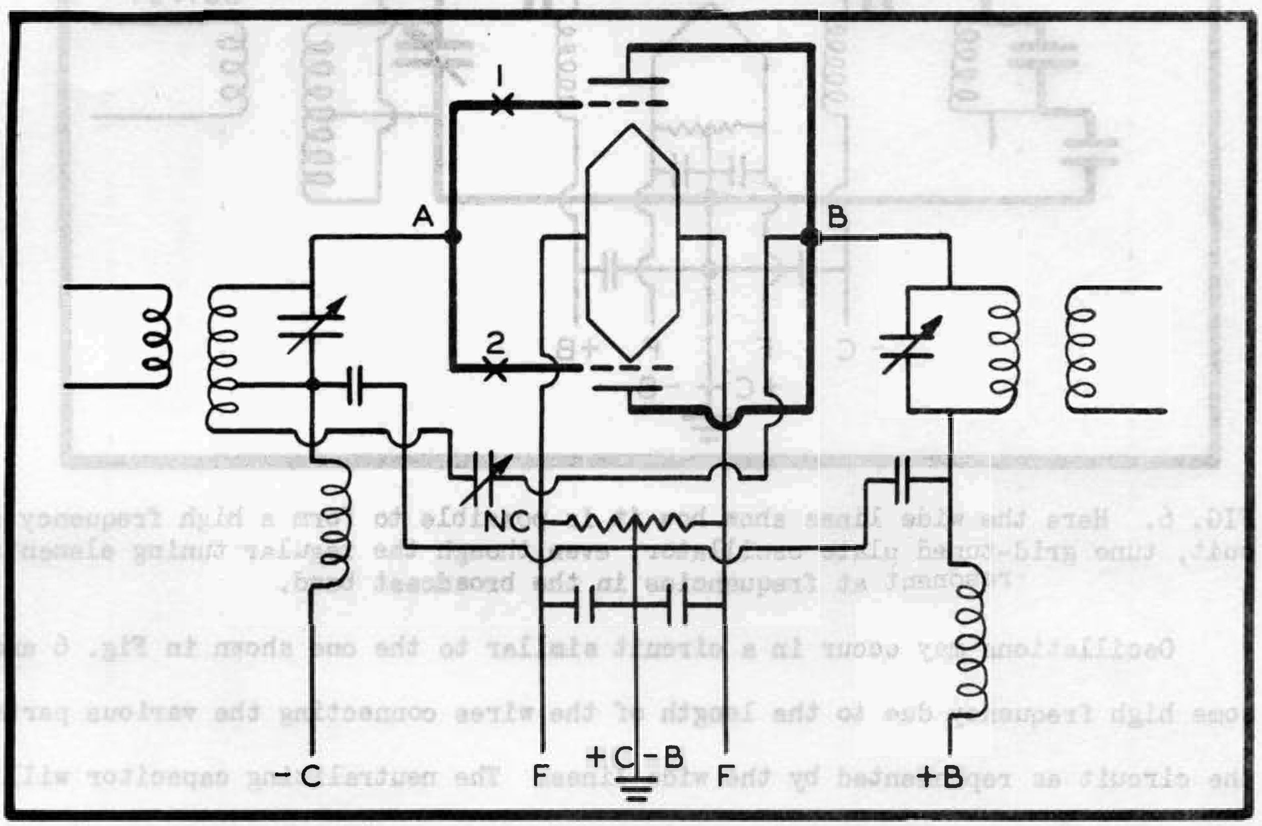

FIG.5. The wide lines between the grid and plate electrodes of tubes connected in parallel form excellent high frequency oscillatory circuits capable of developing considerable power.

Spurious oscillations can also be developed in radio frequency amplifier circuits employing two or more tubes in parallel. A typical circuit is shown in Fig. 5. Again, radio frequencies of ultra high frequency nature may be generated due to the push-pull type of circuit formed by the connecting leads. By inserting non-inductive resistors at points 1 and 2, it is possible to suppress the high frequency oscillations. The efficiency of the amplifier will be increased since the energy originally dissipated within the tube at the high frequency can be transferred to the load circuit. Less plate current will be indicated for the same relative grid current.

