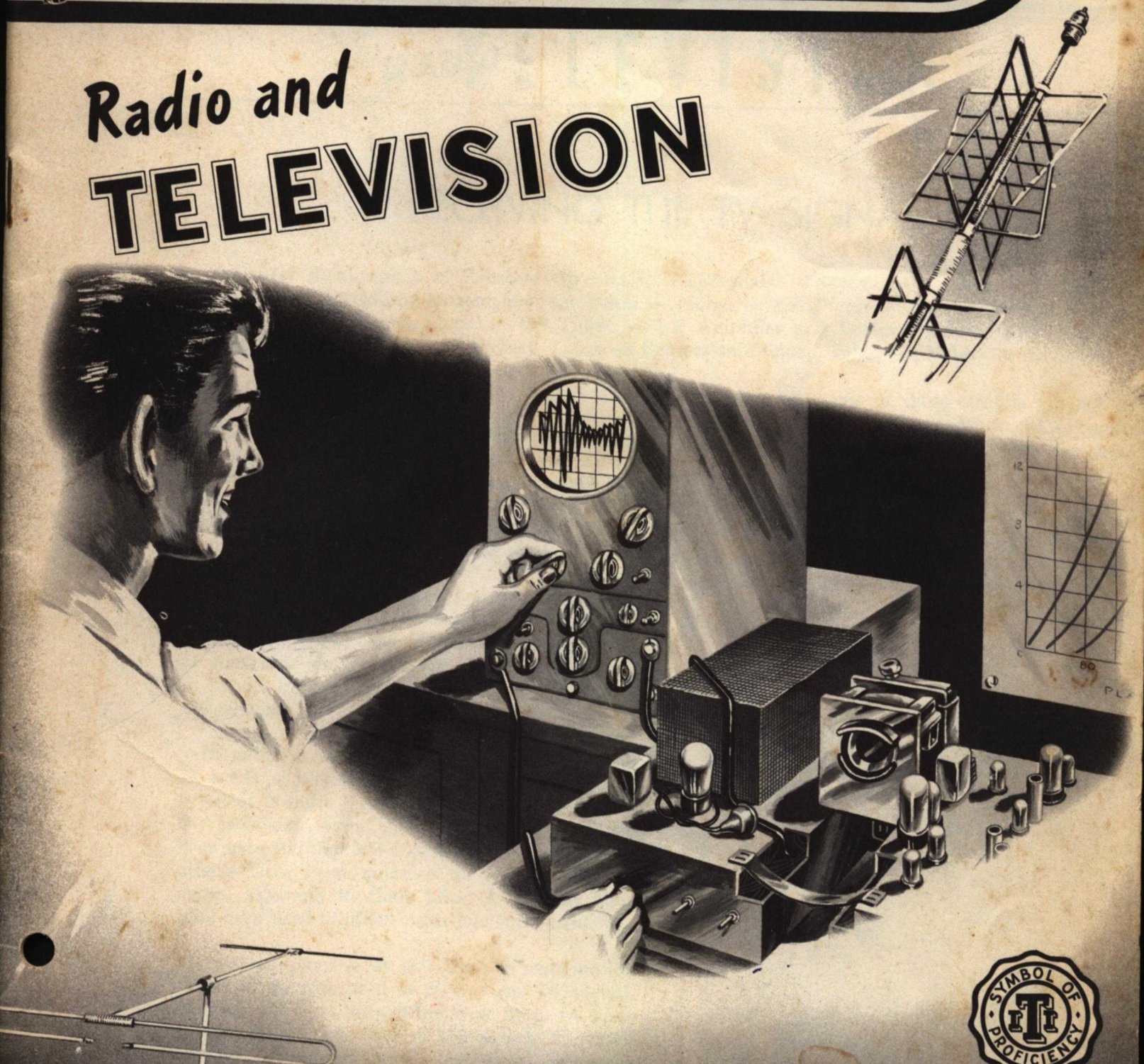


# Technical Training

S E R V I C E

## Radio and TELEVISION



# INDUSTRIAL TRAINING INSTITUTE



# TECHNICAL TRAINING SERVICE

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## RAD<sup>IO</sup> TELEVISION

### RECEIVING THE TV SIGNAL

*Contents:* Relationship of Receiver Circuits to TV Signals — Separator Circuits — Deflection Circuits — Controlling Movement of the Beam — Image on the Picture Tube — Antenna Signal — Handling Antenna Signal in the Tuner — I-F Amplifier and Detector Action — TV Power Supplies — Care Handling Picture Tubes — Projection Picture Tubes — Notes for Reference.

