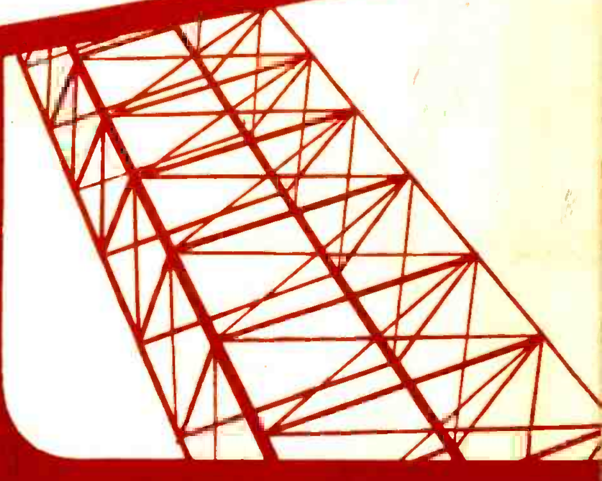
F-M Receiver Circuits

Lesson RRT-18



DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RRT-18

Radio Reception and Transmission

LESSON RRT-18

F-M RECEIVER CIRCUITS

CHRONOLOGICAL HISTORY OF RADIO AND TELEVISION DEVELOPMENTS

1936—Frequency modulation broadcasting developed and announced by E. H. Armstrong. Frequency modulation has more recently come into common use.

1939—The electron microscope was announced by Dr. Vladimir Zworykin and completed in 1940. Magnifications up to 100,000 diameters can be obtained with this instrument.

1939—Color television was demonstrated to the Federal Communication Commission by RCA.

1940—The National Television Systems Committee was organized to draft standards for the television industry.

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INDEX

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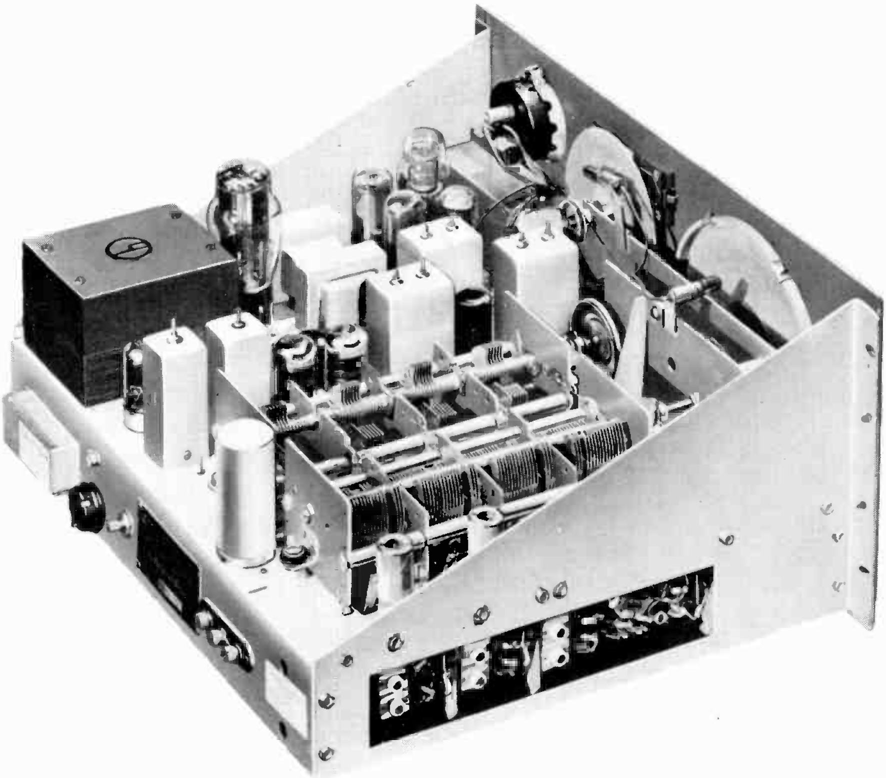
FRIENDSHIP

Oh, the comfort—the inexpressible
Comfort of feeling safe with a person,
Having neither to weigh thoughts,
Nor measure words—but pouring them
All right out—just as they are—
Chaff and grain together—
Certain that a faithful hand will
Take and sift them—
Keep what is worth keeping—
And with the breath of kindness
Blow the rest away.

F-M RECEIVER CIRCUITS

Commercial types and models of f-m receivers consist of various arrangements of the sections or stages explained in the preceding lessons. Reviewing briefly, the output of an f-m receiver detector is essentially the same as that of an a-m receiver detector therefore both types employ the same general forms of audio amplifiers and speakers.

A-M broadcasting was well established with millions of home receivers, before the introduction of f-m therefore, to make this new service available, as quickly and economically as possible, the



A combination a-m and f-m receiver arranged for rack and panel mounting.

Courtesy The Hallicrafters Company

early models of f-m receivers were in the form of adapters or tuners. The f-m tuners included only the r-f, mixer, i-f and detector stages and thus provided a-f input signals for the audio amplifiers of existing a-m receivers or public address systems.

Following the tuners, complete f-m receivers were made available but, due to the large number of popular a-m broadcast programs, comparatively few units of this type were sold. More recently, the f-m tuner is included as an integral part of an a-m receiver to make the popular a-m/f-m combination. Thus, a modern radio receiver may operate over broadcast and short wave a-m bands as well as the f-m broadcast band.

F-M TUNER

To describe these various types of receivers, in the order of their development, the circuit diagram of a typical f-m tuner is shown in Figure 1. The input section consists of a pentode r-f amplifier, a pentagrid mixer, and a triode high-frequency oscillator followed by a two-stage i-f amplifier the output of which is applied to the ratio type of detector. The a-f output of the detector is available as an audio amplifier input. The remaining circuits in the lower left of the diagram are those of the power supply and tube heaters with a tuning indicator tube at the right.

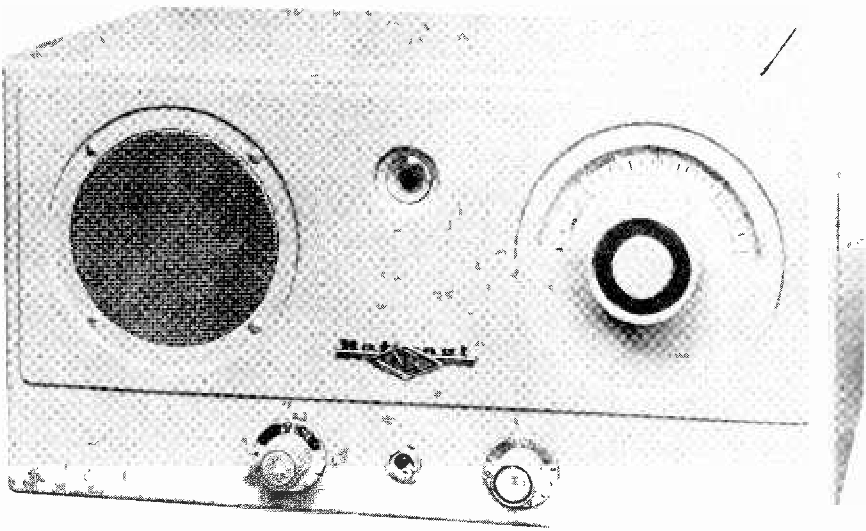
The modulated carrier voltage which appears in the external antenna circuit is coupled inductively through transformer T_1 to the control grid of the r-f amplifier tube, the output of which appears across plate load coil L_1.

With no inductive coupling between the coils, the amplified carrier voltage across coil L_1 is coupled through condenser C_9 to the tuned circuit of coil L_2 and impressed on input grid No. 3 of the mixer tube. The No. 1 grid of the mixer tube is coupled through condenser C_4 to the grid end of the Hartley oscillator tank coil L_4. Applied separately to grids of the mixer tube, the modulated carrier and oscillator frequencies produce the beat or modulated i-f in the plate circuit and a corresponding voltage appears across the tuned primary of i-f transformer T_2.

