RIDER'S VOLUME XVII

HOW IT WORKS

AND

COMPLETE INDEX

FOR

VOLUMES XVI AND XVII

John F. Rider Publisher, Inc.

404 Fourth Avenue New York 16, N. Y.

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Credit is extended to Seymour D. Uslan for his preparation of the technical material contained herein.

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MAGNETIC WIRE RECORDING

Knowledge of recording on wire or tape dates back to the year 1898 when Valdemar Poulsen, a Danish engineer, invented the first so-called wire or tape recorder. Today the technique has advanced to a point where wire and tape recorders are becoming more widely used. The term *recording* as it is generally understood in the communication field is a process whereby a permanent record is produced on some material by making impressions on it. In many earlier types of commercial recording units it was not possible to use the same recording material more than once. In wire and tape recorders of today this reuse of the recording material is possible.

The underlying theory of magnetic wire recording is quite simple, and understanding the basic method of its operation requires only an elementary knowledge of magnetics. As we analyze wire recording we will review some of the basic points of magnetics so that we may better understand this subject. For a full and complete understanding of magnetics we would have to delve extensively into physical theory, including such topics as hysteresis loops, flux density, reluctance, permeance, magnetomotive force, and the like. Such topics are beyond the scope of this discussion, and the basic theory introduced in conjunction with this analysis of wire recording will be limited to that necessary to an understanding of recording. For a full explanation of magnetics it would be wise to consult some textbook dealing with the subject.

Basic Operation of Magnetic Wire Recording

Generally speaking, in recording speech or music, we are essentially concerned with providing a means whereby this sound can in one way or another be impressed on some permanent recording medium. In recording on disks (wax records) the sound of speech or music through electromagnetic action varies a cutting stylus which cuts into the disk so that it leaves a permanent recording on the disk. The resulting grooves, consequently, are said to contain the intelligence of the sound which originally went into the recording, and by a reverse process these grooves can be made to reproduce the original sound. This system is the one most familiar to the layman, and it is commonly known as *disk recording*.

Magnetic wire recording is much different, in that the recording, although permanent, does not involve the use of any cutting stylus for recording or reproducing needles for playback, and the wire can be used over again after a process of demagnetization.

In brief, the principle of magnetic wire recording is as follows: The sound, as speech or music, after passing through a microphone and the necessary amplifiers, is impressed across a coil. This coil, in conjunction with some permeable material, for example, soft iron, is so arranged that the material becomes magnetized. A good permeable material is one that offers less opposition to magnetic lines of flux than air. The less the opposition to the lines of flux, the better the permeability of the material. So long as current flows through the coil, the material will remain magnetized. The rate of magnetization is directly dependent upon the rate of change of the audio voltage impressed across the coil. While it is magnetized, the metal around which the coil is wound, often called the *core*, has a continuous path of flux lines through it, and these are varying at the same rate as the audio signal impressed across the coil. If a wire (or tape) capable of being magnetized were somehow passed through this magnetic field, this wire would become magnetized at a rate depending on the *rate of change* of the flux lines. If the wire is passed through the field at a constant rate it will be magnetized all along its length, but at different instants of time the degree of magnetization varies as the rate of change of the flux lines.

The simple diagram in Fig. 1 illustrates the basic method of wire recording. This drawing is only for illustrative purposes and does not constitute the method of an actual recorder. It consists of a coil wound around a permeable metal mass or core. An audio signal, after passing through the necessary amplifiers and network, is impressed across the coil. This audio voltage causes a current to flow through the coil which in turn magnetizes the core. This is just a simple method of producing an *electromagnet*. The coil in this instance is called the *magnetizing coil*. The shape of the core is such that a small *air gap* is made between its two ends which are specially shaped and called *pole pieces*. Between these two pole pieces the magnetic flux flows to complete the magnetic path within the now magnetized core. Since the current flowing through the magnetizing coil is varying at an audio rate, the flux lines are also alternating at the same audio rate. In other words, the flux lines are varying at a rate

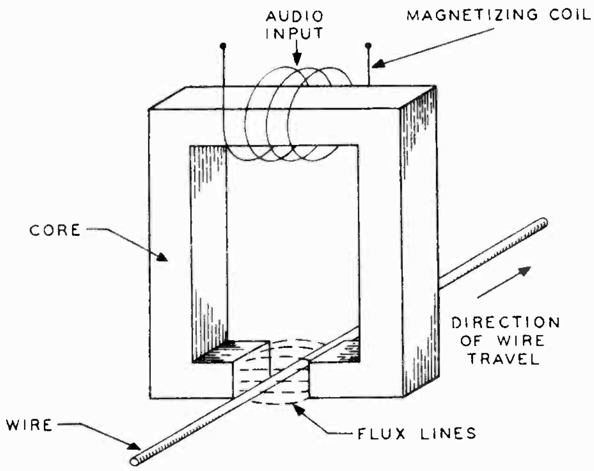


FIG. 1.—Basically, magnetic wire recording requires a coil wound on a permeable core. When the coil is energized with audio, varying lines of flux flow through the core and the air gap, and this magnetizes the wire at the audio rate.

determined by the frequency of the audio input signal to the magnetizing coil.

If the strength of the audio input signal is increased or decreased, the current flowing through the magnetizing coil will increase or decrease proportionately. Since the strength of current flow determines the strength of lines of flux in the core, it also controls the lines of force flowing through the air gap.

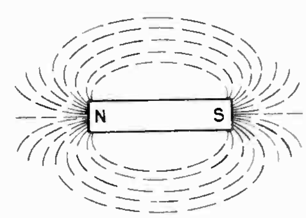
When a certain kind of iron or steel compound is said to have a high degree of *residual magnetic induction* (often called residual magnetism), it means that it can retain its magnetism for a fairly long time. The term *remanence* is applied to the magnetic induction left in a circuit or material after removal of the applied force causing the magnetism. Wire made from material having a high degree of remanence is used in wire recorders. Permanent magnets, such as those used in p-m loudspeakers, are made of material that has a high degree of residual magnetic induction or of remanence. If a piece of wire of such type material is passed through the field in the air gap of the magnet in Fig. 1, this wire will become magnetized and retain the magnetization over a long period of time. Since the magnetic field is varying at the audio rate, the magnetization of the wire will be at the same rate. Likewise the strength of the magnetization of the wire will be in direct proportion to the amplitude of the audio signal.

Consequently, we have a system whereby we can impress across wire of high residual magnetic induction, or of high remanence, a magnetic recording of sound, be it speech or music.

Magnetizing the Wire

It is a basic fact in electricity and magnetism that, if a small steel bar is magnetized, it will become a magnet with a north pole and a south pole. A simple bar magnet is illustrated in Fig. 2 in conjunction with its flux lines. The tendency of these lines of flux is to form a continuous magnetic path between the two poles of the magnet. The lines of flux travel from the south to the north pole inside the magnet and from the north to south pole outside the magnet. If we were to cut this magnet in half, each half also would be a magnet with a north and a south pole. This is shown in Fig. 3 where the magnet of Fig. 2 has been split in half with each half illustrated as a separate magnet. If we were further to divide each of the halves in two, the result again would be two magnets out of each half piece. The num-

FIG. 2.—A simple bar magnet with its lines of flux.



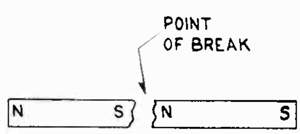


FIG. 3.—Split in half, the bar magnet becomes two separate magnets, each having a north and a south pole.

ber of small magnets we can make by such division is limited only by the size of the bar.

This effect is explained when the construction of a magnet is understood. Every piece of metal, in fact all matter in the universe, is composed of minute particles of the substance in question, which we call *molecules*. These molecules usually have a haphazard arrangement, but in a piece of metal permanently magnetized with d.c. it is said that the molecules align themselves as shown in Fig. 4. Each molecule, or each particle as it is sometimes called, of the metal itself becomes a minute magnet with a north and south pole. The north poles are

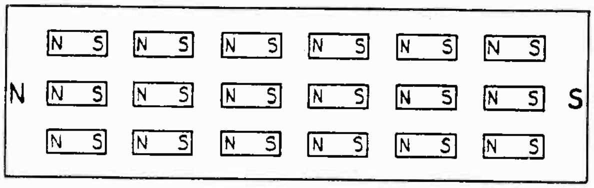


FIG. 4.—In a permanent magnet, the molecules are said to be arranged in this regular fashion with like poles pointed in the same direction.

oriented toward the north pole of the bar magnet, and the south poles are oriented toward the south pole of the magnet.

Once we understand that a magnet actually consists of a number of infinitesimal magnets, we can realize that a piece of wire that becomes magnetized can be made up of many smaller magnets. If a wire moving at a constant speed passes through an alternating magnetic field, the wire will become magnetized in north- and south-pole regions all along its length. The material of the wire and the method of magnetization make it possible to magnetize individual sections of the wire without affecting other parts. Consequently, a long piece of wire can be completely magnetized with individual poles along its entire length. This contrasts with the molecular action in a steel alloy rod which becomes completely magnetized, even though it is effectively energized at only one point. So, we have a method whereby we can record magnetically on wire. Let us analyze this theory a little more thoroughly.

If a coil is wound around an unmagnetized piece of permeable material, and an alternating voltage is applied across the coil, the a.c. that flows through this coil will set up an alternating magnetic field about the material.

The alternating magnetic field will be constantly shifting the position of the molecules of the core material. Consequently, it is said that with the application of an a-c signal the molecules of the core in question, although still considered as individual infinitesimal magnets, will never remain in one fixed position *while* the a-c signal is being applied. Instead they will be changing position at the rate of this applied a-c signal. However, if we suddenly remove the a-c signal, the molecules will remain fixed in their positions at the instant of removal. This theoretical analysis of molecular reaction in the core provides a hypothesis for explaining how the wire becomes magnetized with an audio signal.

It should be remembered that in magnetizing the wire, the wire passes through the air gap between the pole pieces of the magnetizing core. As long as the a-c signal input to the coil exists, there will be a continuous path of alternating flux lines through the air gap. When the wire passes through this air gap, the flux lines will pass through the wire to complete their path through the core. The polarity and strength of the flux lines will vary, and as the wire travels through the air gap, it will become magnetized in different degrees along its length. Thus it is said that the molecules within the wire orient themselves in different positions according to the polarity and strength of the flux lines flowing through the air gap. After recording, the molecules of the completely magnetized wire are said to be permanently arranged in these many different positions, which they assume at that *instant of time* the wire passes through the air gap.

In order to understand this theory let us refer to Fig. 5 which may be one of many methods that can be used to explain the magnetization of the wire. Part (A) of this figure represents a piece of wire that is to be magnetized. The arrows on this piece of wire represent some of the molecules of the wire, and in order to make the discussion to follow somewhat simpler, all are shown in the same position, although it is understood that they are arranged in a haphazard manner. Let us assume that the a-c signal voltage energizing the coil around the core is a sine wave of constant amplitude. Therefore, a sine wave of current likewise flows through the coil in question. One cycle of the current sine wave is illustrated in Fig. 5 (B). Let us further assume that the length of wire shown in Part (A) has passed through the air gap in the time that it takes the sine wave of current to complete one cycle which is shown in (B).

The molecules shown in (A) are those passing through the air gap at the instants of time indicated by numbers 1 to 9 at the sine wave of part (B). As has been said, the position of the molecules during magnetization depends upon the magnitude of the magnetizing force, which in turn is directly proportional to the amplitude of the sine wave of current. Since the amplitude and polarity of the sine wave are changing, then for one cycle of the sine wave, as indicated in (B), the positioning of these molecules will be as shown in Fig. 5 (C) under the assumption that the flux lines flowing through the wire are perpendicular to it. The wire shown at (C) is now magnetized in accordance with the sine wave variation. Since the sine wave passes through zero current (i.e. its baseline) at points 1, 5, and 9, then the molecules of the magnetized wire relative to these points will be unaffected and not change position. This is seen by comparing the arrows in the unmagnetized wire at part (A) relative to points 1, 5, and 9, with those arrows in the magnetized wire at part (C) relative to the same points. At point 2 the wire is subjected to a magnetizing force which is about 0.7 of the maximum force available. Due to this magnetizing force the molecules at point 2 orient themselves in some position which is assumed to be as that shown in Fig. 5 (C). At point 3 the sine wave of current is at its positive maximum and the magnetizing force is likewise at its positive maximum. The molecules at this point will be so positioned that they will be at a maximum displacement from what they were in the neutral state at (A). Consequently, at point 3 the molecules at (C) are shown in a vertical direction pointing upward. At point 4 the molecules are subjected to the same magnetizing force as at point 2. Since point 4 is still in the positive half-cycle region, the molecules at this point in the magnetized wire at (C) take on the same position as the molecules at point 2.

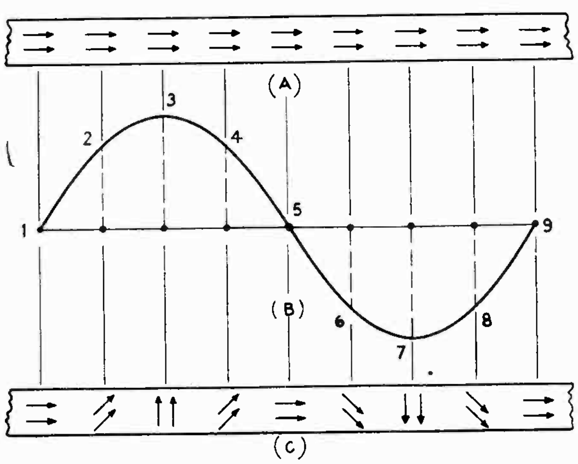


FIG. 5.—The molecules of a piece of wire to be magnetized are shown at (A). (B) shows one cycle of a sine wave of current causing magnetization. The length of wire at (A) is assumed to pass the air gap of a permeable core while one cycle of current is being completed. In (C) the molecules of the wire are already magnetized and are shown rearranged.

The molecules at points 6, 7, and 8 are affected by the *negative* half-cycle of current and consequently they will be pointed in the opposite direction from those molecules affected by the positive half-cycle. This is indicated in part (C). At points 6 and 8 the amplitudes of the sine wave of current are the same, and so the magnetizing forces relative to these points are equal to each other. They have the same magnitude as points 2 and 4 but are of opposite polarity so the molecules relative to points 6 and 8 are oriented in the same direction as seen at part (C) but are opposite to those of points 2 and 4. The magnetizing force at point 7 is a negative maximum and so the molecules that become magnetized at this point are oriented in a vertical direction but with their arrows pointing down, opposite to that for point 3.

The case just illustrated is, of course, hypothetical, but if we realize from it that the wire does become magnetized and that it definitely reproduces the audio signal that is impressed across the magnetizing coil, such an analysis serves its purpose.