A check for spurious oscillations may be made by employing the use of a sensitive all-wave receiver located and operated near the transmitter. The generation of any frequencies other than a direct multiple of the fundamental wave will indicate the presence of spurious oscillations.

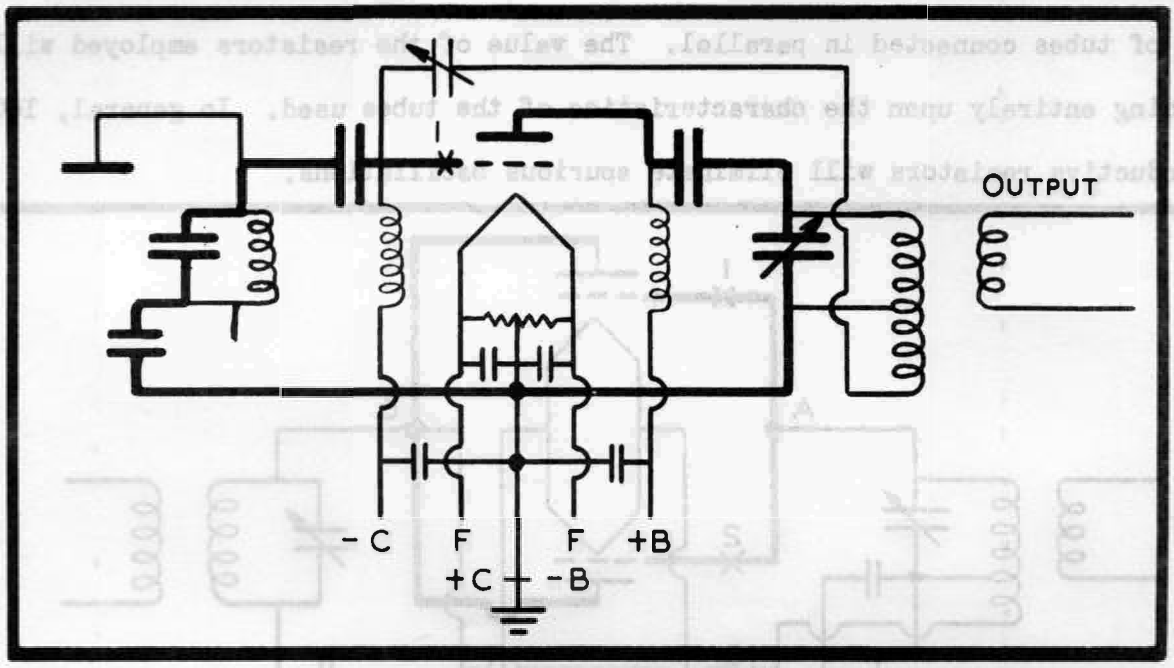

FIG. 6. Here the wide lines show how it is possible to form a high frequency circuit, tune grid-tuned plate oscillator, even though the regular tuning elements resonant at frequencies in the broadcast band.

Oscillations may occur in a circuit similar to the one shown in Fig. 6 and at some high frequency due to the length of the wires connecting the various parts in the circuit as represented by the wide lines. The neutralizing capacitor will not balance out these ultra high frequency oscillations as the circuit can only be neutralized at the frequency upon which it is designed to operate. Spurious oscillations of this nature may be reduced by keeping the leads extremely short and furthermore, by inserting a non-inductive resistor at point 1.

A diagram of a push-pull stage employing cross neutralization is shown in Fig. 7. The wide heavy lines indicate another possibility for the generation of spurious oscillations at ultra high frequencies. Again, the circuit is neutralized only at the resonant frequency upon which it is operating. Non-inductive resistors may be inserted at the points marked 1 and 2 or small inductances consisting of several turns of wire inserted at the points 3 and 4. Just like all of the other circuits discussed the shorter the grid and plate leads are to the parts in the stage, the less will be the tendency for spurious oscillations.