As explained in the preceding lesson, the voltage across the primary of T_2 is amplified by the i-f stages and impressed across the detector where it is demodulated. In the circuit of Figure 1, the a-f or signal voltage appears across condenser C_{23} and after passing through a filter, is available across condenser C_{25} through coupling condenser C_{26}. In operation, the tuner output is connected directly or through a suitable transmission line to the input of an audio amplifier.

As far as the schematic diagram is concerned, the f-m tuner of Figure 1 is similar to the corresponding circuits of the more common broadcast a-m receiver. However, due to the higher carrier and intermediate frequencies and wider bandwidth of operation, special precautions must be taken in its electrical and mechanical assembly. Placement of component parts is quite critical and all r-f leads to parts, including bypass condensers, must be as short as possible and dressed to minimize inter-coupling and capacitance effects.

For this same reason, resistive-capacitive decoupling filters are placed in the plate and screen grid circuits of the r-f amplifier, mixer and 1st i-f amplifier tubes. Also, as shown at the lower left of Figure 1, inductive-capacitive filters are included in the heater circuits of the r-f amplifier, oscillator, mixer and both i-f amplifier tubes. The r-f amplifier input, mixer input, and oscillator circuits are tuned simultaneously by a 3 gang variable condenser while the i-f transformers, T_2, T_3 and T_4 employ permeability tuning.



Commercial f-m communications receiver equipped with magic eye tuning indicator.

Courtesy The National Company

The plate supply is a conventional full wave rectifier type with an output filter made up of resistor R_{15} and condensers C_{18}-C_{19}.

THE AVC CIRCUIT

In a-m broadcast receivers, automatic volume control is employed to help maintain the output volume more nearly independent of changes in signal strength, also to prevent overloading of the r-f and i-f amplifier stages. These same functions are served by the avc systems in f-m receivers, but in models using a discriminator type of detector, the i-f stages are operated near maximum gain in order to insure saturation of the limiter. Therefore, very little increase in i-f gain can be effected by the avc system when the incoming signal drops below the minimum value required to cause saturation of the limiter tube. However, the avc circuit can act to prevent overloading of the various amplifiers, and since any such overloading can result in the production of spurious responses, in this type of receiver the system is useful to counteract excessive increases of input signal strength.

In f-m receivers employing a ratio detector, there is no limiter stage to be saturated, and the i-f amplifier can operate with somewhat less gain than that in the limiter-discriminator type receivers. Therefore, with the ratio detector, an avc voltage can have considerable control over the amount of amplification supplied by the i-f stages, as it can bring about a greater increase or decrease in gain without causing distortion.

Like the avc systems explained for a-m receivers, a negative d-c voltage with a magnitude which is directly proportional to the peak carrier amplitude is required as a source of control. This controlling voltage must be applied in series with the fixed grid bias of the tubes, the gain of which is to be controlled.

Finally, the controlled tubes must be of the remote cut-off type, so that a change in amplification can be obtained by virtue of the change in the slope of the I_pE_g characteristic curve over the operating range, and in order that a large increase of negative d-c grid bias voltage will not result in clipping of the negative signal peaks.

In the ratio detector circuit of the tuner of Figure 1, the upper plate of the large filter condenser, C_{27}, is negative with respect to the lower plate, and the junction between resistors R_{22} and R_{23} is connected to ground. Due to the charge on C_{27} the upper end of R_{22} is negative with respect to ground, and as the condenser charge is directly proportional to the peak carrier amplitude, the required negative control voltage for the avc system is available at point "X".

From point X there is a path up, left and up through resistor R_{12} and the secondary of T_3 to the control grid of the 2nd i-f amplifier tube. Also, there is a path to the left, up through R_8 and the secondary of T_2 to the 1st i-f amplifier grid. Condensers C_8 and C_{14} provide low reactance paths to ground for the i-f signals in their respective grid circuits and with condenser C_{10} form an avc filter. The fixed bias for these tubes is provided by the voltage drops across R_9C_{11} and $R_{13}C_{15}$ connected between the respective cathodes and ground.

The complete grid circuit of the 1st i-f tube can be traced from the grid through the secondary of T_2, through R_8 to point X, through R_{22} to ground and from ground up through R_9 to the cathode. For the second i-f tube, the circuit is from the grid through the secondary of T_3, through R_{12} to point X, through R_{22} to ground and from ground through R_{13} to the cathode. Thus, resistor R_{22} is in series with the grid returns and voltages across it will vary the grid bias.

Briefly, the action of this avc system is such that any slow increase in carrier amplitude will cause C_{27} to be charged to a higher voltage. Thus, point X will become more negative with respect to ground, and when applied to the i-f grids, this increased voltage reduces the amplification of the tubes.

A decrease in the strength of the incoming carrier amplitude causes point X to become less negative and the i-f tubes operate with increased gain. Thus, the action of this avc circuit is the same as that used in a-m receivers and can be applied to the r-f amplifier as well as to the i-f stages.

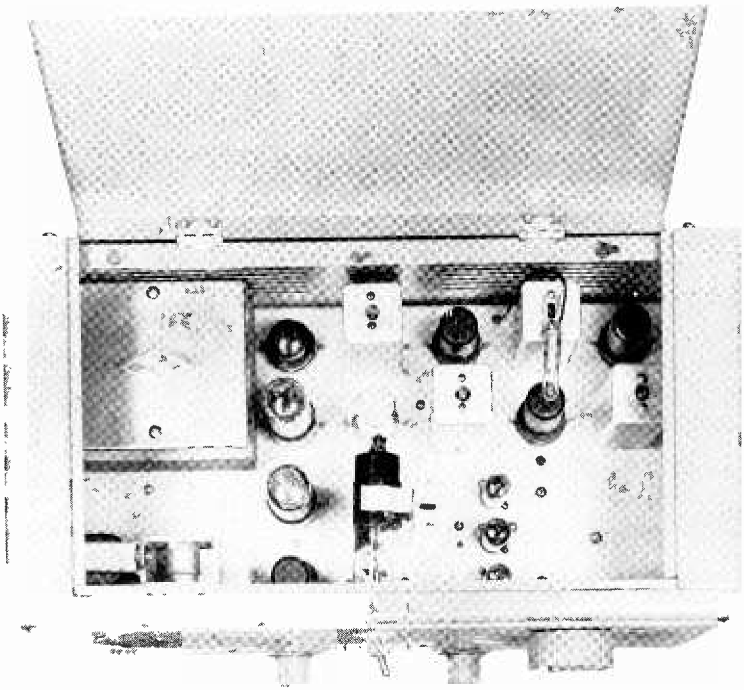
PRE-EMPHASIS AND DE-EMPHASIS

In an earlier lesson it was mentioned that, in an f-m system, the noise and interference effects are much less prominent than in an a-m system and also that most of the noise output occurs in the higher audio-frequency region. This high-frequency noise is more irritating to the human ear and therefore is more objectionable than if it were distributed uniformly over the audio spectrum.

To compensate for this unfavorable condition, f-m systems employ what is called a "pre-emphasis" filter in the transmitters, and a "de-emphasis" filter in the receivers. Briefly, the function of these circuits is to over-amplify the higher audio frequencies before modulation at the transmitter, and then reduce them to their proper relative amplitude at the receiver, thereby reducing the noise voltages in the same proportion.

A simple circuit of a transmitter pre-emphasis filter, shown in Figure 2-A, is normally inserted into the input circuit of one of the early stages of the transmitter audio amplifier. The input voltage, e_i, is impressed across resistor R and inductor L in series while the output voltage, e_o, is the drop across the inductor only. Since the reactance of inductor L varies with frequency while the resistance of R remains constant, when the frequency of the input voltage, e_i, is increased, a greater percentage of its amplitude will appear across coil L as the output voltage e_o.