Methods of Magnetization

At the present time two methods of magnetizing wire are of primary importance. One method is called *longitudinal magnetization,* and the other *perpendicular magnetization.* When a core (as in Fig. 1) becomes magnetized, the flux lines flow through the air gap to complete its path. If the wire to be magnetized passes through the air gap, the flux lines, in order to complete their path from one pole piece to the other, have to pass through the wire. If the two pole pieces are arranged similarly to those in Fig. 6 (A), the flux lines in traveling from one pole piece to the other travel in a straight line or *perpendicularly* to

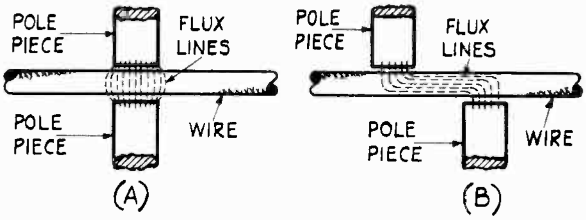


FIG. 6.—(A) When a wire passing between the pole pieces of a magnet is cut at right angles by the flux lines, we have perpendicular magnetization. (B) When the ends of the pole pieces are displaced so that the lines of flux must travel lengthwise through the wire to complete their path, we have longitudinal magnetization.

the wire. The wire becomes magnetized, and, consequently, we obtain the name *perpendicular magnetization* of the wire.

If the pole pieces are so arranged that they are no longer on a straight line but are displaced a certain amount laterally with respect to the wire passing through the air gap between the pole pieces, the lines of flux take on a shape similar to the configuration shown in Fig. 6 (B). Although it is not true of Fig. 6 (A) and 6 (B), in practice the wire occupies practically all of the air gap between the pole pieces. Thus, with the wire filling the space of the air gap, the flux lines of the magnet have to pass through the wire to complete their path from pole piece to pole piece. When the two poles pieces are laterally displaced from each other the flux lines have to travel along the *length* of the wire; or to be more technical, the flux lines have to travel *longitudinally* along the wire [Fig. 6 (B)]. The reason for the term, *longitudinal magnetization,* is thus readily evident.

Wire recorders today use only the method of longitudinal magnetization to achieve successful reproduction. Other methods are not used because the wire, when wound on a spool, will twist and turn somewhat and this will introduce distortion during playback when any method other than longitudinal magnetization is used.

The Magnetization Transfer Characteristic

In the diagram of Fig. 1 we illustrated the fundamentals of magnetizing a wire. In this system we were, in effect, *transferring* the magnetization of the metal core to the wire. It should be remembered that the core is in a state of magnetization as long as the coil wound around it is in continued excitation. Two very important quantities that are usually dealt with in magnetics are termed the *magnetizing force* (usually designated by the letter H) and the flux density (usually designated by the letter B). It is beyond the scope of this book to consider some of the aspects and derivations of such magnetic quantities. However, we can define the term *magnetizing force,* sometimes also called magnetic intensity, as a means of expressing how strong the magnetization is along the path that the flux lines travel. The term *flux density* expresses the number of flux lines per unit area. These two quantities are used a great deal in drawing curves known as hysteresis loops, which topic, as we mentioned at the beginning of this section, we are not going to study. However, we are interested in another purpose for which the relationship between these two quantities is used, that is, the *transferring* of the magnetic characteristic of the core (as in Fig. 1) to the wire. In magnetizing the wire we have to take into account the effective transfer of a magnetizing force (H) and a flux density (B) from the core to the wire. This translation can be represented graphically with respect to B and H, and the graphic representation of this transfer of the magnetization from the core to the wire is called a *transfer curve* or *transfer characteristic.*

This transfer curve is similar in application to the grid-voltage plate-current characteristic curve of amplifying vacuum tubes. In the latter type curve, when dealing with class A audio amplifiers, we have the bias on the tube in question so arranged that the tube operates on the *linear* portion of the curve. It is well known that, if we work on a portion of the curve that is nonlinear, *distortion* in the plate-current output will result. The magnetization transfer characteristic likewise contains linear and nonlinear portions. A typical magnetization transfer characteristic curve is illustrated in Fig. 7. That part of the curve between points 1 and 2 is considered the linear portion over which the magnetization transfer from the core to wire should be made.

If the recording system is as outlined in Fig. 1, the the recording action will be such that the wire will be magnetized over a nonlinear portion of the curve. This means that during reproduction distortion will result in the output of the loudspeaker. Consequently, we see the need for working on the linear portion of the magnetization transfer characteristic to eliminate distortion during reproduction due to the nonlinearity of the transfer characteristic.

A-C Bias

The classification of amplifiers, such as class A, class AB, class B, and so forth, primarily depends upon the factor of grid bias. In fact, in the association of such amplifier classifications we invariably use the grid-voltage plate-current curve of the tube (with respect to a particular set of operating voltages) for a more complete discussion of the amplification, especially when we want to indicate the shape of the plate-current output. The value of bias used compared with the cutoff bias of the tube is a final determining factor in amplifier classification. If we desire to operate the tube as class A, then we need a certain fixed value of bias over which the incoming signal will operate. This is done so that the swing of the incoming signal will never shift the instantaneous voltage on the grid of the tube beyond the linear portion of the grid-voltage plate-current curve. The resultant output plate current will therefore be an undistorted reproduction of the input signal.

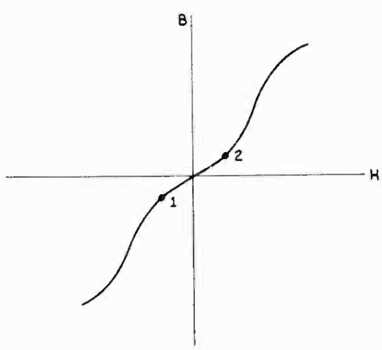


FIG. 7.—The effective transfer of the magnetizing force (H) and the flux density (B) from a core to a wire is here represented graphically. The portion of the curve between points 1 and 2 is considered the linear portion over which the transfer should be made.

In order for the wire recording process to operate over the linear portion of its magnetization transfer characteristic curve between points 1 and 2 in Fig. 7, a bias is applied in a similar manner to that just described. There are many different methods of employing a bias in magnetic wire recording. The bias can be employed in the form of a d-c or a-c signal, which in some prearranged manner will enable the recording apparatus to operate over the linear portion of the magnetization transfer characteristic. Most of the wire recorders today make use of an a-c signal for the bias. Consequently, with many wire recording systems we have to deal with an *a-c bias* for proper magnetic recording.

The a-c signal used in the wire recorder unit of the Majestic combination recorder-radio-phonograph Model 7YR752 is produced by a separate oscillator circuit using a 50B5, a beam power tube. The recorder of this unit appears in Rider's Vol. XVII on Majestic page WIREC. 17-1. The complete schematic of the radio and the aforementioned special oscillator circuit appears in Vol. XVII on Majestic page 17-7. The frequency of this oscillator is set at 40 kc, which is above the audio frequency range. This type of oscillator is often called a supersonic or ultrasonic oscillator.

The audio signal to be recorded on the wire is combined, in one way or another, with the supersonic signal across the same coil that energizes the core for the recording process. In some units the supersonic oscillator signal is applied directly with the audio signal across the coil used for recording. In other units the oscillator signal finds its way across the recording coil by some coupling means, such as inductive or capacitive coupling. Interaction between the supersonic oscillator circuit and the audio circuit that may cause unwanted actions between these circuits should be avoided. In the Majestic wire recorder previously mentioned the a-c bias is inductively coupled to the recording coil. This source of a.c., as will soon be seen, is also used to erase or demagnetize the wire so that it may be used over again.

When the a-c supersonic signal and the audio signal both exist across the recording coil, the effective magnetizing force and flux density of the core change during recording. The change enables the varying audio signal being recorded to fall within the linear portion of the magnetization transfer characteristic of the unit, such as between points 1 and 2 in

Fig. 7. The a-c bias changes the effective magnetizing force, so that the transferring of H will be on the linear portion of the curve. Consequently, with the combined application of the a-c bias and audio signal, the wire will be so magnetized that when it is used for reproduction there will be no output distortion resulting from the nonlinearity of the magnetization transfer characteristic.

The Reproducing Process

After this transfer process, the wire contains the magnetic characteristics of the audio signal plus that of the supersonic oscillator signal. This magnetized wire is now ready to reproduce its magnetized signals. During playback both the audio signal and supersonic

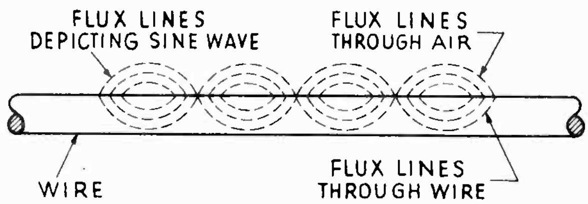


FIG. 8.—After magnetization, a wire contains numerous flux lines flowing through individual sections and completing their paths through the surrounding air.

oscillator signal will be reproduced. But the frequency of the supersonic oscillator signal, as its name implies, is above the audio range, and therefore will not be heard. The flux circuits in the magnetized wire due to the supersonic signal are usually small and can be neglected. Nevertheless, provision can be made to filter out these supersonic signals so that they are not applied together with the audio signal to the necessary audio amplifiers.

The magnetized wire, after recording, contains numerous flux lines flowing through its individual sections (called lines of induction) which complete their path through the medium of the air. One method of illustrating these individual sections of flux lines completing their path through air is shown in Fig. 8. The wire is assumed to be magnetized by a sine wave of constant frequency. The drawing indicates how the wire is magnetized in individual sections, each section containing its own completed path of flux lines.

The material of the wire is such that it can remain in the magnetized state for a long period of time similarly to a permanent magnet. If the wire is kept in the magnetized state for a fairly long period of time, stray magnetic fields should not be allowed to come in contact with the wire, as this may alter the original magnetization somewhat and cause unfaithful reproduction.

The reproducing process of the magnetic recording is very simple to understand. Essentially the method is as follows: As in the recording process the wire passes what we call the pole pieces of the core (that is, through the air gap). A special so-called reproducing or pickup coil is wound around this metal as shown in Fig. 9. The coil, however, is *not* energized as the coil used in the recording process. The magnetized wire passes the pole pieces and the magnetic flux lines of the wire that originally completed their path through the air now pass through the pole pieces of the core. The cores shown in Figs. 1 and 9 are merely schematic methods of representation and their shapes do not typify those actually used in recorders of today.

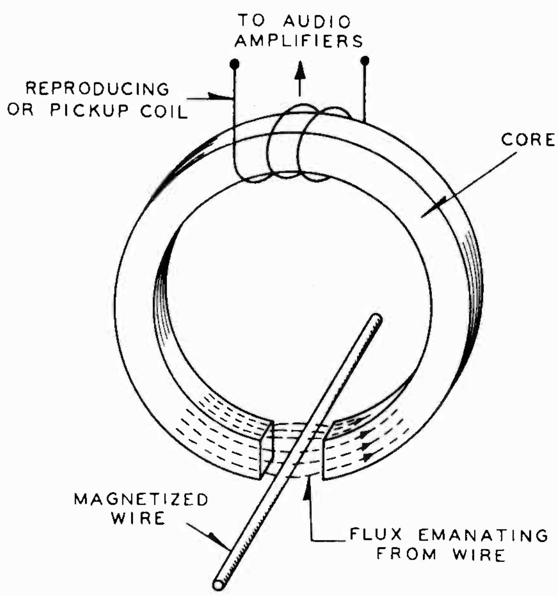


FIG. 9.—The method (See FIG. 1) employed for recording is similar in schematic appearance to that shown here for reproduction. However, the recording process is reversed, and the wire transfers flux lines to the core, and thence a voltage appears across the pickup coil.

As the magnetized wire passes the pole pieces, the magnetic lines of flux emanating from it come in contact with these pole pieces.

The core is of such permeable material that the flux from the wire will flow through the core rather than through the air to complete its path, because the core offers less magnetic resistance to the flux lines than the air.

The flux lines that embrace a pole piece will flow from that pole piece through the core to the other pole piece, thereby completing their path back to the wire. This is illustrated in Fig. 9 by the flux lines flowing in one direction. During the process of flow, the flux passes through that part of the core over which the reproducing or pickup coil is wound. These flux lines cause current to flow through the coil and, consequently, a voltage will be developed across this coil. Since the flux lines emanating from the magnetized wire have the same rate of change (alternation) as the audio signal causing its original magnetization, the voltage across the pickup coil is alternating at the same rate. Thus, the reproduced audio signal is the same as the recorded audio signal. Since the magnitude of the flux lines is directly proportional to the amplitude of the recorded audio signal, the magnitude of the reproduced signal is likewise proportional to this signal. As the magnetized wire travels by the pole pieces of the core, the lines of flux from the wire are continually being cut by the core, thereby enabling the pickup coil to reproduce the original audio signal recorded on the wire. The pickup coil is connected to the input of an a-f amplifying system.

Erasing

Practically all modern wire recorders in use have provision for wiping off the magnetization of the wire, or as it commonly is known today, *erasing*. This process of demagnetization of the wire makes it possible to use it over and over again for recording purposes.

A number of different methods exist for demagnetizing the wire, but that employed in most of today's wire recorders makes use of an alternating signal from a separate oscillator, and it is this method which we shall discuss here. The Majestic model 7YR752 wire recorder, which appears in Rider's Volume XVII, as previously mentioned, uses such an oscillator. A special oscillator coil is supplied with the Webster Model 79 wire recorder foundation unit. This unit also appears in Rider's Volume XVII on Webster pages WIREC. 17-1 to 17-10. Also included with this manual material on the Webster foundation unit is a suggested audio amplifier and supersonic oscillator circuit, including the power supply system.

The use of an alternating field to demagnetize a piece of magnetized metal or equipment has been known for a long time. In fact an a-c field has been employed for demagnetization where a watch or similar delicate instrument had become accidently magnetized. In brief the process of *erasure* using an a-c signal (in most cases it is a supersonic signal) as applied to most wire recorders is as follows:

A coil, usually termed the *erase* or *wipe* coil, is placed around a suitable permeable metal core. This unit — coil plus core — is usually known as the *erase head*. An alternating voltage is applied to the coil, which in turn causes magnetic lines of flux to flow within the core material completing their path through the air gap between the two so-called pole pieces of the core. Thus, an alternating magnetic field exists between these two pole pieces, that is, within the air gap, which is changing at the same rate as the original input a-c signal to the erase coil.

If the applied signal is assumed to be sinusoidal and of constant amplitude, then the alternating magnetic field is also varying sinusoidally. This means that the magnetizing force will be changing in polarity, as from positive to negative to positive and so on. It has been known that if a piece of magnetized material were subjected to such a polarity-changing magnetizing force which at the same time is decreasing in amplitude, it would demagnetize the magnetic material. In other words, this amplitude decreasing alternating field will so affect the field of the magnet that it will reduce the magnetized material to a neutral state. In modern wire recorders the design of the erase core and air gap, in conjunction with the applied alternating field are the criteria for proper demagnetization of the wire.