Strong spurious oscillations of radio frequency nature may be located with a resonant circuit having an indicator tuned to the ultra high frequencies and with the

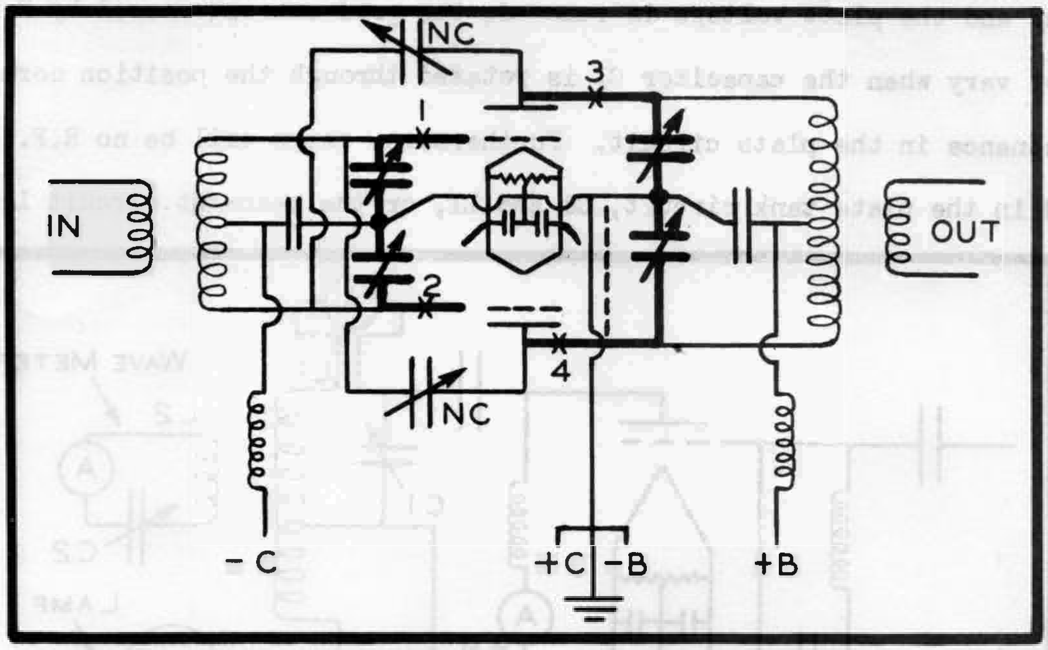

FIG. 7. Here is another circuit that can cause spurious oscillations due to long leads.

transmitter in operation at a reduced power input. A further check may be made with the use of an all-wave receiver. Again, the elimination of spurious oscillations will increase the efficiency of the stage in a transmitter.

CHECKING FOR IMPERFECT NEUTRALIZATION

The amplifier stages of a transmitter may oscillate and develop frequencies other than those desired if it is improperly neutralized. In order to check for imperfect neutralization, we may employ several methods. Practically all of the methods for checking neutralization must be accomplished by removing the plate voltage of the stage to be checked. Since all stages in a radio transmitter have grid and plate current meters, these meters can be used to indicate the operating condition of the tubes. Grid current indicates the relative amount of excitation while the amount of dc plate current assists in indicating the approximate amount of power consumed by the tube and to some extent the amount sent to the following stage.

In Fig. 8 is shown a typical single ended radio frequency amplifier stage. It is neutralized by feeding voltage back to the grid circuit from the lower end of the plate circuit so that it is 180 degrees out of phase, thereby cancelling the energy coupled through the tube capacity. Under normal circumstances, if the stage is neutralized and the plate voltage is removed, the grid current caused by R.F. excitation will not vary when the capacitor C1 is rotated through the position normally occupied for resonance in the plate circuit. Furthermore, there will be no R.F. current indicated in the plate tank circuit, C1 and L1, or the resonant circuit L2 and C2, the