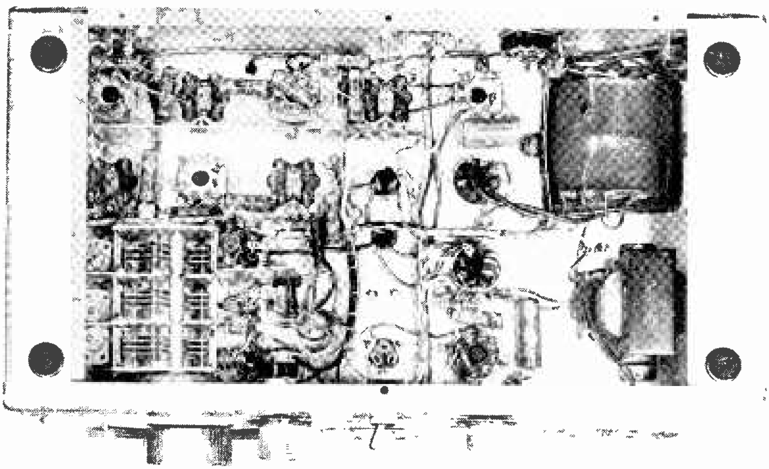
In this way, the output voltage can be made directly proportional to the input frequency and there-



Top-of-chassis view of f-m communications receiver shown in previous illustration.
Courtesy The National Company

fore the higher modulating frequencies cause a much greater deviation of the transmitter carrier wave than they would if pre-emphasis were not employed. Since the high-frequency components of the transmitted signals normally have much smaller power than the low-frequency components, there is relatively little danger of seriously over-modulating the transmitter with the pre-emphasized high audio frequencies.

Thus, at the receiver, the swing of the f-m wave will be much greater for the high audio frequency modulation components than for the modulation produced by noise and interference voltages picked up during transmission or generated within the receiver. However, the various disturbance voltages are amplified the same as the desired signals and appear in the output of the detector with about the same relative amplitude as in the input stage. The detector output is then applied to the de-emphasis filter which attenuates the higher audio frequencies to the proper relative amplitude. This action reduces the higher frequency noise voltages also and thus provides the desired noise reduction.



Bottom view of chassis of f-m communications receiver shown in the two previous illustrations. Note the short connecting leads employed in the high-frequency stages.

Courtesy The National Company

For the simple de-emphasis filter, illustrated in Figure 2-B, the detector output is the input voltage, e_i, which is impressed across resistor R and condenser C, while the output voltage e_0 is the drop across the condenser only. The reactance of condenser C decreases with an increase of frequency while the resistance of R remains constant therefore, as the frequency of input voltage, e_i, is increased, a smaller percentage of its amplitude will appear across condenser C as the output voltage e_0.

In actual practice, the time constant RC of the receiver de-emphasis filter is made equal to the time constant L/R of the transmitter pre-emphasis filter, so that the high audio frequency output of the receiver is attenuated to the exact proportional level that exists at the transmitter microphone. Referring to the f-m tuner circuit of Figure 1, the detector output circuit includes components R_{19}-C_{24} and R_{20}-C_{25} which operate as a two section de-emphasis filter.

In a preceding lesson on f-m reception, graphs were used to show that the noise voltages, present at the detector output, vary directly with the frequency of the audio signal. It was also mentioned that, due to limiting the a-f bandwidth to 15 kc, the maximum noise-voltage amplitude in this circuit is only one-fifth or 20 per cent of what it would be if the amplifier response were flat to 75 kc.

Without de-emphasis, the noise voltage variation vs. a-f output in kc is shown by curve A in Figure 3. The result of high-frequency noise voltage attenuation by the de-emphasis filter is shown by curve B in Figure 3, which represents the amplitude of the noise actually reproduced by an f-m receiver. It is the high-frequency noise components that are most annoying, and as Figure 3B indicates, it is these components which are reduced most by the combined action of the filters in Figure 2.

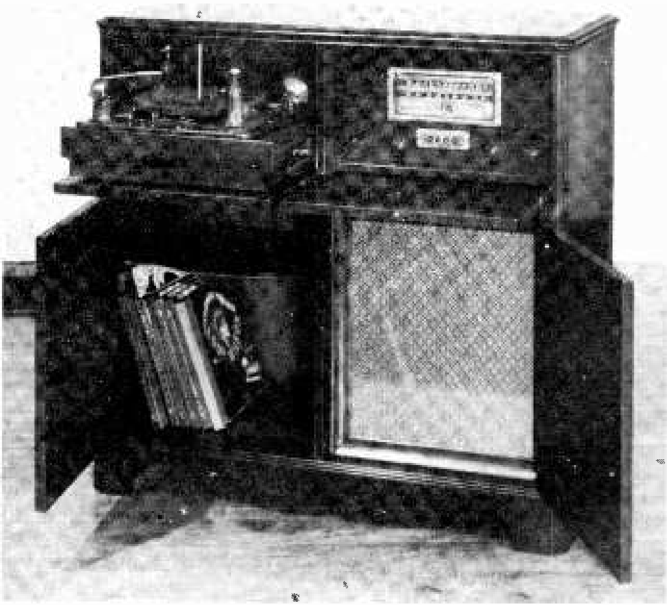
With transmitter pre-emphasis, the higher modulation frequencies have amplitudes much greater than those of the noise voltages. In the receiver circuits, the action of the de-emphasis filter, by reducing desired modulation voltages to the proper proportional level, reduces the noise voltages to insignificant values.

Thus, the noise content in the output of an f-m receiver is held to an extremely low level due to the combined effects of the three operational factors: wide band deviation, 15 kc limit of audio amplifier response, and the application of pre-emphasis and de-emphasis.

TUNING INDICATOR

If an f-m receiver is tuned so that the difference-frequency output of the mixer stage is slightly higher or lower than that to which the i-f transformers are adjusted, the detector will be caused to operate at a point off the center of the linear portion of its characteristic curve. When this condition occurs, the detector output will consist of: 1: an a-f component corresponding to the audio modulation at the transmitter, 2: harmonics of this a-f component, representing distortion due to operation on the curved portion of the detector characteristic, and 3: a d-c component, the magnitude and polarity of which are determined by the amount and direction of mistuning.

As the distortion components in the detector output are undesirable, some means of avoiding or correcting the mistuning is needed. One method consists of including some type of tuning indicator, such as the "magic eye" tube, the theory and operation of which has been explained in a previous lesson on Automatic Tuning Systems. Reviewing briefly, the width of the tuning eye "shadow" is determined by the magnitude of a negative d-c voltage applied to the grid of the tube.



Combination record player—FM-AM receiver.
Courtesy Wilcox Gay Corporation

A magic eye type of tuning eye, included at the lower right in the f-m tuner circuit of Figure 1, has its grid connected to point "X" in the avc circuit. Thus, the negative grid bias, like that of the controlled i-f amplifier tubes, will vary only with relatively slow changes of detector input voltage. For the avc action, an increase of incoming carrier amplitude causes an increase of negative voltage at point "X" to reduce the gain of the i-f amplifier. However, the resonant circuits of the i-f amplifier provide maximum response only at the frequency to which they are tuned.

The tuning condenser of the tuner varies only the resonant frequency of the r-f amplifier input circuit, the mixer input circuit and frequency of the oscillator but does not affect the frequency of the incoming carrier. Thus, as the tuning dial is turned toward the correct setting for a given carrier, the response of the tuned input circuits is increased. Of perhaps greater importance, the change in the oscillator frequency causes the beat frequency in the mixer plate circuit to approach the value at which the i-f circuits are tuned and at which their response is maximum.

Thus, for incoming carriers of any strength or amplitude, maximum detector input and avc voltage occur only when the input and oscillator circuits are tuned correctly. As the avc voltage is applied to the grid of the "eye" tube, correct tuning of the input circuits is indicated by a minimum shadow angle.

AUTOMATIC FREQUENCY CONTROL

With the aid of a tuning indicator, or by ear, a listener may tune his f-m receiver correctly but, due to slight changes of temperature, supply voltage or other causes, the oscillator frequency may vary. This is known as oscillator drift and, by causing a change in the beat or intermediate frequency, it produces distortion in the reproduced signals. This condition can be corrected by retuning but is annoying to the listener especially if it must be done periodically during the reception of a program.