Head Construction

In many of these wire recorders the erase, recording, and reproducing functions are carried out by one head construction. Even in this so-called one head construction, two core sections are used, one for erasure and the other for recording and reproduction. The mechanics and electromagnetic characteristics of recording and reproduction are such that it is possible to use the same core and coil for both processes. During recording the coil is energized directly, and hence the permeable core material will become magnetized (that is, becomes an electromagnet), whereas during reproduction the magnetized wire will magnetize the permeable core which in turn will cause a voltage to appear across the coil. A special switching arrangement with respect to the coil isolates these two functions.

The frequency and wave shape of the alternating field used for erasure are not too important. The reason why a supersonic a-c signal is used for erasure is that such a signal is employed for a-c bias in the recording process and consequently presents an available a-c signal for erasure.

Some wire recorders have separate switching sections for recording, reproduction, and erasure, while others have provision for recording and reproduction only. This latter type applies the process of erasure in conjunction with the process of recording. Before the wire passes through the recording head it passes through an erase head. This means that the coil becomes erased just before recording is begun. During playback (that is, reproduction) the erasing procedure does not function. Erasure alone can be obtained in this type of recorder even when there is no recording to be done. Thus the wire passes the erase head, becomes demagnetized, then passes the recording head but does not become magnetized because the head is not in operation.

In this article we have tried to give the reader a fair idea of the theory of operation of wire recording. With the amount of space available we cannot hope to cover such a topic as we would like to. If the reader desires to know more about the theory of magnetics, it is suggested that he consult some of the numerous texts written on the subject.

For those who are interested in going deeper into the theory and application of wire (and tape) recording, we are including a bibliography on the subject.

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F-M TUNERS

Appearing on the market in recent years have been quite a number of receivers that do not contain, or contain only a part of, an audio system. In reality, these units are not true receivers, since they cannot reproduce within themselves the necessary audio sound. Such units are called tuners or converters. Neither term has been given preference, but the former has been used widely during the past year or so.

Such units are in demand chiefly because they can be used with any audio system, whether part of a phonograph amplifier, the audio system of an a-m receiver, or a specially built high-fidelity audio amplifying system. To make these f-m tuners available to the public, so that they can also receive f-m stations through their a-m receivers (although the reception will not be high fidelity), the trend is toward producing tuners priced well within reach of everyone. In most of these tuners all the necessary design features of regular f-m receivers are incorporated, and nothing is lost so far as the operation of the tuner is concerned. In fact, many of these f-m tuners contain designs that are unique and deserve careful consideration.

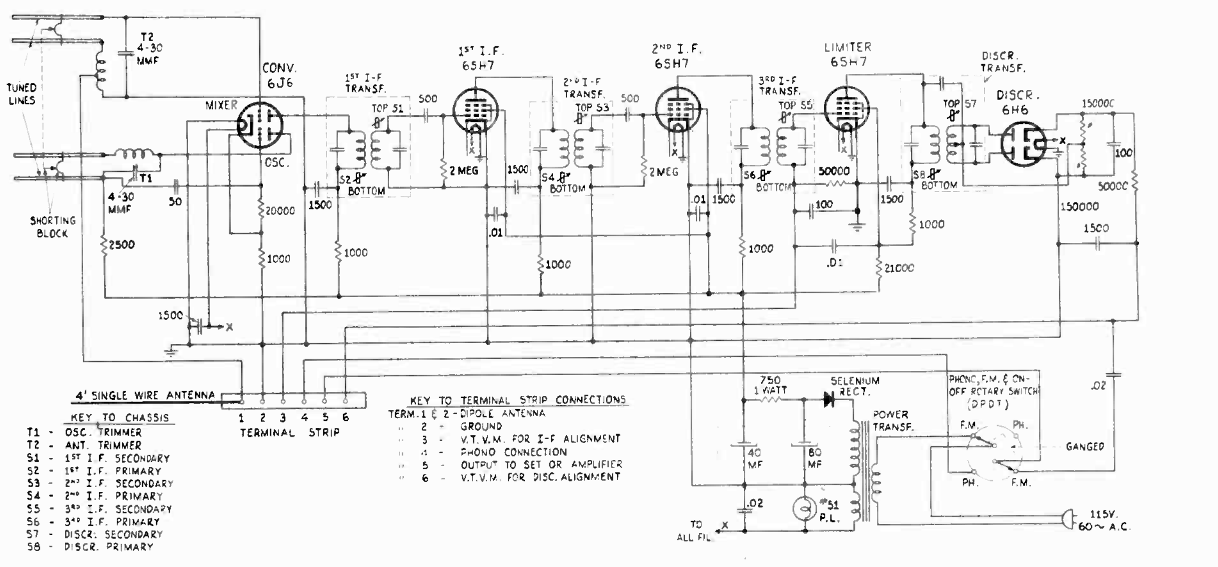
We will analyze two new units that have recently appeared on the market. The units are about the same price, and size, but their over-all designs are different. Rather than discuss each unit completely, we will consider only features that are unique in design and that warrant special mention. Neither unit includes any audio stage at all. One unit uses the limiter-discriminator method of detection, and the other unit uses the ratio detector. The two methods of tuning, as well as the types of i-f transformers employed, are quite different.

One tuner is known as the Edwards Fidelotuner and is manufactured by FM Specialties, Inc., of New York City, and the other tuner is the Pilotuner manufactured by Pilot Radio Corporation of New York City.

The Fidelotuner

The Edwards Fidelotuner, which appears in FM Specialties pages 17-1 to 17-4 in Rider's Vol. XVII, employs the limiter-discriminator method of detection. The complete schematic for this tuner is illustrated in Fig. 1. Five tubes are employed in the unit, with three 6SH7 sharp-cutoff pentodes used as the first and second i-f amplifiers and also as the limiter. The discriminator uses the duo-diode 6H6 tube, and the 6J6 miniature duo-triode is used as the converter.

It is usual procedure to use an r-f amplifier with f-m sets that employ the limiter-discriminator method of detection. This insures



Courtesy FM Specialties, Inc.

Fig. 1.—Schematic diagram of the Fidelotuner which employs the limiter-discriminator method of detection.

a high signal-to-noise ratio and sufficient voltage input to the limiter to produce limiting action. However, in this unit it will be noted that an r-f amplifer is not employed, even though the tuner uses the limiter-discriminator detector network. The reason for this is that the signal-to-noise ratio of the set is high, and the signal input to the limiter is sufficiently great to give satisfactory performance.

The Tuning System

The most interesting feature about this tuner that warrants special mention is the method of tuning. The tuning is inductive, but does not involve any permeability tuning. Open-wire parallel transmission lines are used for varying the inductance of the r-f input and oscillator section of the converter tube. Consequently, this type of tuning is called transmission-line tuning. The variation in inductance is obtained by running a shorting bar along the parallel lines, thus changing the inductance offered by the changing length of each line. A schematic representation of this tuning system is shown in the upper left part of the diagram of Fig. 1. To show exactly how this tuning unit works, a pictorial view of it, showing both the oscillator and r-f tuning lines, is illustrated in Fig. 2 (A), and a schematic representation of how the tuning lines form the tank circuit is illustrated in Fig. 2 (B).

Since the frequencies involved are quite high, the inductive and capacitive values that form the r-f or oscillator tank circuits are very small. Thus, it is possible to use the difference in inductance in the varying length of transmission line as a means of high-frequency tuning. The actual formation of the oscillator and r-f tank circuits uses a fixed inductance and capacitance, which are connected together at one end, in conjunction with a transmission line in each case. From the other ends of these components, the two transmission-line leads are connected. This is indicated in Fig. 2 (B). A metal shorting loop is rigidly placed across each set of lines, and the position of this loop on the lines determines how much extra inductance is added to the tank circuit because the shorting loop completes the tank circuit.

The schematic of Fig. 2 (B) will make this clearer. The inductor L and capacitor C represent the fixed quantities in the circuit and are connected together as shown. Let us assume that the shorting loop is at the position indicated. To complete the tank circuit, the current must travel through one part of the line, then through the shorting loop, and finally through the other part of the line back to the circuit. It can travel from L, then to points W, X, Y, and Z and then to capacitor C; or it can go from C in the direction of Z, Y, X, W, and then to inductor L to complete the circuit. It is the added inductance of the parts of the line from W to X and from Y to Z, plus that of the shorting loop in conjunction with the distributed capacitance of the line parts, which determines the final resonant frequency of the tank circuit. The lengths W to X and Z to Y are equal due to the mechanical nature of the system. The

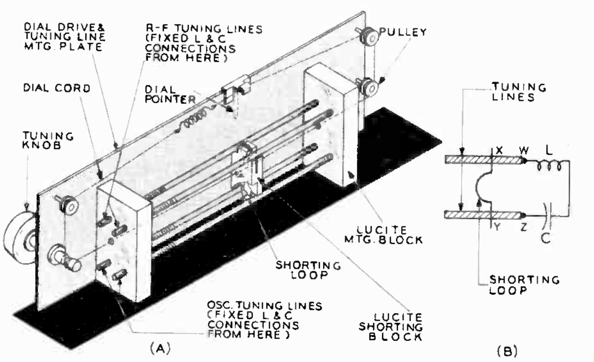
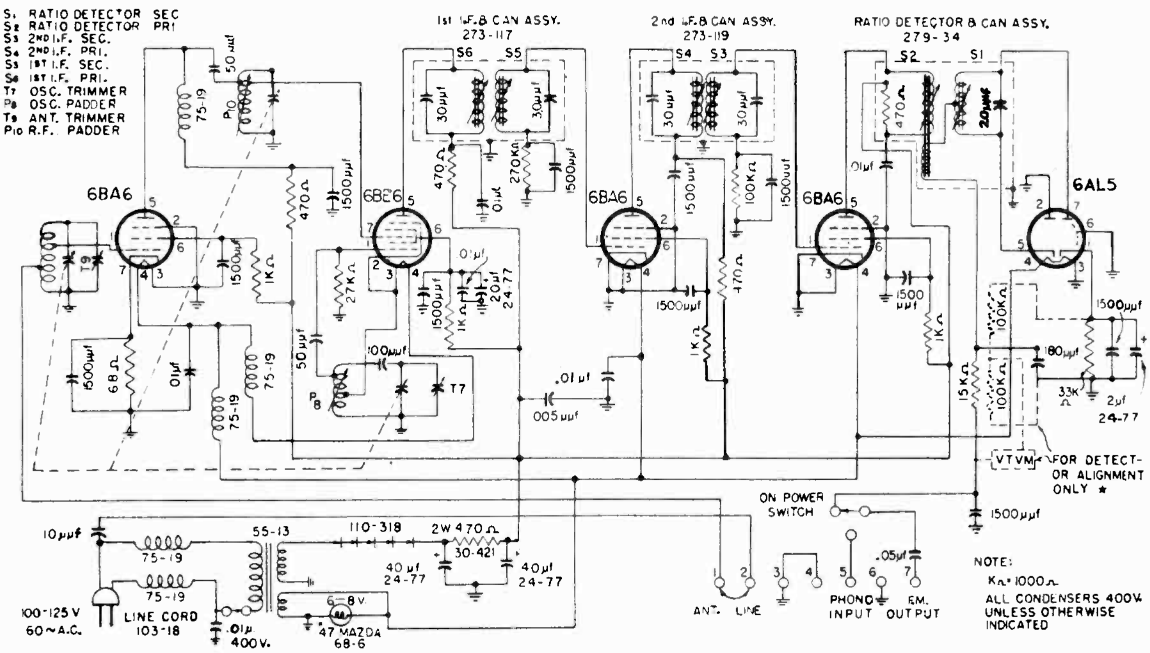


FIG. 2.—Pictorial layout of the tuning unit of the Fidelotuner is shown in (A) and a schematic representation in (B). The shorting block carries two shorting loops, one for each pair of lines.

shorting loops are very thin phosphor bronze springs rigidly mounted in a Lucite block, which in turn is connected to the dial cord and pulley arrangement for the proper tuning of the set. This is seen from Fig. 2 (A). Both the oscillator and r-f shorting loops are placed in the same shorting block, so that they are effectively ganged together and are variable as one upon tuning of the unit. The r-f and oscillator lines are spaced far enough apart, so that no serious interaction between these circuits is possible. The lines are all made of hardened brass tubing $5\frac{1}{2}$ inches long and $\frac{1}{8}$ inch in diameter, and they are covered with a thin layer of silver plate. The shorting loop makes a hairline contact with the lines, and this contact is maintained in a rigid state due to the high spring tension of the phosphor



Courtesy Pilot Radio Corp.

FIG. 3.—Schematic diagram of the Pilotuner.

bronze and the shape of the loop. The lines themselves are fixed in position on two Lucite mounting blocks fastened to a mounting plate.

Although there have been other types of inductive tuning circuits, we believe the type illustrated here to be of a unique yet very simple design, with which proper tuning can be obtained with the least amount of trouble.

Other Interesting Features

This tuner has two other interesting features. One is the use of duo-triode 6J6 miniature tube as a converter, in which one triode section serves as the mixer and the other as the oscillator. Although it has not been mentioned previously, two triodes used for a system of frequency conversion have one of the highest, if not the highest, signal-to-noise ratios among converter systems. This high signal-to-noise ratio obviates the need for an r-f stage to increase the signal input.

The other interesting thing is that the oscillator plate current flows through the transmission line and shorting loop as seen in Fig. 1. This current flow is a good reason why the loop contact to the lines must be tight.

The i-f and discriminator transformers are of the special kind that use magnetic shielding in conjunction wth permeability tuning, as discussed in the section of this book dealing with a special i-f transformer.

The terminal strip shown in Fig. 1 is on the back of the chassis, and it affords a quick means of alignment as well as a fast and easy method of connecting the tuner to an a-m radio or amplifier.

THE PILOTUNER

This f-m tuner, known as model T-601, appears in Pilot Radio pages 17-1 to 17-6 in Rider's Vol. XVII. Five tubes are employed in this tuner also, but they are all of the miniature size, with a 6AL5 duo-diode employed as a ratio detector. Three other tubes are 6BA6 pentodes used as an r-f amplifier and for the first and second i-f amplifiers. A 6BE6 pentagrid tube is used as a converter. The schematic diagram for this tuner appears in Fig. 3, and a top chassis view appears in Fig. 4.

From the schematic diagram, a few interesting things are noted. First, the coils marked as P_8 and P_{10} are shown to be variable without an internal core adjustment. Looking at the ratio detector transformer, we note that the primary does not contain any fixed capacitance for tuning purposes. The core going through the primary coil is also extended to the coil directly underneath this primary, indicating that both coils are wound on the same coil form.

The R-F and Oscillator Padder

In aligning the oscillator and r-f stages on the low end of the f-m band, the tuner provides for inductive padding. The r-f section's inductive padder is designated P_{10} in Fig. 3 and also appears in Fig. 4. The interesting thing about this coil is that the variation of its inductance is made simply by changing the spacing between the coil windings. From Fig. 4 the r-f padder coil P_{10} is seen to consist of only two turns, and the space between these two windings is varied by means of a screw. The screw is kept in place by means of a piece of Bakelite tubing which is threaded on the inside. Upon clockwise rotation of the screw the spacing is increased, thereby decreasing the inductance.