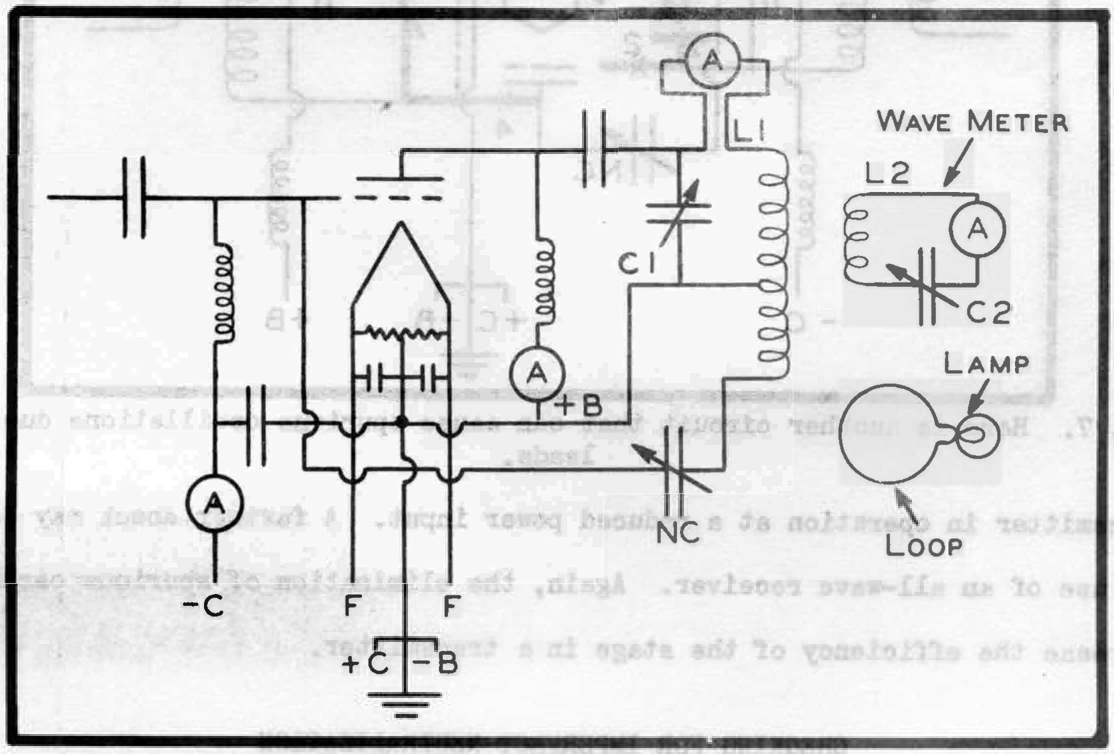

FIG. 8. The triode type R.F. amplifier is shown with its neutralizing circuit, plate tuning circuit ammeter, a wave meter and a pickup-loop lamp circuit for checking neutralization.

wave meter. Complete neutralization means the cancellation of all radio frequency transferred from the grid to the plate within the tube. When there is no radio frequency energy fed into the circuit L1 and C1 the stage is completely neutralized and cannot oscillate of its own accord when its plate voltage is applied.

A radio frequency stage which is imperfectly neutralized may cause very peculiar operating conditions and oftentimes will shorten the life of the tube should it be permitted to operate over any length of time. A careful check can only be made by removing all plate voltage, that is, the A.F. and D.C. plate voltage and checking for the voltages fed to the plate circuit C1 and L1 through the grid-plate capacity when this circuit is in resonance to the frequency applied to the grid circuit.

Incidentally, a gas filled neon lamp may be used to indicate resonance in low powered transmitters. One electrode of the neon lamp may touch the plate electrode. If the gas within the tube does not become ionized (glows) then the stage is properly neutralized providing, however, the circuit L1 and C1 are tuned to resonance with the grid input frequency.

Another simple method of testing for complete neutralization consists of a simple flashlight lamp connected in series with a loop (a single turn of wire) approximately 5 inches in diameter as shown in Fig. 8. Placing the loop near the inductance L1 will cause the lamp to glow if it is improperly neutralized. This arrangement is quite effective when a more accurate andsensitive current measuring device is not available.