To correct this condition and automatically retune the oscillator to the correct frequency control, afc circuits have been developed. A circuit of this type, drawn in the dashed line rectangle of Figure 4, closely resembles the reactance tube modulator employed in f-m transmitters. Here, the grid circuit of the reactance tube is connected across the output of a discriminator type of f-m detector while the plate circuit is in parallel with the oscillator tank circuit.

As mentioned before, if the receiver is mistuned either above or below the correct setting, the detector output will include a d-c component. For example, with the receiver oscillator operating at frequencies above those of the incoming r-f carriers, if the tuning dial is set so that the oscillator frequency is higher than the correct value, the beat frequency, produced in the mixer, will be higher than the resonant frequency of the i-f and discriminator tuned circuits.

This higher frequency will cause the discriminator transformer secondary to be inductive for more than half the range of the i-f swing, and in the circuit of Figure 4, diode V_2 will always carry more current than diode V_1. This will cause the average potential at point "X" to be negative with respect to ground.

On the other hand, with the tuning dial set so that the oscillator operates below the correct frequency, the mixer beat frequency will be lower than the resonant frequency of the tuned i-f circuits, and the discriminator transformer secondary will be capacitive more than half the time. Then diode V_1 will carry more current than V_2, and the average potential at point X will be positive.

A-M and f-m tuner designed for use with external audio amplifier or sound distribution system.

Courtesy Meissner Manufacturing Division

The audio signal will vary uniformly above and below the average potential at point X, whether it is positive, negative, or zero. However, point X has an average potential of zero only when the receiver is tuned so that the mixer mean beat frequency is exactly equal to the resonant frequency of the i-f transformer and discriminator tuned circuits.

As in an f-m transmitter, the magnitude of the reactive effect of the reactance-tube circuit is determined by the amount of plate current allowed by the control grid of the tube. In the circuit of Figure 4, this grid is connected to point X therefore the reactance-tube plate current will be high when the receiver oscillator frequency is low and X is positive, and low when the oscillator frequency is high and X is negative.

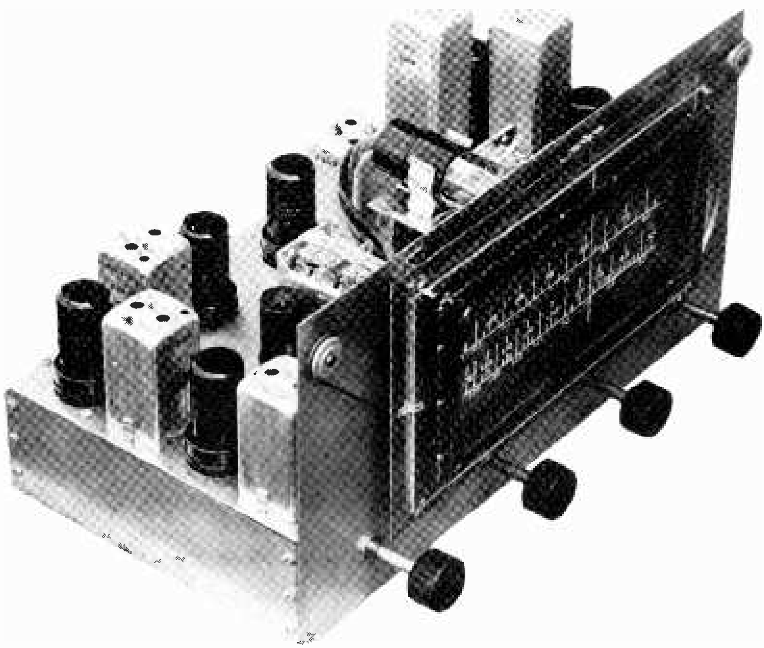
In this example, the reactance-tube circuit is of the inductive type, therefore, an increase in the tube plate current simulates the addition of an inductor in parallel with the oscillator tank, thereby decreasing the total effective inductance and increasing the oscillator frequency. Thus, when the oscillator frequency is low, the i-f is low, point X is positive, the reactance tube plate current is increased, and the oscillator frequency increases toward its correct value. On the other hand, when the oscillator frequency is high, the i-f is high, point X is negative, the reactance tube plate current is decreased, and the oscillator frequency decreases toward its correct value.

With zero average potential at point X, the reactance tube grid will be biased by the drop across the cathode resistor, connected in the usual self bias arrangement. Under these conditions, there will be plate current which will affect the total effective inductance of the oscillator tank circuit. Therefore the various circuit components must be of such value that the oscillator generates the correct frequency when the average potential at point X is zero.

This circuit operates over a rather limited range of frequencies as it is designed only to correct automatically for small degrees of manual mistuning and oscillator frequency drift. However, it is appreciated by the average listener as it relieves him of making precise tuning adjustments or retuning during the reception of a program.

Although mistuning and oscillator drift produce the same effects, as far as the receiver output is concerned, they are due to entirely different causes. Mistuning is done by the operator and is not a fault of the receiver while oscillator drift is due to changes in the receiver circuit and is not a fault of the operator.

As a great part of oscillator drift is caused by changes of temperature, especially during the first few minutes of operation, instead of automatic frequency control, many f-m receiver models are advertised as "drift compensated", "stabilized against drift" or "temperature compensated".



Combined a-m and f-m tuner chassis.
Courtesy Browning Laboratories, Inc.

In technical terms, this means simply that the oscillator circuit is designed for maximum stability. Usually this is accomplished by conventional means such as proper L/C ratios of the oscillator tank, proper type of tube, regulated voltage supply or the installation of some components with negative temperature coefficients to neutralize the effects of other components with positive temperature coefficients. With compensated circuits, the operator must tune the receiver accurately, and retuning, due to oscillator drift, is minimized but with afc, both mistuning and drift are corrected automatically.

SQUELCH CIRCUITS

Although the noise level in an f-m receiver is very low when a program is being received, while tuning from one station to another a certain amount of input noise voltage causes a very undesirable hissing and sizzling sound in the output. To eliminate this interstation noise, some receiver designs incorporate a noise suppression or squelch circuit, which acts to cut off the plate current, in one or more audio amplifier stages, whenever the carrier input falls below a certain minimum level. When a tuned carrier provides an input voltage with an amplitude above the minimum level, the squelch circuit is inoperative but, when the tuning dial is set at any point at which the input circuits are not resonant at an available carrier frequency, the relatively low level of the input noise voltage permits the suppression circuit to become effective and prevent the amplified noise voltages from passing through the audio stages.

To illustrate this action, in the squelch circuit of Figure 5, tube V_1 is the receiver limiter with the control grid bias developed across resistor R_1. As in any grid-leak bias circuit, the amplitude of the bias voltage is directly proportional to the average amplitude of the input voltage which, in this case, is the output of the i-f amplifier.

Checking the circuits of the squelch tube, the plate connects directly to the B+ of the supply, the suppressor grid connects to the cathode, the screen grid connects to a tap on a voltage divider across the plate supply, the control grid connects to the control grid of the limiter tube while the cathode connects to the cathode of the 1st a-f amplifier tube V_3 and resistor R_2, the other end of which is grounded. Thus, the control grid voltage of the limiter is impressed across the grid circuit of the squelch tube while its cathode voltage, with respect to ground, is the same as that of the 1st a-f amplifier tube.

The squelch tube is a sharp cut-off type and, when a carrier is tuned in, the drop across R_1 is of sufficient value to drive the grid to plate current cut-off. Under these conditions, resistor R_2 carries only the plate and screen currents of tube V_3 to provide the proper bias for its control grid and permit normal amplification of the audio signals.

When the tuning dial is turned to any position at which the input circuits are not resonant at the frequency of an incoming carrier, the receiver input consists of only the relatively low noise voltages. As a result, the i-f amplifier output is reduced and the drop across R_1, Figure 5, falls to a value which permits squelch tube plate current. Without a plate load resistor, the plate current of the squelch tube is relatively high and carried by resistor R_2, increases the negative bias on the grid of the 1st a-f amplifier tube to plate current cut-off. Under these conditions, no signals pass through the tube and therefore no noise is reproduced by the speaker.