The oscillator padder P_5 is located on the underside of the chassis and also consists of about two turns of wire. A drawing of this oscillator padder construction is shown in Fig. 5. The variation of the inductance of this padder is somewhat different from that for the r-f padder P_{10}. The spacing between the coil turns of this padder P_5 are kept stationary, but the effective magnetic field about the coil is varied. Between the spacing of the winding is a thin strip of Bakelite, which is mounted above the chassis by two brass spacers. This Bakelite strip runs through the spacing of the coil and contains a threaded hole where the center of the coil winding appears. Into this hole is inserted a screw which has a round metal plate attached to the underside of the screw head. This metal plate is about 7/8 of an inch in diameter and 1/16 of an inch thick. Its diameter exceeds the diameter formed by the coil winding.

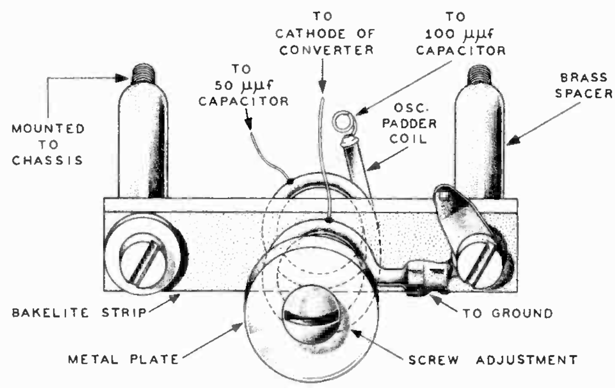


FIG. 5.—The construction of the oscillator padder used in the Pilotuner. The threaded portion of the screw adjustment was omitted from the drawing for greater clarity.

Inductance of this oscillator padder coil is

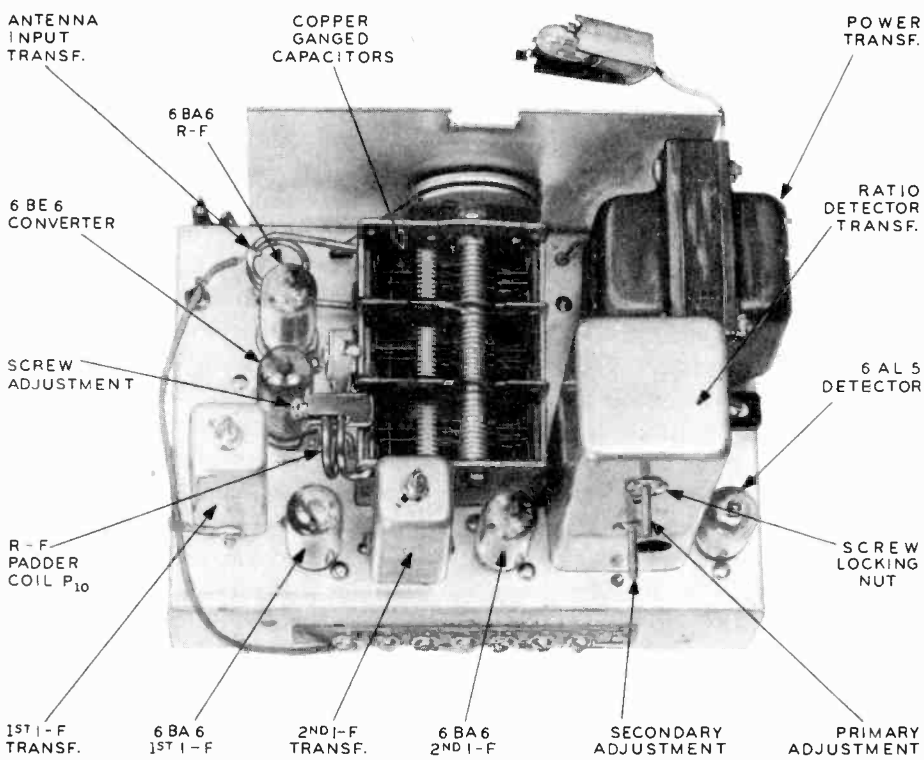
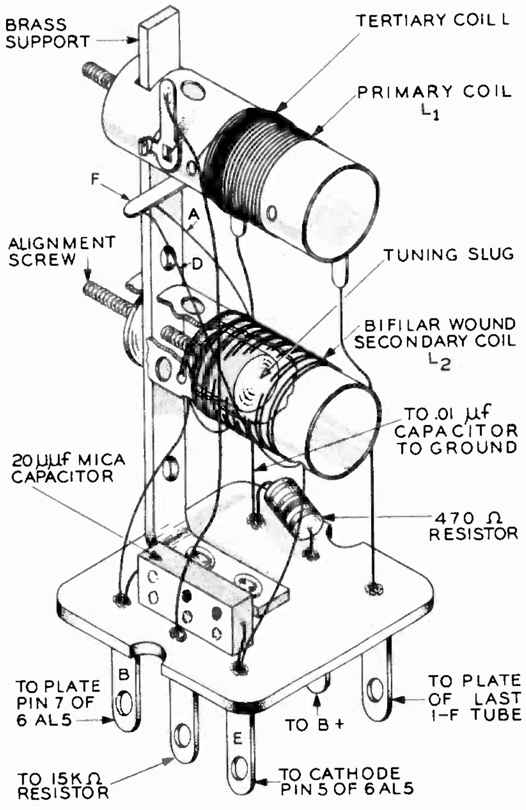
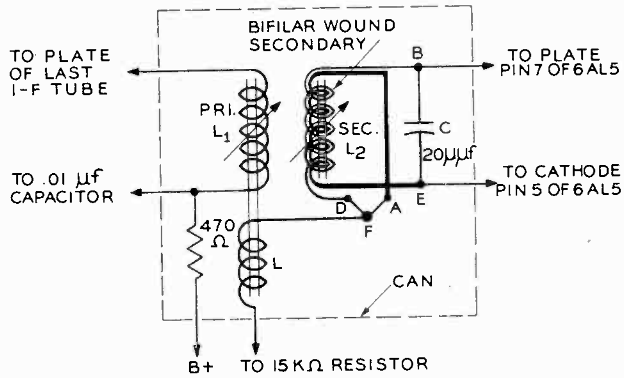


FIG. 4.—Top view of the Pilotuner chassis showing locations of the tubes, transformers, and other components.



(A) RATIO DETECTOR TRANSFORMER



(B) SCHEMATIC OF RATIO DETECTOR TRANSFORMER

FIG. 6.—Construction of the ratio detector transformer of the Pilotuner is shown in (A) and the schematic diagram in (B).

varied by turning the screw in or out. This variation is explained as follows: The metal plate acts as a short-circuited secondary winding to the oscillator padder coil, which effectively acts as the primary winding. The short-circuited secondary reflects a reactance into the primary which is capacitive. This reflected capacitance is effectively in series with the primary inductance, and therefore reduces the effective value of the inductance. With the movement of the screw and, hence the metal plate, the coupling between the plate and coil changes. As a result, the mutual reactance which exists between the plate and coils also varies, which in turn varies the reflected capacitance into the coil circuit. Turning the screw so that the plate moves toward the coil increases the coupling and also increases the reflected capacitance into the primary. This increased reflected capacitance decreases the effective inductance of the oscillator tank circuit, thereby *increasing* its frequency. Adjusting the screw so that the plate moves away from the coil increases the effective inductance and, hence *decreases* the frequency of operation of the circuit.

The Ratio Detector Transformer

The primary of the ratio detector transformer has no fixed capacitance across its coil, but it still forms a tuned circuit with the output capacitance of the last i-f tube, stray wiring capacitance, and inherent capacitance between the coil windings. The amount of this capacitance is high enough at the 10.7-mc i.f. to form a tuned circuit with the primary coil Besides this feature, the physical constructon of the ratio detector transformer is quite interesting. A picture of the construction of the transformer is shown in Fig. 6 (A), and a detailed schematic drawing is shown in Fig. 6 (B). This schematic drawing is somewhat different in appearance from the ratio detector circuit which is shown in Fig. 3, but they are effectively the same in circuit operation.

The tertiary coupling coil L is wound over one end of the primary coil L_1 which appears on the top coil form of Fig. 6 (A). Because of this close coupling between L and L_1, the voltage appearing across L effectively appears in series with L_1 but 180° out of phase. The secondary coil is wound on the lower strip, and each coil form contains a variable core to change the effective inductance of the coils. The cores are adjustable by means of two screws which appear on one side of the brass strip as seen in Fig. 6 (A). These screws are about 1 5/8 inches apart.

Particularly noteworthy in the construction of this transformer is the bifilar winding of the secondary coil. This bifilar winding is obtained by using a very closely spaced twin lead, which is insulated with a transparent plastic and is wound around the bottom coil form with both ends open. The plastic insulator at the ends is split, exposing two bare wires at each end. These two wires of the twin lead are shown in the drawing of Fig. 6 (B) as coil *A* to *E* and coil *B* to *D*. A trace of the coil circuit across capacitor *C* starting at point *B*, would travel from point *B* to *D*, then to point *F* to *A* to *E*. Therefore, each part of the bifilar winding L_2 contributes to the inductance for the secondary tuned circuit.

Coil *L* must be tapped to the center of the secondary inductance to maintain the balance for the detector circuit. This tap is obtained by connecting one end of *L* to point *F*, the junction of *A* and *D*, as seen in Fig. 6 (B). The complete inductance of the secondary is made up of the coil winding *BDFAE*, and since the length of *DB* is approximately equal to length *AE*, it is readily seen that by connecting to point *F*, junction of *A* and *D*, we are effectively center-tapping the coil. It is advisable that, if any trouble is suspected in the ratio detector circuit within the transformer shield, the serviceman not attempt to take the circuit apart. It is suggested that the manufacturer or one of his representatives be contacted.

SINGLE-TUBE F-M DETECTOR AND AUDIO AMPLIFIER

In f-m receivers that employ the limiter-discriminator method of detection a duo-diode tube is invariably employed as the discriminator. The output from this discriminator, being audio, is applied to the grid of an audio voltage amplifier which is a separate tube distinct from the discriminator. In the duo-diode tube generally used as the discriminator, such as a 6H6 or a 6AL5, two separate plates and two separate cathodes are employed.

But in the General Electric receiver Models 41 to 45, the complete schematic diagram, which appears on G.E. page 17-1. 2 of Rider's Vol. XVII, shows a single tube performing the function of discriminator action and first audio amplification. The tube used is a 6AQ7-GT which contains a duo-diode and a triode section. The duo-diode part contains a separate cathode and so does the triode. Before analyzing this particular circuit let us discuss the functioning of a typical discriminator circuit using a diode tube with separate cathodes and plates. There are various modifications of such a circuit, but the one illustrated in Fig. 1 will serve the purpose.

Phase Discriminator Circuit

This type of circuit is also commonly known as the *phase discriminator*, Foster-Seeley discriminator, or center-tuned type discriminator. We are studying this circuit first, so that later the functioning of the discriminator circuit using the 6AQ7-GT tube for f-m detection can be compared with the conventional circuit. In the circuit of Fig. 1 appear some voltage and component designations.

The two diode sections are connected in series opposing, and in conjunction with their individual load resistors they form a differentially connected rectifier system. Resistor R_1 is the load for diode D_1, and resistor R_2 is the load for diode D_2.

The diode circuits of Fig. 1 are completed through coil L, and the respective half of the center-tapped coil associated with each circuit. Besides providing the d-c paths between the diode plates and their associated cathodes, this common coil has another function which will be shown later.

Voltage E_1 is the i-f signal voltage developed across the tuned primary circuit. Examining

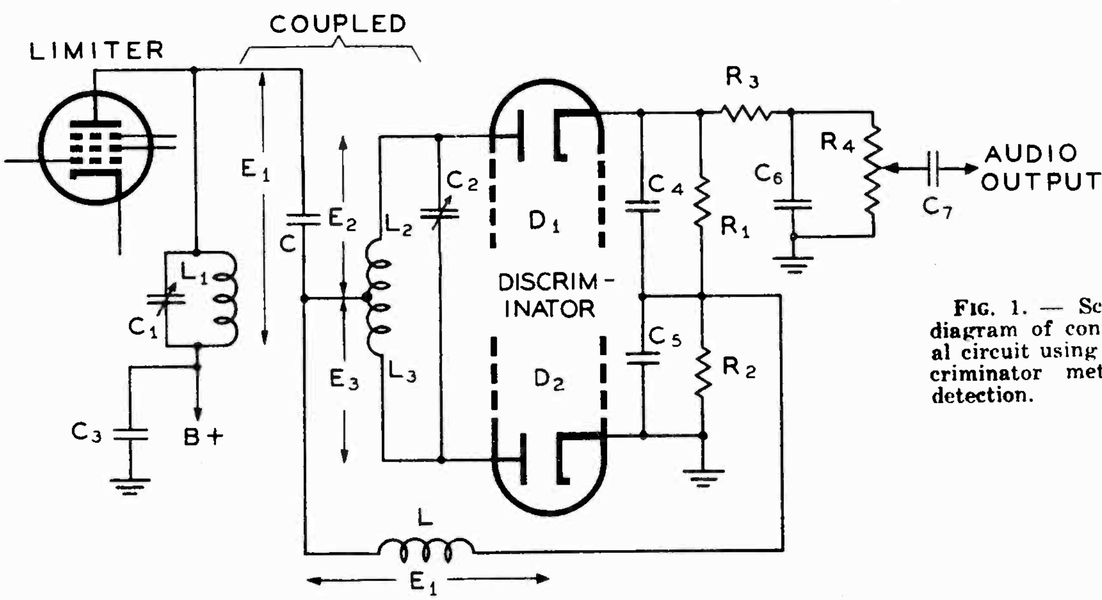


FIG. 1. — Schematic diagram of conventional circuit using the discriminator method of detection.

the secondary of this i-f transformer, we note certain significant details. It consists of two windings L_2 and L_3 in series, resonated to the i-f peak by means of C_2. The center tap on the secondary winding is connected to a coupling capacitor C and also, to an r-f choke L.

Associated with the two circuits and the r-f choke L are three voltages, designated as E_2, E_3, and E_1 respectively, the latter being virtually identical to E_1 across the i-f transformer primary. To explain these designations, it is necessary to discuss the coupling between the primary and secondary circuits of this transformer, as well as what happens in a transformer when the secondary is tapped at the mid-point. This operation of the discriminator circuit of Fig. 1 is best explained in terms of three major actions.

In the first place, although a single tuned winding is used for the secondary circuit, the center tap on this winding causes a division of the signal voltage developed in the tuned circuit across the two halves of the secondary winding, that is across L_2 and L_3. The signal voltages across these two halves are always equal to each other, irrespective of the frequency of the signal voltage fed into this circuit from the primary.

The second major consideration is that the signal voltage present across the primary winding L_1 is also present across a winding L, which is common to both halves of the secondary circuit with respect to the signal voltage eventually applied to the two diodes D_1 and D_2.