RENEUTRALIZATION OF TRANSMITTERS

At the beginning of this lesson and in Fig. 2 is shown a schematic wiring diagram of a crystal oscillator, a buffer or intermediate R.F. amplifier and a final R.F. amplifier of a radio frequency transmitter. Neutralization is employed in the second and last stages. In order to reneutralize a transmitter, we, of course, must remove all of the plate voltages except for the first stage. Excitation is then applied to the grid of the buffer tube. This will be indicated by flow of grid current through meter, M2. We may, in this case, use the neon lamp as a decice for indicating when the radio frequency voltage is at a maximum across C11.

With one terminal of the neon lamp on the plate terminal of the buffer amplifier stage. Adjust the tuning capacitor C11 in the plate circuit until the neon lamp glows. This will indicate resonance in the plate circuit. This is with the neutralizing capacitor C9 set at minimum capcity. Now increase the value of the neutralizing capacitor until the neon lamp goes out. For a finer adjustment readjust the plate tuning capacitor C11 again for maximum glow and then turn the neutralizing capacitor C7 for the final adjustment reducing the neon glow to zero. Now to double check swing the tuning capacitor C11 through resonance again and watch the grid current meter, M2. If this grid current meter, M2, indicates a change then the circuit is not completely neutralized and further adjustment is necessary.

Having neutralized the buffer stage in a transmitter, we are then ready to apply plate voltage to this stage. After the applying of the plate voltage, then the plate tank circuit capacitor C11 should be tuned to resonance so that the average plate current is at a minimum value. When this occurs maximum rectified grid current will flow in the final amplifier grid circuit meter, M4. With the plate voltage removed and the neutralizing capacitor set at minimum capacity, adjust the plate tuning capacitor C14 until resonance is obtained. Resonance will, of course, be indicated by maximum glow obtained by contacting one terminal of the neo lamp to the plate terminal of the final amplifier stage.

Neutralization should not be attempted until the antenna coupling inductance is disconnected or adjusted for minimum coupling. Either remove a terminal clip, rotate the coil 90 degrees, or separate the two inductors. Having adjusted the plate circuit C14 - L3 to resonance, then increase the capacity of the neutralizing capacitor C13 until minimum glow is obtained from the neon lamp. It should be, under normal circumstances, possible to cause the neon lamp to stop glowing. When this condition is reached, then the plate circuit C11 - L2 of the buffer amplifier stage should be retuned, that is, retuned so that maximum grid current is indicated by the meter M4. Again, to insure complete neutralization adjust the plate tank circuit C14 of the final amplifier stage for maximum glow of the neon lamp. Then adjust the neutralizing capacitor C13 and rotate it until there is no glow. Only a small change will be necessary. Having removed all radio frequency from the plate circuit then vary the tuning of the plate capacitor C14 and notice in particular whether or not the grid current meter M4 varies. If the grid current varies slightly then you may increase the capacity of the neutralizing capacitor C13 and again check to see whether or not the grid current change has increased or decreased. It is necessary to repeat this process until a setting of C13 is obtained where the grid current M4 will be absolutely stationary regardless of the position occupied by the plate tuning capacitor C14.

Having completely neutralized the final R.F. amplifier we may then couple the antenna inductance loosely to it and then tune it to resonance. Of course, the plate voltage must now be applied to the final R.F. amplifier tube. Minimum average plate current will indicate resonance in the plate circuit C14 - L3. Maximum antenna current will indicate resonance. After obtaining resonance in the antenna circuit of which L4 is a part, then increase the coupling to the proper value d.c. current which when multiplied by the d.c. plate voltage will indicate the amount of power to be dissipated by the final R.F. amplifier tube and as specified in the station license.

We have now completely reneutralized the transmitter and placed it into operation. If more excitation is required then the values of C6 and C12 may be increased or the plate voltage of the buffer stage increased. On the other hand, if the excitation is too great, the lowering of the plate voltage will be satisfactory. Better regulation of the applied R.F. voltage will be obtained by connecting the left hand lead going to the coupling capacitor C12 by connecting it on a turn closer to the lower terminals of bypass capacitor C10.