Thus, as the receiver is tuned across the band, the audio amplifier is operative only when an incoming carrier provides sufficient i-f amplifier output to bias the squelch tube to plate current cut-off. At other positions of the tuning control, plate current in the squelch tube biases the 1st a-f amplifier tube to plate current cut-off and thus the interstation noise is "squelched".

DOUBLE SUPERHETERODYNE RECEIVER

In previous explanations, it was stated that, in a conventional a-m type of receiver, the major portion of the gain and selectivity is provided by the i-f amplifier. This is due to the fact that, designed for operation at a fixed frequency, maximum efficiency can be obtained and also, at the lower i-f, greater gain per stage is possible without instability due to regenerative coupling.

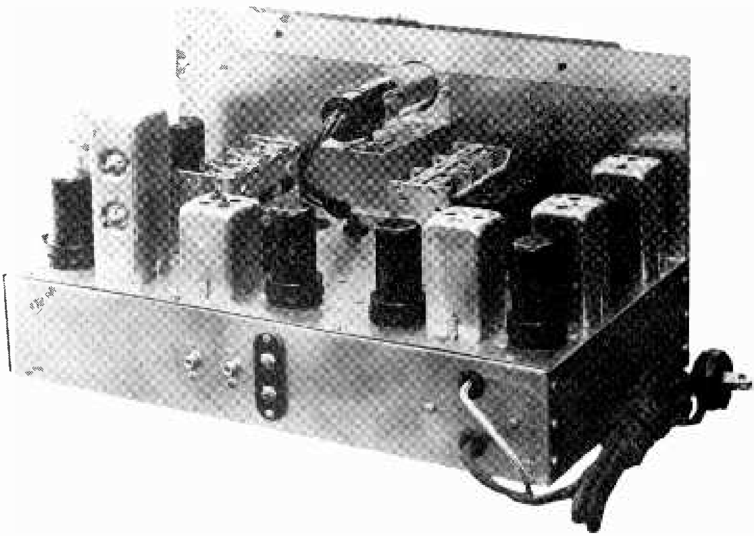
For f-m broadcast systems, conditions are somewhat different and to minimize image frequency interference at the higher carrier frequencies, the intermediate frequencies must be increased. Also, the tuned circuits must respond to a much wider band of frequencies and, in general, this wider response is accompanied by a reduction of gain. Thus, compared with an a-m broadcast receiver, the advantages of low frequency stability and high stage gain are reduced appreciably.

In addition, to realize the full possibilities of f-m noise reduction, the i-f amplifier output must be sufficient to saturate the limiter. Usually, to obtain the required amplitude of i-f amplifier output, the f-m receiver requires more gain, between the antenna and detector, than an a-m receiver. Thus, for the satisfactory reception of weak carriers, the required i-f amplifier gain may be greater than it is possible to obtain without instability due to regenerative coupling.

One method of solving this problem is illustrated in the block diagram of Figure 6 which represents a double superheterodyne or triple detection receiver circuit. Starting at the left, the incoming carrier passes through the r-f amplifier to the first mixer where it heterodynes with a harmonic of the oscillator to produce a comparatively high intermediate frequency. This i-f, which provides effective image frequency suppression, is carried through an amplifier to the second mixer where it heterodynes with the fundamental frequency of the oscillator. The beat frequency output of this mixer, of lower value than either input, is the second i-f which is carried through several amplifier stages to the detector. Operating at a lower frequency, the second i-f amplifier increases the selectivity. quency rejection and adjacent channel selectivity as well as increased gain.

FREMODYNE RECEIVER

Although operating only as an f-m tuner, the circuit of Figure 1 requires 6 tubes, plus rectifier and tuning indicator. Much research has been done to develop a simple f-m tuner or converter



Rear view of a-m and f-m tuner chassis shown in preceding illustration.
Courtesy Browning Laboratories, Inc.

Perhaps the main advantage of this arrangement is that the i-f gain occurs at different frequencies thereby reducing the tendency of regenerative coupling and permitting a higher gain per stage. Also, compared to the ordinary types, it has greater image fre- and the circuit of one of these, known as the "Fremodyne" is shown in Figure 7. It requires but two triodes, usually mounted in a single envelope, eliminates the common form of i-f amplifier and f-m detector yet provides the desired a-f output.

Referring to Figure 7, tube V_1 operates as the oscillator with a tank circuit consisting of coil L_1, condenser C_1 and tuning condenser C_3. Condenser C_2, connected across the coil, acts as a trimmer to provide proper tracking. From the junction between C_1 and C_3, the oscillator frequency is coupled through C_{11} to the grid of V_2. Also, between antenna and ground there is a path through C_{12}, and the tuned circuit consisting of coil L_2, bypass condenser C_{16} and tuning condenser C_4. The grid of tube V_2 connects to the junction between C_{12} and C_4 therefore both the oscillator and incoming carrier frequencies are impressed on the grid of V_2.

With both these frequencies impressed on its grid, a beat or intermediate frequency appears in the plate circuit of V_2 therefore the tube serves as a mixer. As the heterodyne action occurs in the grid circuit, there will be the normal amplification and thus the tube serves as an i-f amplifier also.

Connected in series with the plate, the tank circuit consisting of $C_5C_6C_7$ and L_3 is tuned slightly off the center or mean intermediate frequency, therefore, the voltage across it varies with changes of frequency to provide "slope" detection. Thus, as far as its functions are concerned, tube V_2 of Figure 7 replaces the mixer, i-f amplifier and detector tubes of Figure 1. To provide satisfactory audio output under these conditions, as a detector, tube V_2 must have extreme sensitivity.

In the earlier Simple Receivers lesson, it was stated that the sensitivity of a triode tube type of detector can be increased by "regeneration". To provide this action, energy from the plate circuit is fed back to the grid circuit, in proper phase, and the sensitivity increases with the amount of feedback until the tube breaks into oscillation. Operating as an oscillator, the tube will not act as a detector therefore the feedback must be held below the point of oscillation.

To provide a further increase of sensitivity and therefore output, in Figure 7 the Colpitts type of tank circuit, connected in the output of V_2, provides sufficient feedback to cause oscillation. To permit continuation of the detector action, the oscillator action is stopped periodically at a frequency above audibility. This action is known as "super-regeneration" and the stopping or "squelch" voltage is developed across the parallel arrangement of C_7-R_1.

The circulating tank current charges condenser C_7 to a value which stops oscillation and, as the circulating current dies out, C_7

discharges through R_1 until oscillation is re-established. The time constant of C_7R_1 is of such value that the oscillation stops and starts at a frequency above audibility and therefore can not be heard. The advantage of superregeneration is that the changes of plate current can be greater than required for oscillation and thus the detector sensitivity and output is increased greatly.

The cathode circuit can be traced from the cathode, through RFC_2, resistors R_2 and R_8 to ground. In conjunction with R_2, condensers C_8 and C_9 act as a filter to remove any i-f variations of voltage drop, therefore, only the signal or audio voltages appear across resistor R_8.

The de-emphasis filter, made up of R_4 and C_{10} is connected across R_8 and the resulting voltage across condenser C_{10} is coupled through C_{17} to the volume control R_3. Like the f-m tuner of Figure 1, the output of the Fremodyne of Figure 7 can be connected across the input of any audio amplifier which has a suitable range of frequency response.