The final major action is the phase relation which exists between the signal voltage across L_2, which we can call E_2, and the signal voltage across L which, because it is the same as that across L_1, *is* also idendtified as E_1; also the phase relation between the signal voltage across L_3, or E_3, and the signal voltage across L, or E_1. The function of this discriminator network with particular reference to these three actions will now be discussed in detail.

Coupling Methods

Two methods of coupling the signal from the primary to the secondary circuit are used in this system. The resonant primary is inductively coupled by transformer action to the resonant secondary winding; at the same time the signal voltage E_1 across the primary is fed to the r-f winding L via the coupling capacitor C. If the circuit of C, L, and C_5 is traced, it will be seen that L is in shunt with the tuned primary, the latter being grounded through C_3. None of the quantities C, L, C_3, or C_5 is of a magnitude to alter the resonant conditions of C_1 and L_1, the resonant primary. Thus, with respect to magnitude and phase, whatever signal voltage exists across C_1-L_1, also exists across L. The direct connection between the coupling capacitor C and the mid-point of the secondary winding is of no consequence to the signal transfer between the primary and the secondary tuned circuits; however, it is the point to which the choke L must be connected to complete the differential rectifier circuit. Thus, the secondary system receives signal voltages in two ways: the resonant secondary receives its signal voltage by inductive coupling, and the r-f choke derives its signal voltage by means of capacitive coupling through the fixed capacitor C.

The equal voltages across each half of the secondary winding are obtained in the following manner. When a winding is tapped at the mid-point and a voltage is induced in that winding by means of a varying magnetic field, the total voltage developed across the entire winding divides between the two halves. This is logical in view of the fact that half the total number of turns exists between the center tap and one end, and between the center tap and the other end. So, whatever the nature of the signal voltage which will be developed across the tuned secondary circuit C_2-L_2-L_3, it is possible to show that this voltage divides into two parts, that is, across each half of the winding. These voltages are designated as E_2 and E_3.

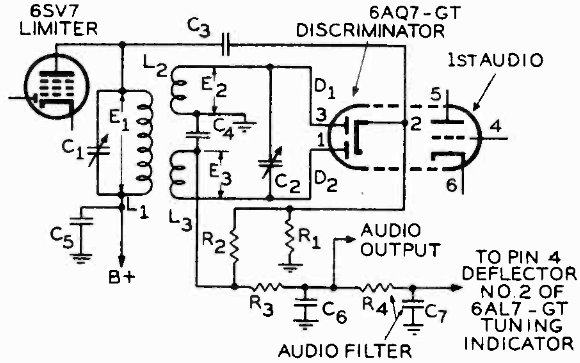
Consequently, we now see how these three voltages E_1, E_2, and E_3 are impressed across the diode circuits. The important point is that two voltages are acting on each diode, voltage E_1 and E_2 on diode D_1, and voltage E_1 and E_3 on diode D_2 and that voltage E_1 (that existing across the primary circuit) is *common* to both diodes.* This is very important for the proper operating of the discriminator circuit, and this voltage common to both diodes is always neces-

*For a comprehensive analysis of this discriminator circuit with respect to resonance and off-resonance conditions in reproducing the audio signal, see the FM Section of the "How It Works" book of Rider's Vol. XV, pages 169-178.

sary in any modified form of this discriminator circuit. This will now be seen in the analysis of the discriminator circuit using the diode sections of the 6AQ7-GT tube in the General Electric Models 41 to 45.

Use of 6AQ7-GT Tube

A schematic representation of the 6AQ7-GT tube illustrated in Fig. 2. The cathode, pin 2, is common to both diode plates, pins 1 and 3, and together they are used for the discrimina-



Courtesy G. E.

FIG. 3.—Schematic diagram of Pilotuner. sections of the 6AQ7-GT tube are used on the f-m bands in General Electric Models 41 to 45.

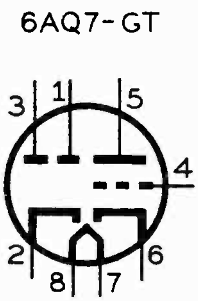


FIG. 2.—Schematic representation of the 6AQ7-GT tube.

tor circuit. Pins 4, 5, and 6 compose the triode section of the tube which is used as the first audio amplifier. The heater, pins 7 and 8, is common to both cathodes. The schematic diagram of how the diode sections of this tube are used in the model under discussion is illustrated in Fig. 3. The pentode section of a 6SV7 tube is used as the limiter. It will be noticed that two separate coils L_2 and L_3 comprise the secondary of the discriminator transformer. However, both coils have the same number of turns and are so wound that the inductances of both are equal.

Diode Sections

The voltages marked on this schematic, E_1, E_2, and E_3 are similar to those of Fig. 1. The coil and diode designations are also the same. As mentioned previously the chief difference in the operation of the circuit of Fig. 3 and that of the conventional discriminator circuit of Fig. 1 is the method of applying reference voltage E_1 to both diodes D_1 and D_2. Coil L_2, and thus voltage E_2, are common to the upper diode D_1, and coil L_3 and voltage E_3 are common to the lower diode D_2. Capacitor C_4 connecting L_2 and L_3 is of high enough capacitance, so that both coils are effectively in series to the i.f. As with the conventional discriminator, capacitor C_2 is shunted across these two coils and with them forms the secondary tuned circuit. This analysis reveals how the respective induced voltages E_2 and E_3 are applied across the individual diodes D_1 and D_2, but the method of obtaining E_1 across both diodes is not readily evident.

Tracing the d-c path for each diode, we find that resistor R_1 is the load for D_1 and resistor R_2 is the load for D_2. The reference voltage E_1 is capacitance-coupled through C_3 to the common cathode of the diodes. Capacitor C_5 is a bypass capacitor for the primary tuned circuit and completes the r-f path to ground. The reactance of C_5 at the i.f. is so small that negligible i-f voltage appears across it.

If we trace the i-f path from the top of L_1, we find that there are essentially two parallel paths which appear across the primary circuit to ground. This circuit is shown in simplified form in Fig. 4. Going from the top of L_1 we pass through C_3, and find two paths available: one through resistor R_1 to ground and the other through resistor R_2 and capacitor C_4 to ground. The capacitances of C_3 and C_4 are so chosen that they will offer a low reactance at the i.f. compared with the resistance of R_1 and R_2. This means that practically all of E_1 also appears across R_1 and R_2. So far as the high-frequency i.f. is concerned, R_1 and R_2 are both effectively in parallel with L_1, and the reference voltage E_1 also appears across the load resistors R_1 and R_2.

Since R_1 is the load resistor for D_1, both voltages E_1 and E_2 act on diode D_1, and, since R_2 is the load resistor for D_2, both E_1 and E_3

act on diode D_2. The on- and off-resonance conditions function as in the conventional discriminator. The audio output appears across C_4 or between the high side of R_2 and ground. In this circuit resistor R_3 and capacitor C_6 represent a de-emphasis network, and the de-emphasized audio is taken across C_6.

This de-emphasized "audio output", after passing through the necessary coupling components and volume control, is effectively impressed onto the grid, pin 4, of the first audio section of the 6AQ7-GT tube. This de-emphasized audio output due to the rectifying action of the diodes of the 6AQ7-GT tube actually consists of an audio signal superimposed upon a d-c component. From Fig. 3 it is noted that this audio output from the discriminator also goes to pin 4 deflector No. 2 of a 6AL7-GT tuning indicator. However, it passes through an R_4-C_7 resistance-capacitance network before being applied to this deflector electrode. This R_4-C_7 network is an audio filter for filtering out the audio component of the output signal which is superimposed upon d.c. Consequently, with the audio filtered out, a d-c signal is applied to this deflector electrode of the tuning indicator

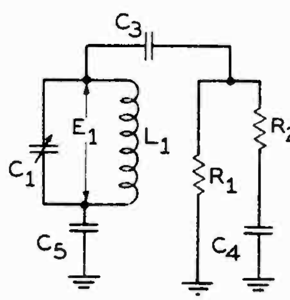


Fig. 4.—A simplified schematic of the parallel circuits which appear across the transformer primary circuit.

tube. This indicator tube is discussed in detail in this book under "F-M and A-M Tuning Indicator."

In most f-m and a-m receivers a 6E5 or a 6U5 type tuning eye tube is used as an indicating device (if any is employed). Such tubes by virtue of shadow indications tell us whether a station is properly tuned in or not. These tubes function very well for a-m receivers, but, when they are used in f-m receivers that employ the limiter-discriminator method of detection, certain disadvantages are prevalent. The limiter grid voltage is used as the source for actuating such tuning indicator tubes as the 6E5 or 6U5 and also as a source of automatic volume control (avc).

These types of tuning indicators in conjunction with the limiter grid work as follows:

When a station is exactly tuned in, the maximum signal input is being received; this means that there is a maximum input to the limiter grid at that tuned frequency. Consequently, the maximum current flows through the grid resistors, and the maximum value of avc voltage as well as bias is developed. The tuning indicator operates on the principle that the greater the input avc voltage the more the eye will close. Therefore, when the station is tuned in properly, the shadow angle of the tuning indicator will be at a minimum.

Although the great simplicity of this system is an advantage not to be overlooked, it has a definite disadvantage, which lies in the fact that the avc (or first limiter grid) voltage may not be a maximum at exactly the frequency that is optimum for operation of the detector. This condition should not be found in a set which has just been aligned, but some time after a set has been aligned it is natural that drifts will have occurred. Consequently, it may not be possible to obtain exactly this tuning by means of the avc voltage-controlled tuning indicator tube, because the avc voltage depends upon the over-all i-f amplifier tuning, and not upon the tuning of the detector. A further defect in this system is that the i-f characteristic of an f-m receiver is usually more flat topped than that of an a-m receiver, so that there is no definite easily observed peak in the avc voltage coinciding with the center i.f.

F-M AND A-M TUNING INDICATOR

In late 1946 the General Electric Company released a new tuning indicator* which worked on cathode-ray tube principles and was ideally suited for f-m receivers, although it can also be used on a-m receivers. This type tube is known as the 6AL7-GT, a schematic of which appears in Fig. 1. From this diagram it is seen that there are three deflector electrodes, and it is these three electrodes in conjunction with the rest of the electrodes that make its function unique as an f-m tuning indicator. For f.m. there are three possible ways it can be used with certain control voltages: with a discriminator voltage alone (as is done in the G.E. Model 502 to be discussed in this section), with a discriminator and squelch voltage, or with a discriminator and limiter voltage. When the tube is used in a-m receivers or a-m sections of combination a-m and f-m receivers, the avc voltage from the a-m detector is used to actuate the tuning indicator. With each of these four methods the sequence of patterns on the 6AL7-GT tuning indicator when on tune, off tune, or off channel is different in one or more respects.

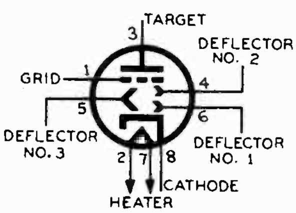


FIG. 1.—Schematic diagram of the 6AL7-GT visual tuning indicator tube.

The pattern that appears on the screen of the indicator tube under normal conditions essentially consists of four squares as seen in Fig. 2. Patterns P_1, P_2, and P_3 are produced and controlled by deflection electrodes No. 1, 2, and 3 respectively; there are two P_3 squares.

*F. M. Bailey, "An Electron-Ray Tuning Indicator for Frequency Modulation," *Proc.*, IRE, p. 1158, vol. 35, October 1947.

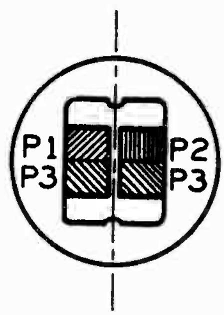
The deflector electrodes 1 and 2 (pins 6 and 4 respectively) can be considered as a single deflector which is divided in the center to form a means whereby one half of the pattern can be compared with the other half. One half of the divided deflector is usually grounded (deflector No. 1 in Fig. 1), providing a reference pattern with which the pattern due to deflector No. 2 may be compared. The reference voltage, such as the discriminator output in f-m receivers or avc in a-m receivers, is applied to deflector No. 2.

In Fig. 3 is shown a number of different patterns which appear on the 6AL7-GT indicator tube under different modes of operation. The first three rows illustrate the use of the tube in f-m receivers, and the last row its use in a-m receivers. By comparing these rows of patterns it will be noted that no two rows are exactly alike, indicating the variety of use of such a tube. In order to show how it functions let us analyze its use with respect to a limiter and discriminator voltage.

Used With Limiter and Discriminator Voltages

Fig. 4 illustrates a typical circuit hookup of the 6AL7-GT tube used with a limiter and discriminator voltage. We choose to analyze this circuit from a general viewpoint because it makes use of all the deflector electrodes in con-

FIG. 2. — The pattern which appears on the screen of the indicator tube under normal conditions essentially consists of four squares.

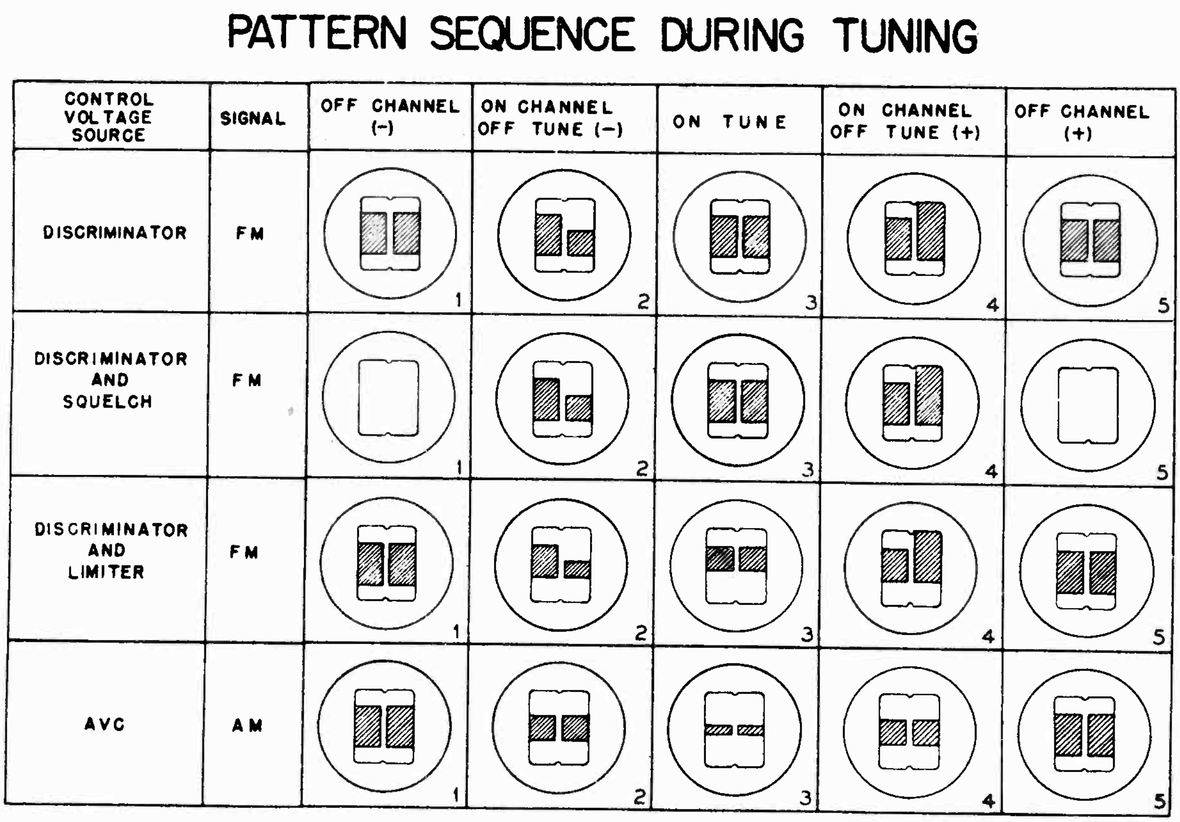


junction with limiter and discriminator voltages.