MEASUREMENTS OF DOUBLE FREQUENCIES

Generators of radio frequency like all other oscillating devices have harmonics of sufficient intensity to be detected. Radio transmitters operating on low frequencies and employing high power generate harmonic frequencies which will interfere with other services operating on multiples of the fundamental frequency. It is essential that the intensity of the harmonic radiation be reduced to a minimum, thereby keeping interference at a low value.

The second harmonic signal generated by a transmitter used for broadcasting purposes may be sufficiently suppressed by using traps or suppressor circuits. Some of the common practices employed in reducing the intensity of harmonics generated by transmitters will be discussed. The intensity of harmonics may be reduced considerably by making certain that there are no wires placed near the antenna system such as guy wires which resonate at two, three or four times the transmitter frequency. If these wires are one-half wave length long thereby resonating at the harmonic frequencies they have then the possibilities of re-radiating these harmonics. Changing the lengths of these wires by inserting insulators will decrease the radiation of harmonics.

One of the more simple yet effective methods of reducing harmonics is to employ the use of a high frequency by-pass capacitor C1 in the grid circuit of the radio frequency amplifier tube as shown in Fig. 9. The reactance of the capacitor is lower

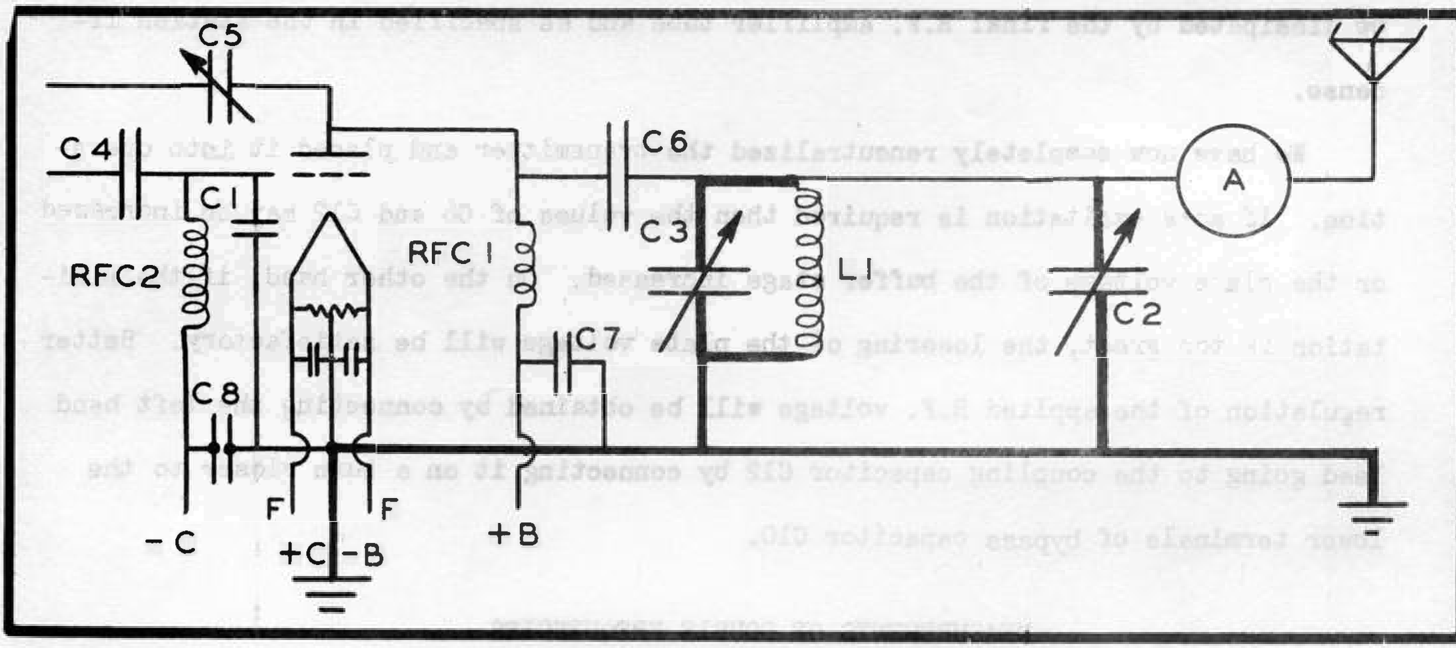

FIG. 9. Note that this final R.F. amplifier employs three capacitors; C1, C2 and C3, all of which should have short leads for effective bypassing of double or harmonic C3, frequencies.

as the frequency increases. Mounting the capacitor with short leads between the grid and cathode terminals of the tube so that it will by-pass the higher radio frequencies, we will reduce the high frequencies present at the input of the final stage of a transmitter.