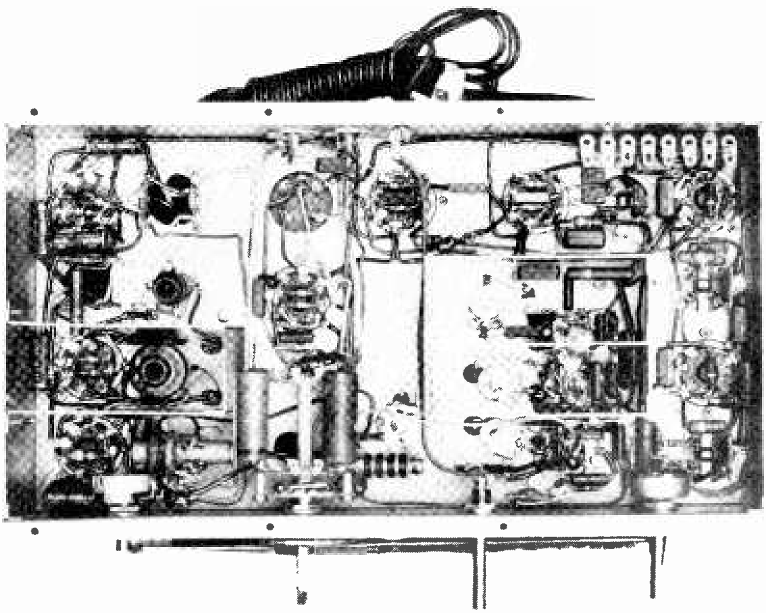
As the output does not depend entirely upon the amplitude of the input signal, the Fremodyne provides considerable limiting action. However, due to its mode of operation, in comparison with conventional f-m circuits it has a lower a-f output, higher distortion and a lower signal-to-noise ratio. Its main advantages are simplicity and lower cost.

A-M/F-M RECEIVERS

As stated previously, most modern f-m receivers are made as an integral part of a "combination" which receives a-m signals also and frequently an automatic record changer is included. Therefore, the circuits of an a-c/d-c unit of this type are given in Figure 8 which has a total of seven tubes plus rectifiers, and with the exception of V_5, which operates as f-m limiter, all tubes are employed for both a-m and f m reception.

Starting at the upper left, tube V_1 is the r-f amplifier, V_2 the mixer, V_3 the 1st i-f, V_4 the second i-f, V_5 the f-m limiter, V_6 the f-m detector, a-m detector and 1st a-f amplifier, V_7 the power output and V_8 the plate supply rectifier. The choice of the type of radio reception is controlled by the 6 gang switch, S1-A, S1-B etc. while the choice of radio or phono is controlled by the two gang switch S2-A, S2-B. Thus, the two stage audio amplifier has three available input signals, 1: f-m radio, 2: a-m radio and 3: phonograph.

The switches are shown in position for f-m reception and starting at the upper left, carrier energy in antenna coil L_1 is inductively coupled to coil L_2 which has an adjustable iron core and is tuned also by condenser C_1 and its trimmer. The voltage across this tuned circuit is impressed on the control grid of the r-f amplifier tube V_1 through switch S1-A and appears with increased amplitude across plate choke coil L_3.



Bottom view of a-m and f-m tuner chassis shown in two preceding illustrations.
Courtesy Browning Laboratories, Inc.

Condenser C_7 couples L_3 to switch S1-B which connects to the tuned circuit of L_1-C_2 and the resulting carrier frequency voltages are impressed on grid 3 of the mixer tube V_2 through a limiting resistor R_1.

The oscillator tank circuit, C_3-L_5 is connected to the cathode of V_2 through switch S1-E and coupled to grid No. 1 through switch S1-D and condenser C_0. The beat or intermediate frequency is carried by coil L_6 which is connected to the plate of V_2 through switch S1-C. From here the i-f is carried through the amplifier stages of V_3, V_4 and limiter stage of V_5 to the discriminator transformer primary L_{12}.

The discriminator circuits are conventional with the upper end of secondary L_{13} connected to the right hand diode plate of V_6 and the circuit completed from the cathode through resistor R_2 and back to the center tap. The lower end of L_{13} connects to the lower left diode of V_6 and the circuit is completed through the cathode to ground and back through resistor R_3 to the center tap.

The audio voltages which appear across R_2-R_3 are connected through de-emphasis filter resistor R_4, through switch S1-F, coupled by condenser C_{11} through switch S2-B to the ungrounded end of the volume control potentiometer P_1. The sliding contact of P_1 is coupled through condenser C_{12} to the triode grid of V_6, the plate of which is resistor-condenser coupled to the control grid of output tube V_7. The plate circuit of V_7 contains the primary of the output transformer the secondary of which is connected across the voice coil of the speaker.

Automatic tone control is provided by a tap on volume control P_1 which is connected to ground through resistor R_6 and condenser C_{15}. Manual tone control is provided by potentiometer P_2, the upper end of which is coupled to the triode plate of V_6 through condenser C_{14} while the sliding contact is grounded. As P_2 is turned to "High" it shorts out condenser C_{15} of the automatic tone control circuit.

Going back to the i-f transformer that couples tubes V_3 and V_4, primaries L_{21} and L_8 are in series in the plate circuit of V_3 while secondaries L_{22} and L_9 are in series with the control grid circuit of V_4. Coils L_8 and L_9 are tuned to the f-m intermediate frequency of 10.7 mc while coils L_{21} and L_{22} are tuned to the a-m intermediate frequency of 455 kc.

Due to this great difference of resonant frequencies, at 10.7 mc, the condensers across the 455 kc coils have negligible reactance while at 455 kc, the 10.7 mc coils have negligible reactance. Thus, for either frequency, the tuned circuits provide the desired action while the other pair are effectively shorted.

For the reception of standard a-m broadcast carriers, switch S_1 is turned to the position opposite to that shown. All sections of this switch are ganged mechanically and operate simultaneously with the turn of a single control knob. Starting at the upper left again, the input coil is in the form of a loop, L_{16} tuned by condenser C_4. In many cases the loop provides a satisfactory antenna but coil L_{15}, with its external terminals, will accommodate an external antenna.

The upper end of the loop is connected through switch S1-A to the control grid of tube V_1 and again, the amplified input voltage appears across plate choke L_3. Now, switch S1-B connects coupling condenser C_7 to the tuned series circuit L_{17}-C_5. Condenser C_5 is not ganged mechanically with the panel controlled tuning condenser but is adjusted so that its circuit provides minimum response at the intermediate frequency. Thus it acts as an i-f trap but, at other frequencies, develops a voltage drop which is applied through resistor R_1 to grid No. 3 of mixer tube V_2.

Switch section S1-D couples the No. 1 grid of V_2 to the L_{18}-C_6 oscillator tank which is tuned to provide the 455 kc i-f in the plate circuit and connected to the cathode through switch S1-E. Switch section S1-C connects primary L_{19} in series with the plate and, due to the inductive coupling, the i-f appears across L_{20}. The circuit of coil L_7, tuned to the f-m i-f, is in series with the circuit of L_{20} which is tuned to 455 kc. As explained previously, at 455 kc the reactance of L_7 is negligible as far as the voltage across L_{20} is concerned. Thus, the i-f is carried through the lower frequency tuned circuits of the V_3 and V_4 stages and appears across coil L_{24}.

From the upper end of L_{24} there is a circuit down and left to the upper left diode of V_6, to the left cathode to ground and from ground up through resistors R_8 and R_7 to the lower end of L_{24}. Because of the diode action, this is the a-m detector circuit, the a-f voltages appear across R_8 and, with respect to ground, the average voltage across R_8 is negative.

This is a conventional a-m diode detector which provides the avc voltage. Thus, from the junction between R_8 and R_7 there is a circuit through R_9, which with C_{17} acts as an avc filter, up through R_{10} to the control grid of tube V_3. Also the circuit extends to the left, through R_{11} up to grid No. 3 of the mixer tube V_2 and also to the control grid of the r-f amplifier tube V_1.

Going back to the junction between R_7 and R_8, there is a path down through switch section S1-F, coupling condenser C_{11} and switch S2-B to the upper end of volume control P_1. From here, the path of the signal through the audio amplifier is the same as for f-m.

For phonograph operation, switch S2-B is thrown to the position opposite to that shown in Figure 8, This completes a circuit from the phono pickup to the upper end of volume control P_1 and the signals are carried through the audio amplifier the same as those provided by the f-m and a-m detectors. To prevent radio interference while the phonograph is in operation, the cathode circuit of tube V_4 is opened by switch section S2-A which is ganged mechanically with S2-B.