The tube is sensitive enough to respond to a voltage difference between plus and minus 0.2 volt with respect to ground, which is within 2 kc of the discriminator tuning for distortion-free signals. As mentioned, this discriminator output is connected to one side of a center-divided deflector (deflector No. 2 in Fig. 1). A space-charge grid is used to increase the sensitivity of the tube. Since one side of the discriminator load is usually grounded, the changing discriminator output voltage appears across both deflector electrodes 1 and 2. On one side of the cathode this divided deflector is placed, and on the other side deflector No. 3 is placed to form a fixed boundary for one side of the pattern. The first limiter grid (if more than one limiter is used) is connected to this electrode, and the limiter voltage therefore appears on this deflector and is used as a voltage which determines one boundary of the target pattern. This deflector enables us to distinguish, by different patterns, when the receiver is on tune or off channel. The different patterns for this hookup are illustrated in the *third row* of Fig. 3. Patterns 1 and 5 are for minus and plus off-channel conditions respectively. These patterns are identical, because there is zero voltage output from the discriminator and no limiter voltage. The size of squares P_3, see Fig. 2, is controlled by the amount of limiter voltage; the higher this negative voltage the smaller the squares, and the lower the negative voltage the larger the squares. Consequently, in patterns 1 and 5 the bottom half of the pattern is of maximum depth due to the absence of limiter voltage.

In pattern 3 the receiver is on tune, which means a maximum negative limiter voltage and a zero discriminator output voltage. Thus the pattern is much smaller than those off-channel patterns of 1 and 5. The decrease in pattern No. 3 is seen to be in the bottom half due to the limiter voltage.

In pattern 2 and 4 where the discriminator is off tune, limiter voltage, although perhaps not a negative maximum, is still present, limiting



Courtesy G. E.

Fig. 3.—These four rows of patterns corresponding to five tuning conditions appear on the screen of the 6AL7-GT indicator.

the bottom half of the patterns to a smaller size as compared with the patterns of 1 and 5. In pattern 2 the discriminator is off tune and presents a negative signal to the No. 2 deflector grid, which reduces the size of square P_2 (Fig. 2). In pattern 4 the discriminator is also off tune and presents a positive signal to the No. 2 deflector grid, increasing the size of square P_2. Note that the deflection due to the positive off-tune signal is greater than the deflection for the negative off-tune signal for the same amount of positive and negative discriminator voltages. This is a result of the use of space-charge operation of the deflecting system (due to the space-charge grid). Deflection in the positive region would be much greater if a cathode bias resistor (3300 ohms as seen in Fig. 4) were not used. This resistor places a positive voltage on the cathode with respect to the deflectors and the space-charge grid, so that with a positive discriminator signal the deflectors do not draw appreciable current.

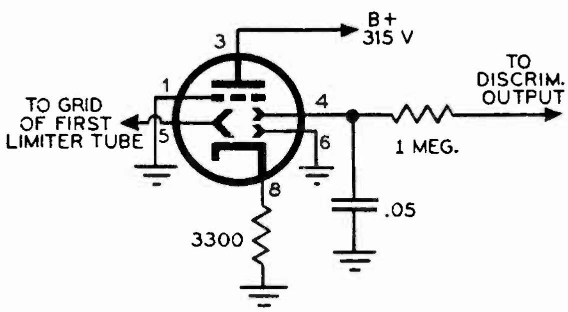


FIG. 4.—The 6AL7-GT tube uses a cathode bias resistor to reduce the amount of deflection due to the positive off-tune signal.

The negative bias on the space-charge grid reduces the brightness of the pattern and increases the deflection sensitivity.

Used With Discriminator Alone

In the f-m sections of the G.E. Model 205 this indicator tube makes use of only the discriminator voltage and not the limiter voltage. The specific reason for not using the limiter voltage in this set is that, with a good antenna installation, if the receiver is located in an area where the signal strength is strong, the limiter voltage may become so high that it makes the pattern of the indicator tube incomprehensible.

The circuit when using the discriminator voltage alone, as employed in the model under discussion, is illustrated in Fig. 5. This differs from the circuit of Fig. 4 in that pin 5, the deflector that originally received the limiter voltage (deflector No. 3), is now grounded. The patterns in the first row of Fig. 3 represent those for the circuit of Fig. 5. The primary difference in these patterns is that squares P_3 which were controlled by deflector electrode No. 3 (pin 5 of the 6AL7-GT tube) are always stationary and at their maximum size. This is indicated by the bottom halves of the five patterns on the first row of Fig. 3 all appearing the same.

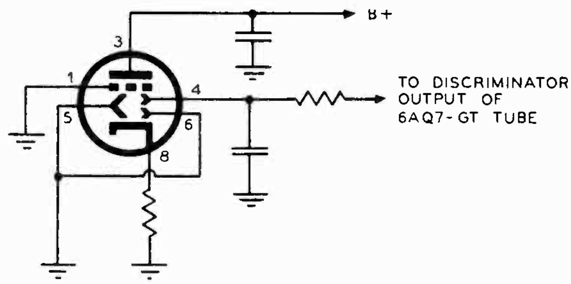


FIG. 5.—Schematic diagram of the 6AL7-GT indicator when it uses the discriminator voltage alone.

Further study of these patterns will reveal that patterns 1 and 5 for off-channel conditions appear the same as pattern 3 for the on-tune condition. Although the off-channel and on-tune patterns appear the same, we can easily

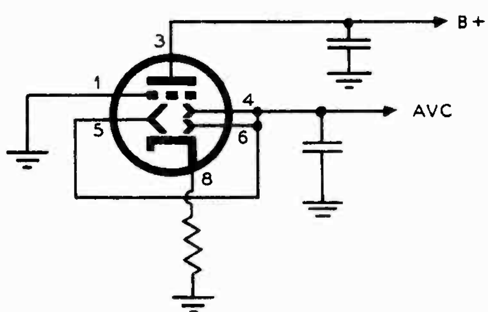


FIG. 6.—A simplified schematic diagram of the 6AL7-GT tuning indicator as used on the a-m band of General Electric Model 205.

distinguish between the two. Thus when a station is on tune, proper reception will be heard in the loudspeaker, whereas for off-channel conditions the desired station will not be heard.

Used in A.M.

A simplified schematic diagram of the 6AL7-GT tuning indicator as used on the a-m bands of the G.E. Model 205 is illustrated in Fig. 6. When it is used for a.m., all the deflector electrodes are tied together and receive the avc voltage from the a-m part of the receiver. Under these conditions the sequence of patterns will appear as indicated in the last row of Fig. 3. Note that from these patterns we distinguish between off-channel and on-tune conditions, which makes this tube very acceptable to a-m receivers as a tuning indicator.

When the a-m receiver is on tune, the upper and lower part of the pattern, namely all squares P_1, P_2, and P_3 (see Fig. 2) are reduced in size toward the center of the target. This happens because, as the set is properly tuned in, a greater avc voltage manifests itself, and as this voltage increases, the squares on either side of the center of the pattern diminish. When the set is exactly on tune, the avc voltage is a maximum and pattern 3 is a minimum but symmetrical on either side of its center.

Patterns 2 and 4 of the last row of Fig. 3 indicate off-tune conditions, which means that the avc voltage is less, and, consequently, the pattern size is greater than in the on-tune case.

SPECIAL I-F TRANSFORMER

A new type of i-f transformer that affords high i-f stability has recently appeared on the market. I-f transformers in general can be tuned by varying either the capacitance or inductance of the tuned circuit. In i-f transformer design, there is a striving for adequate magnetic shielding of the coils to provide greater i-f stability by preventing any stray fields from influencing the magnetic field set up by the coils of the transformer itself. The new type transformer is designed for the different i.f.'s of both a-m and f-m broadcast receivers. The i-f transformer to be discussed here is used in f-m receivers for operation at 10.7 mc.

This type of transformer is permeability tuned and possesses magnetic shielding which automatically coincides with the tuning of the transformer. This type of i-f transformer is known as a K-Tran and is manufactured by the Automatic Manufacturing Corporation. It is used in a number of f-m receivers and tuners on the market, of which the Fidelotuner manufactured by FM Specialties is an example. (This tuner appears on FM Specialties pages 17-1 to 17-4 in Rider's Vol. XVII and is discussed in detail in the section on "F-M Tuners" in this "How It Works" book.)

A pictorial cutaway view (isometric drawing) of the transformer appears in Fig. 1(A), the magnetic core in Fig. 1(B), and a schematic drawing of this transformer is illustrated in Fig. 1(C). In Fig. 2 appears a detailed assembly drawing of this same transformer in three different views. In Fig. 2(A) a front view of the transformer is shown, in Fig. 2(B) a right side view, and in Fig. 2(C) a top view is illustrated. This detailed mechanical drawing of Fig. 2 is included so that in conjunction with Fig. 1 you will be able to visualize the operation and construction of the transformer.

Magnetic Shielding

A unique feature about this i-f transformer that accomplishes the magnetic shielding is the design of the iron core used for permeability tuning the unit, a sectional view of which appears in Fig. 1(B), and a broken front view which appears in the top part of Fig. 2(A). By these two drawings the shape of this magnetic iron core, termed the "threaded tuning cylinder and plunger," is easily visualized.

This single unit is used to tune the primary, and another one to tune the secondary of the i-f transformer. Due to the shape of the core, permeability tuning and magnetic shielding of the inductor are accomplished at the same time. Each core has a screwdriver slot on top to permit adjustment of the core within and around the coils. Referring to Figs. 1 and 2 it will be seen that the cores are threaded, and so are the plastic walls of the mechanical support of the i-f transformer. The core itself is a hollow cylinder about 7/16 of an inch long, one end of which has a solid flat top cap which is slotted for the screwdriver adjustment. This is depicted in Figs. 1((B) and 2(A). Inside this cylinder, a rod of about 9/64 inch diameter protrudes from the underside of the flat cap. This part is termed the "plunger" rod in both drawings. The complete core is one solid piece and is made of powdered iron.

Two cores are used, each placed in the threaded parts of the transformer's plastic supports as seen in Figs. 1(A) and 2(A). The upper coil is the secondary of the transformer, and the lower coil is the primary. Special provision in the i-f transformer can and assembly is made so screwdrivers can be inserted to reach the slotted parts of the cores for alignment purposes. This is readily seen from the bottom part of the front view of Fig. 2(A) with reference to tuning the primary core. Upon turning any core clockwise, the solid rod portion is inserted into the hollow coil forms, and thereby increases the inductance; at the same time the cylindrical part of the core surrounds the coil. Since the core is completely made of powdered iron, not only does it vary the inductance of the unit by means of the center rod, but also the cylindrical part provides magnetic shielding about the coils themselves, thus increasing the stability of the i.f.

The Fixed Capacitances

Since the frequency is high, the capacitors needed to complete the inductance-capacitance (L-C) tank circuits for the primary and secondary are small. It should be remembered that this i-f transformer being discussed operates at a center frequency of 10.7 mc. To conserve space and avoid the use of separate mica capacitors with connecting leads, the capacitors in this transformer are included within the base of the unit in conjunction with the connecting pins also called terminal lugs. The fixed capacitance is formed by the pins (or lugs) extending inside the base of the unit. There are four terminal lugs in this unit where two are used for the primary circuit and two for the secondary. In other words these four lugs are broken up into two pairs. Consequently, in each case (for the primary and secondary) two of the lugs from one pair are made to overlap each other inside the base of the transformer, and this overlap is separated by a sheet of mica. These overlapped lugs or pins are silver coated and serve as the plates of a capacitor, which is one of a simple parallel-plate type where the value of capacitance is determined by the common area between the overlapped lugs, the distance between them, and the dielectric constant of the mica. The value of the capacitance in micromicrofarads ($\mu\mu$f) is given by the following simple formula:

$$C = 0.225 \frac{KA}{D} \text{ in } \mu\mu f$$

where A is the common area between the plates expressed in square inches

D is the distance between the plates in inches

K is the dielectric constant of mica which may be anywhere between 2.5 and 6.0, the exact value depending upon the type of mica used.

The two leads from each coil are attached to the terminal lugs at the point where they protrude from the assembly. This is readily noticed in Figs. 2(A) and (B). Consequently, we have a double-tuned transformer with permeability tuning for both the primary and secondary and with fixed capacitors for each.

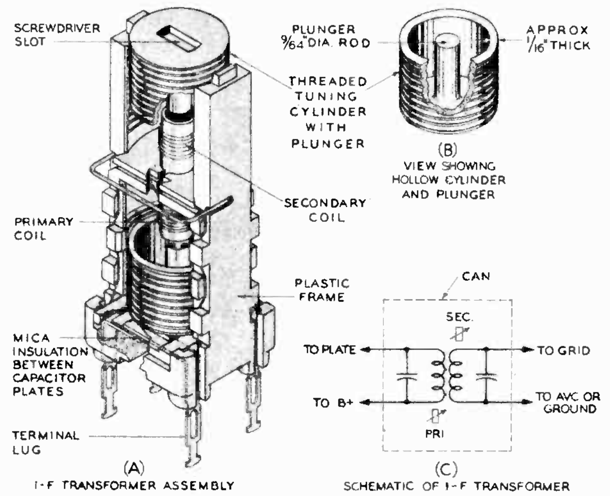


FIG. 1.—Cutaway views of the K-Tran 10.7-mc i-f transformer and the movable core are shown in (A) and (B) respectively. The schematic of the transformer is in (C).