Further reduction of harmonic radiation is obtained by employing a circuit in the antenna coupling system which uses a capacitor. The capacitor C2 as shown in Fig. 9 will effectively by-pass the higher radio frequencies of harmonic relationship when its leads are short for it has low reactance at the higher frequencies. This shows that certain circuits have better characteristics than others, especially for the reduction of harmonic radiation.

Another combination which may be employed effectively in reducing the intensity of harmonics is shown in Fig. 10. In this system, a transmission line is used and connected to two low-pass filters consisting of two series resonant circuits, connected to each side of the R.F. line to ground. These series resonant circuits are

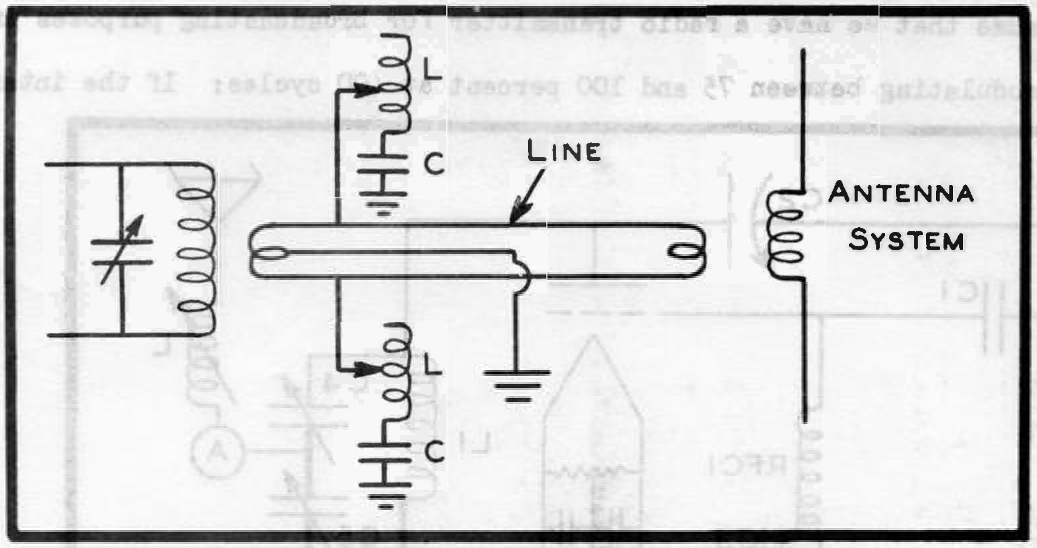

FIG. 10. Here the R.F. transmission line is used to convey the modulated R.F. signal to the antenna system several hundred feet away.

used to offer low resistance to the high harmonic frequencies generated within the final R.F. amplifier tube of the transmitter.

Of the various combinations shown for the elimination or reduction of harmonics, the capacitor C1 in Fig. 9 and the parallel capacitor C5 shown in Fig. 11 are most effective. There are other forms employing capacitors in shunt with the circuits feeding the antenna system and in the grid circuits of the final amplifier tube elements which have proven to be effective but these are the important ones.

MEASUREMENT OF HARMONIC DISTORTION

The presence of audio frequency harmonic distortion is important in broadcast transmitters as the combined harmonic content must not be more than ten percent.