The power supply is conventional for a-c/d-c receivers and, although not shown, the heaters are connected in series across the supply with a 100 ohm dropping resistor. In this particular Majestic model, the tube types are as follows: V_1-6BA6, V_2-6BE6, V_3-6SG7, V_4-6SG7, V_5-6SH7, V_6-6S8, V_7-25L6 and V_8-25Z6. All heaters operate at 300 ma for a total drop of 87.9 volts and the 100 ohm resistor develops a drop of 30 volts for a grand total of 117.8 volts.

The plate supply operates directly off the supply line with tube V_8 connected as a half wave rectifier, the d-c output of which appears across R_{13} and C_{21}, in series. Resistor R_{13}, with a resistance of 25 ohms, serves only to limit the surges of C_{21} charging current. Therefore, for all practical purposes, the entire d-c output appears across C_{21}. One circuit extends through filter resistor R_{12} to the plate of output tube V_7 only. Another circuit, through filter choke L_{14}, extends to all the other plates and screen grids. Tubes V_1, V_4 and V_7 are self biased with cathode resistors, avc is applied to the grids of V_1, V_2 and V_3, V_5 is biased by the output of the i-f amplifier and the triode section of V_6 is biased by the high value grid resistor R_5.

The complete receiver requires a total of but five panel controls, 1: Tuning, for control of condensers C_1, C_4, C_2, C_3 and C_6, 2: Band switch S_1, 3: Phono-Radio switch, S_2, 4: Volume control P_1 and 5: Tone control P_2 which carries the on-off switch.

IMPORTANT WORDS USED IN THIS LESSON

AUTOMATIC FREQUENCY CONTROL—A circuit system employed in some superheterodyne receivers by means of which the oscillator frequency is adjusted automatically to provide and maintain the correct i-f.

DE-EMPHASIS—The process of decreasing the relative strength of the higher audio frequencies in an f-m receiver, usually by means of an R-C circuit. It removes the emphasis that was impressed on the higher audio frequencies at the transmitter.

DOUBLE SUPERHETERODYNE—A receiver circuit which employs two mixer stages and two i-f amplifiers which operate at different frequencies. The incoming carrier and oscillator frequencies heterodyne in the 1st mixer to produce a comparatively high i-f which is amplified by the first i-f amplifier. In the second mixer, the first amplifier output heterodynes with an oscillator to produce a lower i-f which, after amplification, is impressed across the detector circuit.

F-M TUNER—A unit consisting of an f-m radio frequency input and mixer stage, an i-f amplifier and a detector or demodulator, used for supplying an f-m program to an audio amplifier or sound system.

OSCILLATOR DRIFT—The gradual shift in frequency of an oscillator resulting from a change in value of some circuit component. Such drift frequently manifests itself during the warm-up period.

PRE-EMPHASIS—The process of increasing the relative strength of the higher audio frequencies in an f-m transmitter, usually by means of an R-L circuit.

REACTANCE TUBE—An electron tube connected and operated so that it draws a 90° leading or lagging current, and in this manner simulates a capacitive or inductive circuit element.

SQUELCH CIRCUIT—A section or stage in a radio receiver by means of which the audio amplifier is squelched or rendered inoperative whenever the input amplitude drops below a predetermined minimum.