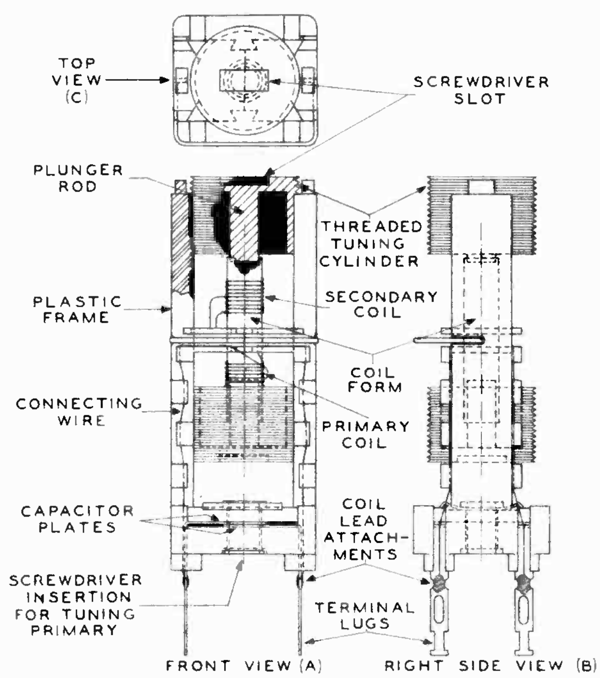


FIG. 2.—Detailed assembly drawing of the K-Tran transformer: front view (A), right side view (B), and top view (C).

I-F WAVE TRAP FORMED BY SPECIAL CAPACITOR

In many ac-dc receivers most of the units within the set are kept above ground by a number of methods as illustrated schematically in Fig. 1. Some use just a capacitor of 0.2 μf or so [Fig. 1(A)]; others use a similar capacitor and shunt it by a high-valued resistor anywhere between 100,000 and 250,000 ohms [Fig. 1(B)], and still others use a resistor shunted by a series network of a capacitor and a coil [Fig. 1(C)]. In the latter case, besides producing a return path from B minus to ground, the series capacitor and inductance are usually made resonant somewhere around the i. f. of the set. Therefore, this *L-C* combination presents a ready path to ground for any stray i-f currents that may find their way into the B-minus lead and thus prevent i-f feedback to the circuits through this common B-minus lead.

This inductance-capacitance combination in most instances represented a somewhat crude resonant circuit in that it did not present so sharp a response curve as the i-f transformers. However, its purpose as an i-f trap in the B-minus circuit was served adequately. Many of these *L-C* circuts, as used in the B-minus lead, do not make as fine i-f traps as those that appear in the r-f sections of receivers. Many of these B-minus i-f wave traps appear in table model ac-dc receivers and essentially consist of a paper capacitor varying in the vicinity of 0.2 μf and around or near this capacitor is usually wound some simple connecting wire of enough inductance to make it resonate with this capacitor at the i. f.

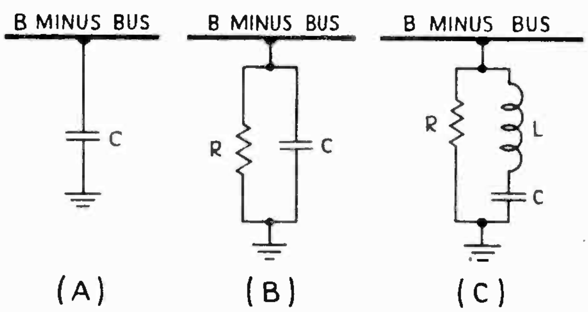


FIG. 1.—Three methods of keeping most of the units of ac-dc receivers above ground: (A) use of a capacitor, about 0.2. μf, (B) addition of a high-valued resistor to shunt a similar capacitor, (C) use of a resistor shunted by a series network of a capacitor and coil.

Usual B-Minus I-F Trap Construction

This process of using a separate piece of wire to form the resonant circuit does take some time and effort besides the small amount of cost involved. One main disadvantage of such an arrangement is that the coil of wire may become loose or somewhat disconnected from its original position, and then may be mistaken for a lead elsewhere in the receiver and may confuse the serviceman. This is especially likely when the circuit diagram of the receiver does not exactly identify this coil, and it appears only as seen schematically by *L* in Fig. 1(C).

To overcome the use of a separate coil and retain the advantageous features of an i-f wave trap in the B-minus return, the Philco Model 48-214 (code 125) uses what is called a "special" capacitor. In this ac-dc receiver, the schematic of which appears on Philco page 17-11, 12 in Rider's Vol. XVII, this unit appears as a normal paper capacitor. The label on it reads in part: *.2 MFD. 400 V.D.C. Special.* The construction of this capacitor essentially consists of two sheets of tinfoil such as appears in most paper capacitors, but the method of attaching the pigtail leads differs from the usual paper capacitor. The knowledge that the tinfoil itself is a metallic substance and possesses its own self-inductance made it possible, by special attachments of the pigtails, to use a paper capacitor to form an i-f wave trap.

Construction of a Paper Capacitor

Every paper capacitor that uses tinfoil or some similar metallic substance for the effective capacitor plates represents a series inductive-capacitive circuit which is resonant at some frequency. With reference to Fig. 2 this

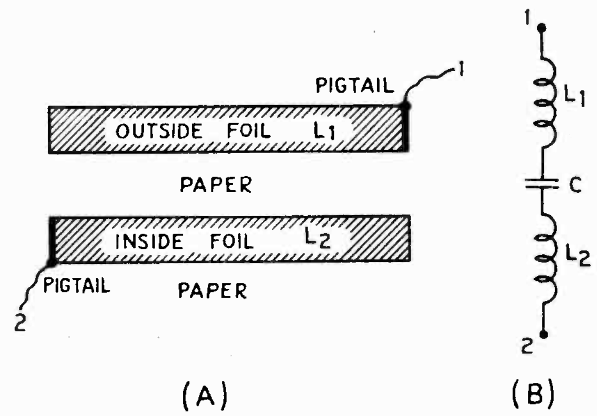


FIG. 2.—Unwound, the tinfoil plates of a typical capacitor appear as in (A). The circuit representing the capacitor appears in (B).

resonant effect of most paper capacitors is best explained as follows:

The two tinfoil plates used in a typical paper capacitor are indicated in Fig. 2(A) as flattened out. The plates are separated by paper which is usually impregnated with wax or oil. Paper insulator also appears on the underside of the inside foil. The outside foil is designated as L_1 in Fig. 2(A), the inside foil as L_2, and it is readily conceivable that each foil has a certain amount of self-inductance, the exact amount being determined by the dimensions of the foils themselves. These two foils in conjunction with the impregnated paper are rolled up together so that foil L_1 is on the outside and foil L_2 is on the inside.

Pigtail leads are attached to the foils in different ways, but for the case under discussion we chose the type that has the pigtails attached to opposite ends of the foils as shown by pigtail points 1 and 2 in Fig. 2(A). The capacitance of this unit is directly proportional to the common area between the two tinfoils and inversely proportional to the separation distance between the foils. The capacitance is also a direct function of the dielectric constant of the paper insulator. (The exact equation for the capacitance value of two parallel plate capacitors is included at the end of the section of this book called "Special I-F Transformer.")

If we were to draw the true circuit of this "capacitor," neglecting any resistance or leakage losses, we would have to take into account the self-inductances of each tinfoil. Under this circumstance the circuit representing the capacitor of Fig. 2(A) is illustrated in Fig. 2(B). Coil L_1 represents the inductance of the outside foil, capacitor C represents the effective capacitance between the two foil plates, and coil L_2 represents the inductance of the inside foil. By tracing the capacitor of Fig. 2(A) from point 1 to point 2, you will note that the circuit of Fig. 2(B) is truly represented.

Since the network in Fig. 2(B) is a series inductance-capacitance, it will be resonant at some frequency offered by the amount of inductance and capacitance in the circuit. If we can fix the total value of inductance of the capacitor and keep the capacitance constant, we have a ready means of making the circuit resonant to a desired frequency.

Design of the Special Capacitor

This is exactly what is accomplished in the Philco special capacitor. A drawing of the layout of this capacitor is illustrated in Fig. 3(A).

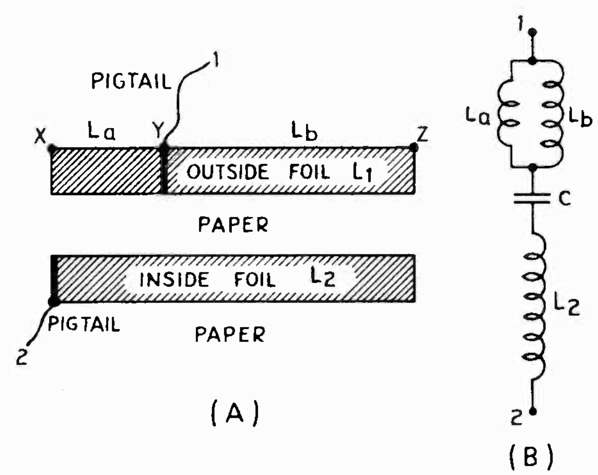


FIG. 3.—(A) The pigtail lead, 1, on the outside foil has been moved to Y from its position in FIG. 2. (A). The schematic circuit for this new condition is shown at (B).

The difference in design between this capacitor and that of Fig. 2(A) is that pigtail connection point 1 is moved down 2/3 of the length of the foil from the point at the right end of the outside foil where it formerly was connected. This means that the outside foil has a tap on it to which the pigtail lead is connected. Consequently, inductance designated as L_a exists between points X and Y and inductance designated as L_b exists between points Y and Z of the outside foil. Under this division inductance L_a equals 1/3 of the total inductance of L_1, and L_b equals 2/3 of the total inductance L_1; likewise $L_a + L_b$ equals inductance L_1.

To trace the path from pigtail to pigtail starting with that of the outside foil, we can take either of two paths. One path encompasses inductance L_a and the other inductance L_b. With this understanding of choice of paths we can draw the circuit diagram representing this capacitor arrangement. This is indicated in Fig. 3(B). From this circuit it is noted that inductances L_a and L_b of outside foil L_1 are represented schematically as two coils in parallel. The capacitance C is not changed, because, no matter where the pigtails are connected along either foil, the factors determining the value of capacitance do not change. The inductance of the inside foil L_2 also does not change, inasmuch as the pigtail connection to this foil remained as it was in Fig. 2(A).

Effective Inductance of Outside Foil

Consequently, the circuit of Fig. 3(B) consists of inductance L_a in parallel with L_b. This combination, in series with the capacitor C and L_2, altogether represents the series resonant circuit. The tap at point Y of the outside foil of Fig. 3(A) is especially chosen so that the parallel combination of L_a and L_b will offer a lower inductance than L_1. By this method of lowering the inductance, the resonant frequency of the series circuit is increased.

Since the inductance of L_a is equal to 1/3 of L_1 and that of L_b equal to 2/3 of L_1, we can readily evaluate the inductance of L_a and L_b in parallel in terms of L_1. Two inductors in parallel are like resistors in parallel—thus:

$$\frac{L_a \times L_b}{L_a + L_b}$$

Substituting for L_a and L_b in terms of L_1 we find:

$$\frac{1/3\ L_1 \times 2/3\ L_1}{1/3\ L_1 + 2/3\ L_1} = \frac{2/9\ L_1^2}{L_1} = 2/9\ L_1$$

The foregoing answer tells us that when the pigtail tap on the outside foil is so situated that L_b is equal to twice L_a, the total inductance offered by the outside foil to the series circuit of Fig. 3(B) is equal to 2/9 of its complete self-inductance. The total value of the inductance of this special capacitor in conjunction with its value of 0.2 µf is designed so that it will be broadly resonant at the i.f. of the receiver, which is 455 kc. At this frequency and with 0.2 µf, the total value of series inductance offered by this special capacitor should be approximately equal to 0.6 microhenry.

THE F-M FREMODYNE CIRCUIT

Until very recently there were on the market only three types of f-m detector circuits as used in f-m receivers. These were the limiter-discriminator type (employing the Foster-Seeley or phase discriminator), the ratio detector type, and the locked-in-oscillator detector. The first two detector circuits were analyzed in detail in the "How It Works" section of Rider's Vol. XV. In Vol. XV on Philco page 15-53, 54 is the f-m schematic diagram of the Philco Model 46-1213 which contained the locked-in oscillator.

Each one of these f-m detector circuits follows the i-f circuits of the receiver. Altogether quite a number of tubes are employed. When the set is a combination a-m and f-m receiver, as most of them are, most of the r-f, oscillator, and i-f tubes are used for both a.m. and f.m. However, separate circuits for a.m. and f.m. have to be employed in each of these sections because of the frequency range involved. Consequently, this still entails many extra component parts such as special coils and i-f transformers.

The Hazeltine F-M Circuit

These extra components elevate the cost of such combination receivers. In order to supply f-m detection with use of only a few extra component parts, the Hazeltine Electronics Corporation designed the so-called *FreModyne FM Circuit*. It is one of the latest developments in f-m design and uses a single tube employing two triode sections and functioning as *a superheterodyne frequency converter, superregenerative i-f amplifier, and an f-m detector*. It is evident from the many functions this tube takes over how it reduces the cost of combination a-m and f-m receivers. Its performance is not so good as the other f-m circuits previously mentioned, but it is designed specifically to be used with small table model receivers and as such is considered to give satisfactory performance. It may seem somewhat amazing that a single tube can perform so many functions. However, if the circuit included in this section is followed carefully in conjunction with the accompanying discussion, the performance of these functions will become readily apparent.

Howard Model 474

One of the receivers using the FreModyne circuit is the Howard combination a-m f-m receiver Model 474, the complete schematic circuit of which appears on Howard page 17-11

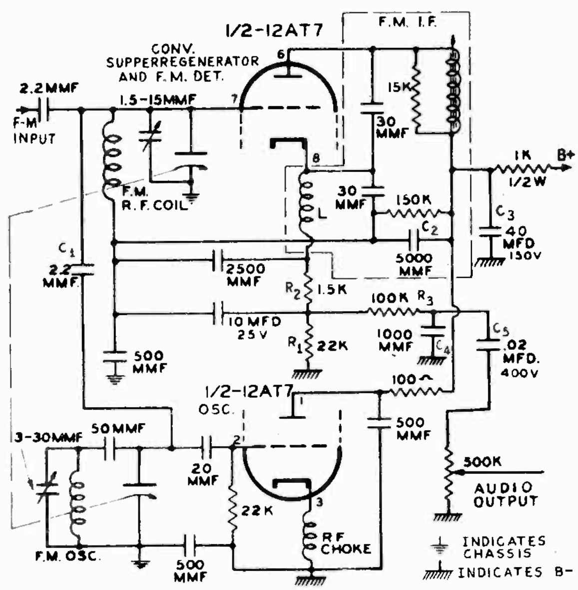


FIG. 1.—Schematic diagram of the f-m section of the circuit of Howard Model 474.

in Rider's Vol. XVII. The f-m part of this circuit is illustrated in Fig. 1.