The measurement of the intensity of the audio frequency harmonic content is quite simple when suitable equipment is available for the purpose. A selective audio frequency amplifier with a calibrated dial and a means for calibrating its overall amplification can be employed to measure harmonic voltages individually. A special calibrated vacuum tube voltmeter and a special phase shifting circuit for the removal of the fundamental signal, which allows all of the harmonic voltages to come through, may be used. Then a circuit whereby the fundamental frequency is filtered out and all other harmonic voltages added togethef may be used.

Let us assume that we have a fadio transmitter for broadcasting purposes in operation and modulating between 75 and 100 percent at 400 cycles: If the intensity

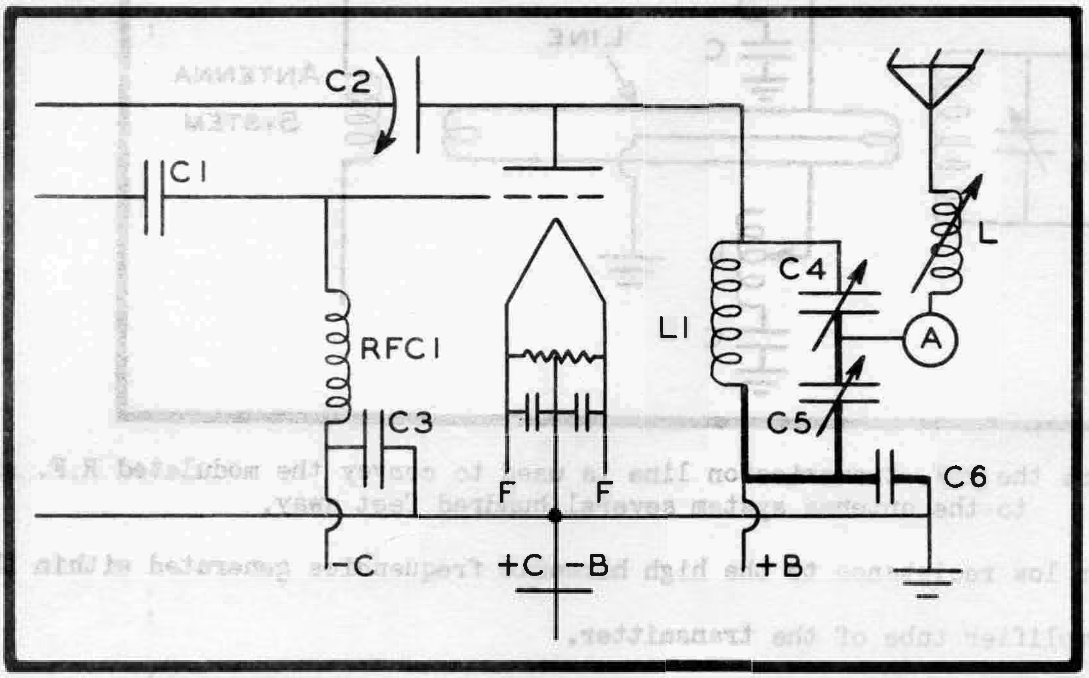

FIG. 11. Here the R.F. modulated signal, which is applied to the antenna, is developed across C5.

of the second harmonic, which is 800 cycles with respect to the fundamental, equal to 4 percent, as measured on a selective audio frequency amplifier, it will mean that the second harmonic of the audio signal is 4 percent as strong as the fundamental. Another check is made upon the harmonic signal intensity as radiated and detected on the third harmonic of the fundamental audio frequency signal of 400 cycles which is 1200 cycles, may be 6 percent. We can, of course, go on and find the intensity of the various harmonics at four, five and six times the test signal frequency, however, they are usually very weak and do not materially add to the total harmonic content. Then, too, we are more concerned in mastering the procedure than the actual percentage.

After we have measured the intensity of the second and third harmonics by the use of a selective A.F. amplifier, we may determine the combined audio frequency harmonic content present in the radiated signal. This is found by the square root of the sum of the squares of the harmonics present or measured. That is, 4 squared will give us 16, while 6 squared will give us 36. Adding these two together, we obtain a combined sum of 52. Then we extract the square root of this number and get 7.2 percent. This is the total combined harmonic distortions.

Examination questions on following pages.