STUDENT NOTES

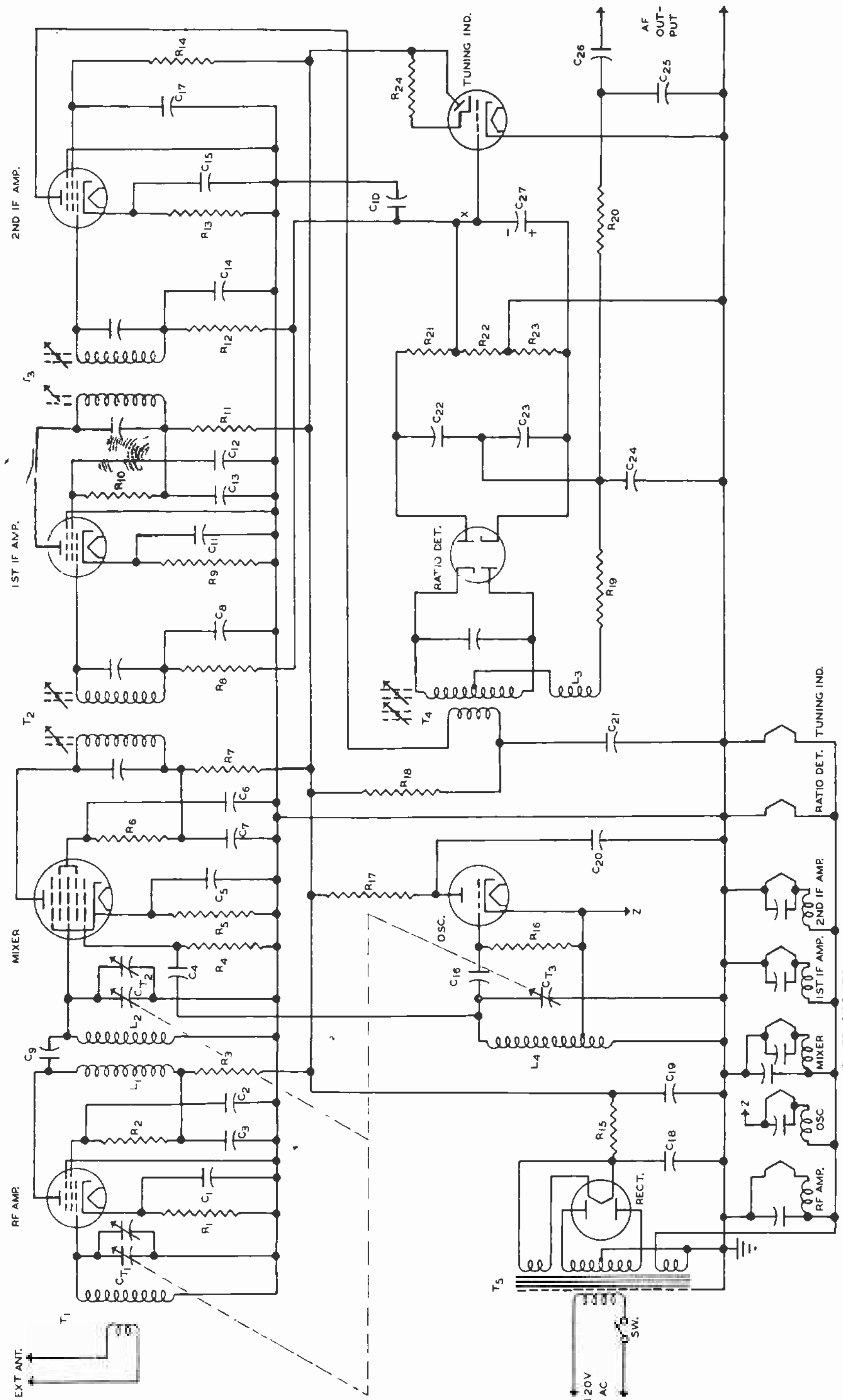


FIGURE 1

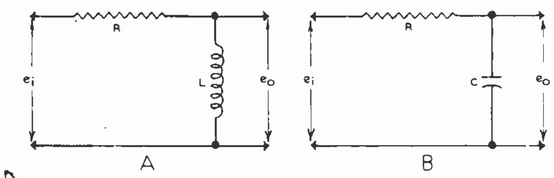


FIGURE 2

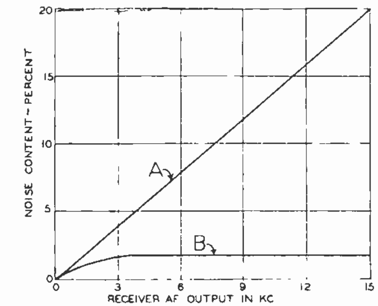


FIGURE 3

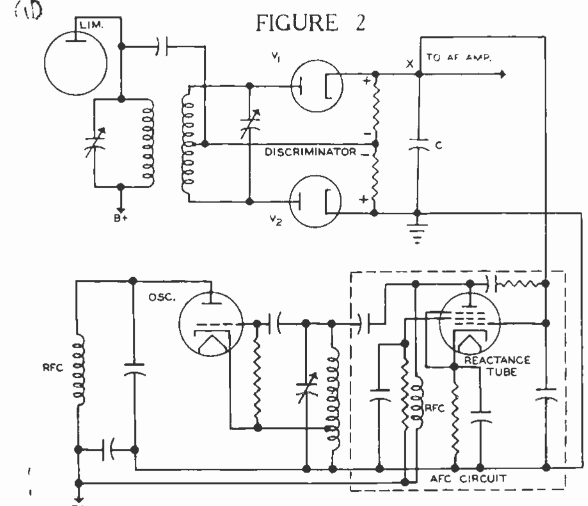


FIGURE 4

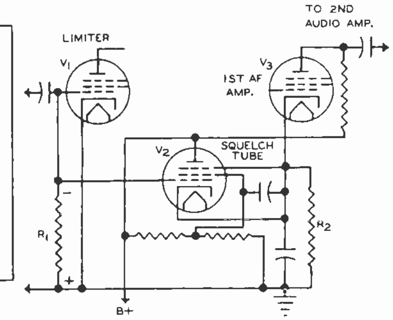


FIGURE 5

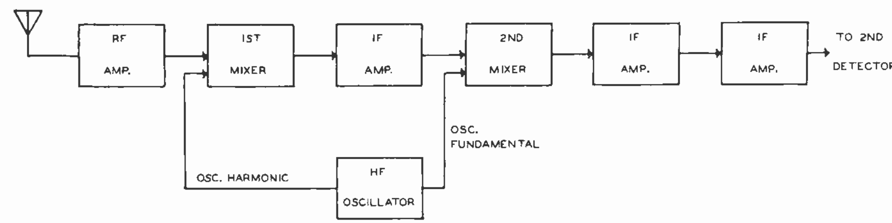


FIGURE 6

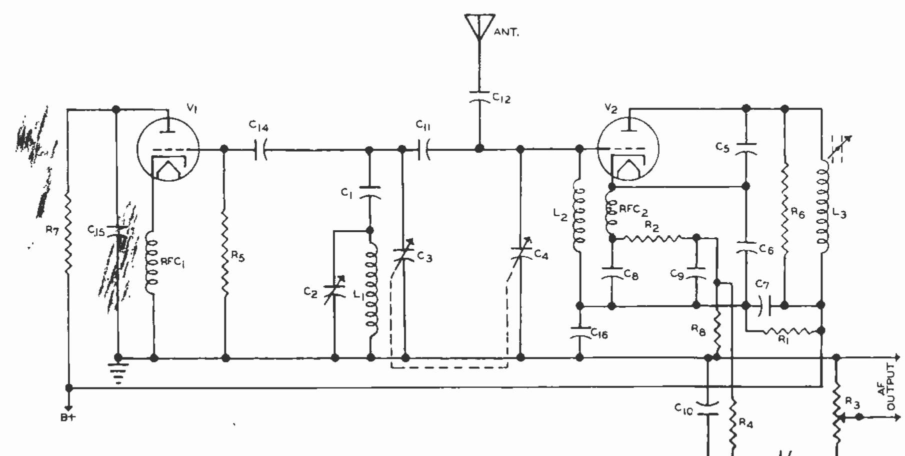


FIGURE 7

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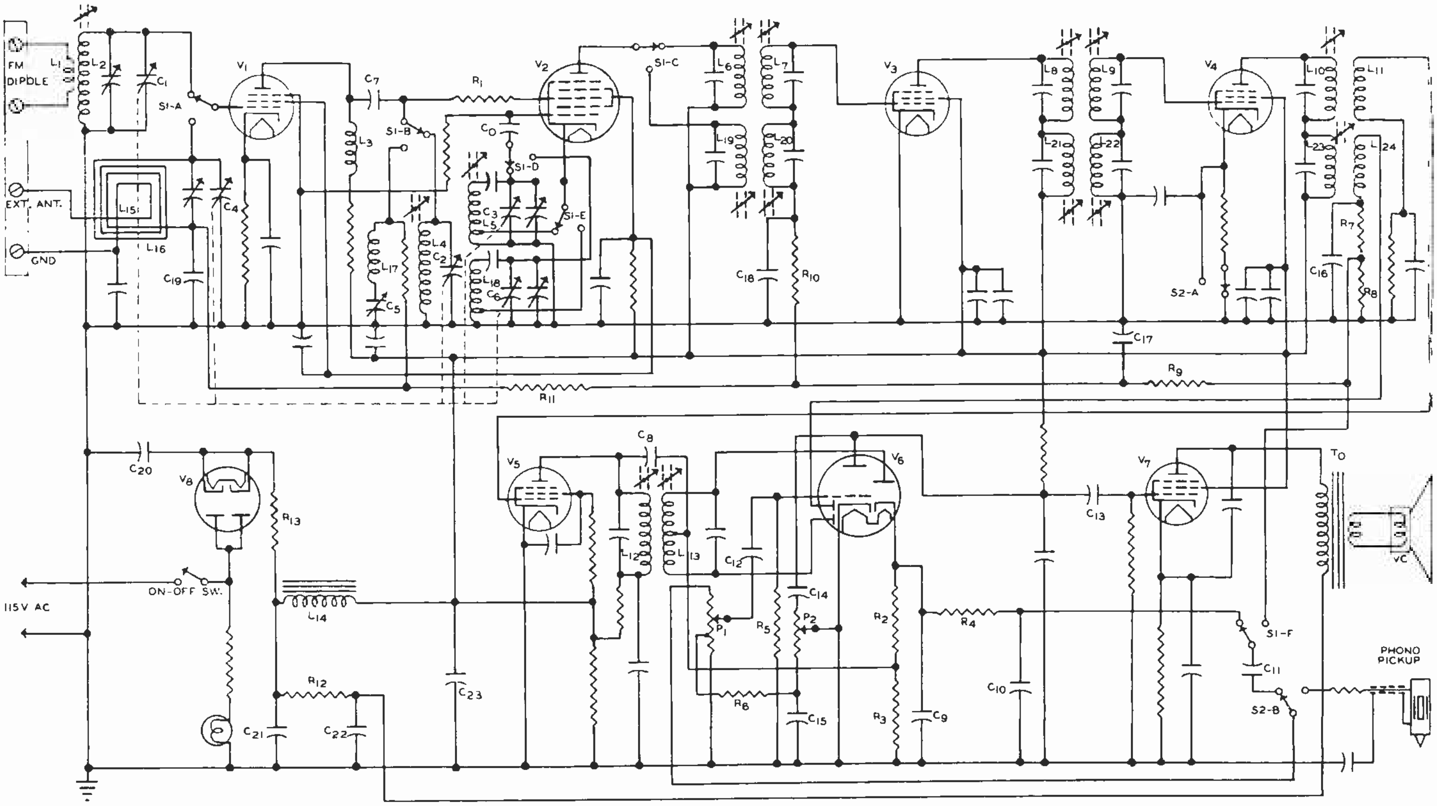

RRT-18

FIGURE 8

FROM OUR *President's* NOTEBOOK

THE MAN WHO FAILS

The man who fails is the sort of chap
Who is always looking around for a snap;
Who neglects his work to regard the clock;
Who never misses a chance to knock.
He is grouchy and slow when work begins,
When it's time to quit, he jokes and grins;
He's always as busy as busy can be.
When he thinks the boss is around to see.
He believes that a "pull" is the only way
By which he can ever draw bigger pay;
And he sulks and growls when he sees his plan
Upset by the "push" of another man.
He's on the job when he draws his pay;
That done, he soldiers his time away,
While the men who tackle their jobs with vim
Keep pushing and climbing ahead of him.
For the man who fails has himself to blame
If he wastes his chances and misses his aim;
He'd win if he'd used his hands and wits;
The man who fails is the man who quits.

—Charles R. Barrett

Yours for success,

E. B. DeVry

PRESIDENT

PRINTED IN U.S.A.