The duo-triode used is a 12AT7 tube (which has a 9-pin base) one half of which is used as the superheterodyne oscillator, and the other half as the converter, superregenerative i-f amplifier, and f-m detector. Some of the oscillator voltage from the f-m oscillator section is injected into the grid of the other triode section through a 2.2 $\mu\mu$f coupling capacitor designated as C_1 in Fig. 1. The f-m oscillator and r-f tank circuit have their tuning capacitors ganged. With the set properly tuned to some f-m station, the oscillator signal mixes with the f-m signal in the upper triode section. Conversion action occurs, and a number of frequencies result. The desired i.f. is chosen by the selective f-m i-f transformer at the output of this latter triode. The f-m i-f transformer is tuned to a frequency of 21.35 mc, which is considerably above the usual 10.7-mc f-m i.f. This f-m i-f transformer circuit is in the form of a superregenerative Colpitts oscillator tank, in which the f-m i-f signal is fed back to the grid of the top triode section through C_2 (5000 $\mu\mu$f) and the f-m r-f coil. Thus this triode section also functions as a superregenerative i-f amplifier.

The circuit is so arranged that by tuning the receiver slightly off frequency, f-m detection is brought about by working on the *sloping* characteristic of the i-f response curve. When the receiver is so tuned, the i.f. produced by conversion action is not exactly equal to the 21.35-mc peak of the i-f transformer. If the detuning is done with care, the i.f. produced will be somewhere along either sloping characteristic of the i-f response curve. The slope is practically a straight line, and therefore conversion of the f-m signal into one that varies in amplitude in accordance with the rate and strength of the audio modulating signal will be brought about. This type of detection is commonly known as *slope detection*.

In order to show how an f-m wave can be detected by the method of *slope detection* let us refer to the selectivity curve of Fig. 2. This curve approximates the selectivity curve of the f-m i-f transformer of the FreModyne circuit in Fig. 1. As mentioned, the receiver is slightly detuned.

This is to make sure that the f-m signal is passed by the i-f transformer, and also to make sure that distortion is a minimum, so that the f-m variations can be changed into a-m variations for detection. The amount of detuning is such that the reproduction of audio will be at its best. By thus slightly detuning the set, the r-f and the oscillator sections both become detuned. The amount of r-f detuning, however, is slight, and the f-m signal picked up still comes through. The oscillator becomes detuned to a point where an i.f. will be produced that is different from the peak frequency of the i-f transformer. If the detuning is such that the peak of the new i-f signal lies on the linear portion

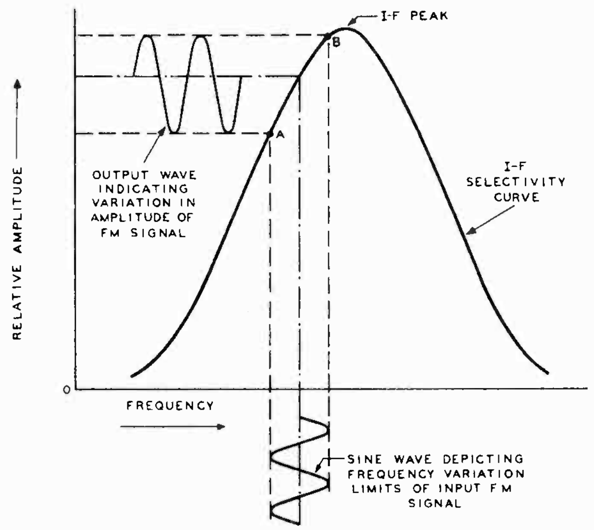


FIG. 2.—This i-f selectivity curve illustrates how slope detection of an f-m i-f transformer comes about.

of the transformer characteristic on either side of the transformer peak, the f-m signal will be properly detected.

Assuming that the detuning is such that the i.f. produced is less than the peak of the i-f transformer (21.35 mc), the detection will occur on the left slope of the i-f selectivity curve of Fig. 2. The sine wave signal at the bottom of the drawing is supposed to represent only the *frequency variations* of the produced f-m i-f signal and is not the actual f-m i-f signal itself. This sine curve is drawn merely for the sake of illustration. The upper curve in the left-hand side of Fig. 2, shows how the frequency variations of the lower sine curve cause amplitude variations due to the so-called *slope* of the i-f curve. The actual part of the left slope of the selectivity curve concerned is the portion in Fig. 2 between points A and B. The upper curve of Fig. 2 is varying at the audio rate of the modulating signal of the picked-up f-m wave because the frequency variations or deviations (as they are better known) of this f-m signal, and hence the produced f-m i-f wave, also are varying at the rate of the modulating audio signal.

The interesting thing about this circuit is that both the input and output signals from the i-f transformer are f-m signals, but the transformer characteristic has incorporated amplitude variations into the output f-m signal, these amplitude variations changing in accordance with the audio intelligence of the f-m signal. The r-f part of this output signal will be filtered out by the 1000-$\mu\mu$f capacitor C_4 (as will be seen later) and only the audio signal will be available. Therefore, the audio signal reproduced by the slope detection of the f-m i-f wave will contain the intelligence of the f-m signal. Looking at the selectivity curve of Fig. 2, that portion of the curve between points A and B is seen to be fairly linear. Therefore, with the f-m signal changing in frequency between these two limits, the f-m i-f transformer will reproduce these frequency variations, which are at an audio rate, with a minimum amount of distortion. In other words, the more linear the portion of the curve between points A and B becomes, the less distortion will appear in the output.

If the set is not detuned and an f-m signal is received, the oscillator will beat with the incoming f-m signal to produce an i-f f-m signal that is exactly on the peak of the i-f transformer.

This signal will pass through the i-f transformer because it is well within the bandwidth of the transformer. However, the f-m signal in passing through the i-f transformer will produce an output that is badly distorted because the signal will be working on a very nonlinear portion of the i-f characteristic, namely the portion of the i-f peak.

If the detuning were such that the right-hand slope of the selectivity curve were used, detection would likewise occur. Consequently, two distinct points of tuning for every station can be heard because there are two slopes to the response characteristic.

Tracing the Detected Signal

The a-f signal currents produced after detection flow in the following path: from the plate (pin 6) to the upper triode through the f-m i-f coil, through C_3 (40μf) to B minus. From B minus the a-f current is returned to the cathode of the tube through R_1 (22,000 ohms), R_2 (1500 ohms), and the cathode coil L. The greatest impedance offered to the a.f. is in R_1, and most of the audio appears across this resistor. The audio then passes through the R_3C_4 de-emphasis network and is capacitance coupled through C_5 to the volume control. As mentioned previously, the 1000-$\mu\mu$f capacitor C_4 bypasses to ground the r-f component of the detected signal, and thereby only audio is coupled through C_5.

For the i-f alignment the manufacturer suggests using a 21.35-mc unmodulated signal effectively at the input to the grid of the upper triode. The tuning control is set off station, and the i-f permeability adjustment made. The adjustment is made for minimum output noise in the speaker. This adjustment is based upon the action of superregenerative rush noise that is heard on either side of the correct i-f setting. Consequently, when the noise is a minimum, the i.f. is correctly aligned. The oscillator and r-f alignment is made by the usual method of adjusting the oscillator and r-f trimmer for maximum output in accordance with usual tracing procedure.

GENERAL A-M ALIGNMENT PROCEDURE

Many manufacturers do not list any specific alignment procedure with their service notes on a-m receivers. The primary reason for this in most cases is that the alignment method is general and does not deviate from commonly accepted procedure. Receivers that are multiband sets may contain any number of bands besides the standard broadcast band. For instance, some may have their tuned circuit coils and capacitor arrangements so situated that the broadcast band may have to be aligned first, the short-wave bands next, and then the long-wave band (if any is used). For other multiband receivers it may be necessary to start with the short-wave section, or sections, and then follow with the other bands.

We are here presenting three tabulated alignment procedures, A, B, and E. These procedures refer only to a-m receivers and are to be applied in instances where the manufacturer does not provide specific alignment notes. In all of the procedures it is assumed that the peak frequencies of the i-f transformers and the locations of the different trimmers and padders are known. All such information usually is included with the manufacturers' service notes. In Rider's Vol. XVII these three alignment procedures, A, B, and E have been referred to in instances where no alignment data accompanied the service notes.

The assignment of an alignment procedure to any particular set does not mean that the adjustment of the set can follow the procedure exactly as it is tabulated. This is especially true of i-f transformer alignment. In all instances the i-f's of the set in question should be aligned first on the broadcast band. However, more than two i-f's (that is, the output and input i-f's) may be listed. When this is so, the other transformers should be aligned in between the output and input transformers. In other words the i-f's are aligned in order, starting from the i-f transformer at the second detector, usually termed the output i-f transformer, and working back toward the front end of the set to the converter stage.

Procedure A is for a-m receivers that contain only the standard broadcast band. This procedure is straightforward, as no other bands are present. However, procedures B and E are a little more intricate as they represent multiband receivers.

A glance at these two latter procedures will reveal that each contains provisions for aligning a broadcast, long wave, intermediate short wave, and short wave band. Whenever in Rider's Vol. XVII there is reference to procedure B or E for circuits which do not contain one of the bands, such as a long wave or intermediate short wave, the alignment procedure for the missing band should simply be ignored and the next step followed. The same method should be followed if the r-f and/or oscillator section of a receiver has one less trimmer than mentioned. If there is one or more trimmers than mentioned in the procedure, they also should be included according to the method of i-f alignment.

Explanation of Columns

In procedures B and E four columns are indicated, as compared with the three listed in procedure A. It will be noted that the column omitted from procedure A and included in the other two is *Wave-Band Switch Position*. This results naturally from the fact that procedure A is for a-m receivers containing only the standard broadcast band and procedures B and E pertain to all-wave a-m receivers.

Signal Generator Connection (Column 1)

The high side of the signal generator should be connected to the specific point in the receiver circuit that is indicated in this first column.

The low side of the signal generator is connected directly to the receiver chassis, with the exception than in ac-dc receivers this connection be preferably made through a 0.1 μf capacitor.

Signal Generator Frequency (Column 2)

The first column specified where to place the output leads of the signal generator for the proper alignment of certain sections. The second column specifies the frequency at which the signal generator should be set for making the necessary alignment adjustments.

Wave-Band Switch Position (Column 3 in B and E)

In receivers incorporating two or more bands, it is important that the wave-band switch be turned to the correct position. This is understandable since it is desired to have the correct tuned circuits and trimmers on the proper band. In aligning i-f transformers, it is customary to throw the wave-band switch to the "Broadcast" position. However, this is not an invariable rule; for, to compensate for a change in 'biasing' or to obtain lessened avc action, it may be necessary to throw the band switch to the 'Short-wave' position.

Trimmers Adjusted (In Order Shown) (Last Column)

This column lists the names of the trimmers to be adjusted. These trimmers are all to be adjusted to secure a maximum output indication such as that on an output meter, which is usually connected across the voice coil of the speaker. The word "shunt" in this column means that the trimmers are in parallel with the tuned circuit, and the word "series" means that the trimmer to be adjusted is in series with the tuned circuit to be aligned. Sometmes the series trimmer in a receiver is referred to as a series padder.

ALIGNMENT PROCEDURE A

(For standard-band superheterodyne receivers)

Note: Check adjustments at the high-frequency end of the band after aligning the low-frequency end.

Signal Generator Connection	*Signal Generator Frequency*	*Trimmers Adjusted (In Order Shown)*
1. Mixer grid	Specified i-f	Output i-f secondary, output i-f primary, input i-f secondary, input i-f primary
2. Antenna	Specified oscillator high adjustment frequency	Oscillator shunt
3. Antenna	Specified antenna adjustment frequency	Mixer shunt, antenna shunt
4. Antenna	Specified oscillator low adjustment frequency	Oscillator series or ganged capacitor plate

ALIGNMENT PROCEDURE B

(For all-wave superheterodyne receivers)

Note: Check adjustments at the high-frequency end of each band after aligning the low-frequency end.

Signal Generator Connection	*Signal Generator Frequency*	*Wave-band Switch Position*	*Trimmers Adjusted (In Order Shown)*
1. Mixer grid	Specified i-f	Broadcast	Output i-f secondary, output i-f primary, input i-f secondary, input i-f primary
2. Antenna	Specified B.C. oscillator high adjustment frequency	Broadcast	Oscillator shunt
3. Antenna	Specified B.C. antenna adjustment frequency	Broadcast	Mixer shunt, antenna shunt
4. Antenna	Specified B.C. oscillator low adjustment frequency	Broadcast	Oscillator series
5. Antenna	Specified L.W. oscillator high adjustment frequency	Long wave	Oscillator shunt
6. Antenna	Specified L.W. antenna adjustment frequency	Long wave	Mixer shunt antenna shunt
7. Antenna	Specified L.W. oscillator low adjustment frequency	Long wave	Oscillator series
8. Antenna	Specified S.W. oscillator high adjustment frequency	Intermediate short wave	Oscillator shunt

ALIGNMENT PROCEDURE B—(Continued)

Signal Generator Connection	*Signal Generator Frequency*	*Wave-band Switch Position*	*Trimmers Adjusted (In Order Shown)*
9. Antenna	Specified S.W. antenna adjustment frequency	Intermediate short wave	Mixer shunt, antenna shunt
10. Antenna	Specified S.W. oscillator low adjustment frequency	Intermediate short wave	Oscillator series
11. Antenna	Specified S.W. oscillator high adjustment frequency	short wave	Oscillator shunt
12. Antenna	Specified S.W. antenna adjustment frequency	short wave	Mixer shunt, antenna shunt
13. Antenna	Specified S.W. oscillator low adjustment frequency	short wave	Oscillator series

ALIGNMENT PROCEDURE E

(For all-wave superheterodyne receivers)

Note: Check adjustments at the high-frequency end of each band after aligning the low-frequency end.

Signal Generator Connection	*Signal Generator Frequency*	*Wave-band Switch Position*	*Trimmers Adjusted (In Order Shown)*
1. Mixed grid	Specified i-f	Broadcast	Output i-f secondary, output i-f primary, input i-f secondary, input i-f primary
2. Antenna	Specified S.W. oscillator high adjustment frequency	Short wave	Oscillator shunt

ALIGNMENT PROCEDURE E—(Continued)

Signal Generator Connection	*Signal Generator Frequency*	*Wave-band Switch Position*	*Trimmers Adjusted (In Order Shown)*
3. Antenna	Specified S.W. antenna adjustment frequency	Short wave	Mixer shunt, antenna shunt
4. Antenna	Specified S.W. oscillator low adjustment frequency	Short wave	Oscillator series
5. Antenna	Specified S.W. oscillator high adjustment frequency	Intermediate short wave	Oscillator shunt
6. Antenna	Specified S.W. antenna adjustment frequency	Intermediate short wave	Mixer shunt, antenna shunt
7. Antenna	Specified S.W. oscillator low adjustment frequency	Intermediate short wave	Oscillator series
8. Antenna	Specified B.C. oscillator high adjustment frequency	Broadcast	Oscillator shunt
9. Antenna	Specified B.C. antenna adjustment frequency	Broadcast	Mixer shunt, antenna shunt
10. Antenna	Specified B.C. oscillator low adjustment frequency	Broadcast	Oscillator series
11. Antenna	Specified L.W. oscillator high adjustment frequency	Long wave	Oscillator shunt
12. Antenna	Specified L.W. antenna adjustment frequency	Long wave	Mixer shunt, antenna shunt
13. Antenna	Specified L.W. oscillator low adjustment frequency	Long wave	Oscillator series

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