#### Section 1. INTRODUCTION

We have discussed many circuits which are common to all types of electronic devices. Power supply circuits, for example, are all much the same despite the fact some are used in radios, others are used in industrial electronic equipment, and still others in television work.

Much the same is true of amplifier circuits. Those used in television work are not much different from those used in radio and other kinds of electronic devices except they are designed to handle higher frequencies, or wider bands of frequencies.

In addition to the circuits commonly used in all kinds of electronic equipment certain special types of circuits have been developed to receive the television signal. Some have not previously been used in other kinds of electronic equipment; others have been modified to receive the TV signal although in their basic form they have long been used in other electronic equipment.

It is our purpose at this time to examine the principal circuits used to receive the TV signal, and see just how they differ from those we have previously studied. Most of the circuits to which you are introduced in this lesson will be examined more closely in later lessons. Whole lessons will be devoted to each of the circuits to explain the part each plays in the reception of the TV signal.

If you feel some of these circuits are not entirely clear to you it is not an occasion for concern. They will be explained in greater detail later in the course.

We will try to point out how these circuits work together, and show their relationships to each other. By introducing them to you at this time, so you can become acquainted with them, it will be easier for you to understand them



Figure 1. Table model receiver with rectangular tube. (Courtesy Sentinel.)

when we later take up the study of each individually.

We have previously hinted that I-F circuits in a TV receiver are essentially the same as those found in radio receivers. Basically, that is true. But there are special characteristics about television I-F circuits which set them aside from those used in radio work. The matter of frequency is one such characteristic. The increasing tendency among TV manufacturers to handle both the video I-F signal and the sound I-F signal in the same I-F amplifying circuits is a matter worth close study. How that is done will be explained in detail later.

The video amplifier is another type of amplifying circuit deserving special consideration. A video amplifier is one which handles the video signal in a receiver after the I-F signal has been demodulated. It is the special wide-band amplifier used to amplify the composite video signal.

Video amplifiers do not occupy the important place in receiver design and construction they once did. There is a growing tendency to handle the video signal as little as possible after it passes through the detector stage. Nevertheless, it is a subject to which it is well worth paying close attention. This is especially true if you take up the study of color receivers.

Another type of circuit which plays an important part in television receivers, yet is not known in ordinary radio receivers is the synchronizing circuit. The "sync" circuits tie the receiver deflection circuits into tight synchronization with the sweep circuits in the transmitter. It is hard to over-estimate their importance.

The special sync separator circuit, which separates the synchronizing pulses from the camera signal in the composite video signal, is another television circuit not known in ordinary radio work.

Deflection circuits — which act to move the electron beam around to the various parts of the picture tube screen — are not necessarily peculiar to television work. They are found in oscilloscopes and radar equipment. But they are new to those whose electronic experience has been confined to radio receivers.

We will devote entire lessons to the details and actions of these special television circuits. Our purpose at this time is to introduce you to them, so you are aware of their existence. Then, when you later begin studying them in detail, you will be in better position to understand how they fit together, and work together, to make an operating television receiver.

## Section 2. RELATIONSHIP OF RECEIVER CIRCUITS TO TV SIGNAL

When becoming first acquainted with the various circuits in a television receiver it is probably a good idea to examine the manner in which each is affected by the signals picked up by the antenna. Then by following the path of those signals, as they pass through the receiver circuits, it is easier to recognize the job each of the circuits plays in the proper functioning of the receiver.

The principal circuits found in one type of television receiver are laid out in block diagram form in Fig. 2. No attempt has been made to show the exact composition of any of those circuits, but the manner in which the signals pass through them becomes somewhat more clear. Their relationship to each other and to the TV signal, becomes a little more understandable.

In the television receiver outlined in Fig. 2 the video carrier signal and the sound carrier signal are both picked up by the antenna. It is interesting to note, and remember, that the sound carrier and the video carrier operate on different frequencies. Those carriers are separated from each other by 4.5 megacycles.

Both carrier signals — one amplitude modulated, the other frequency modulated — are amplified in the RF amplifier circuit, then converted to lower frequencies in the mixer circuits.

It will be noted that in most respects the action is very similar to that which occurs in the front end of an ordinary radio receiver. The principal difference is that the frequencies involved in a television receiver are much higher than those used in radio work.

One other difference is that the tuner section of a television receiver must be capable of hand-

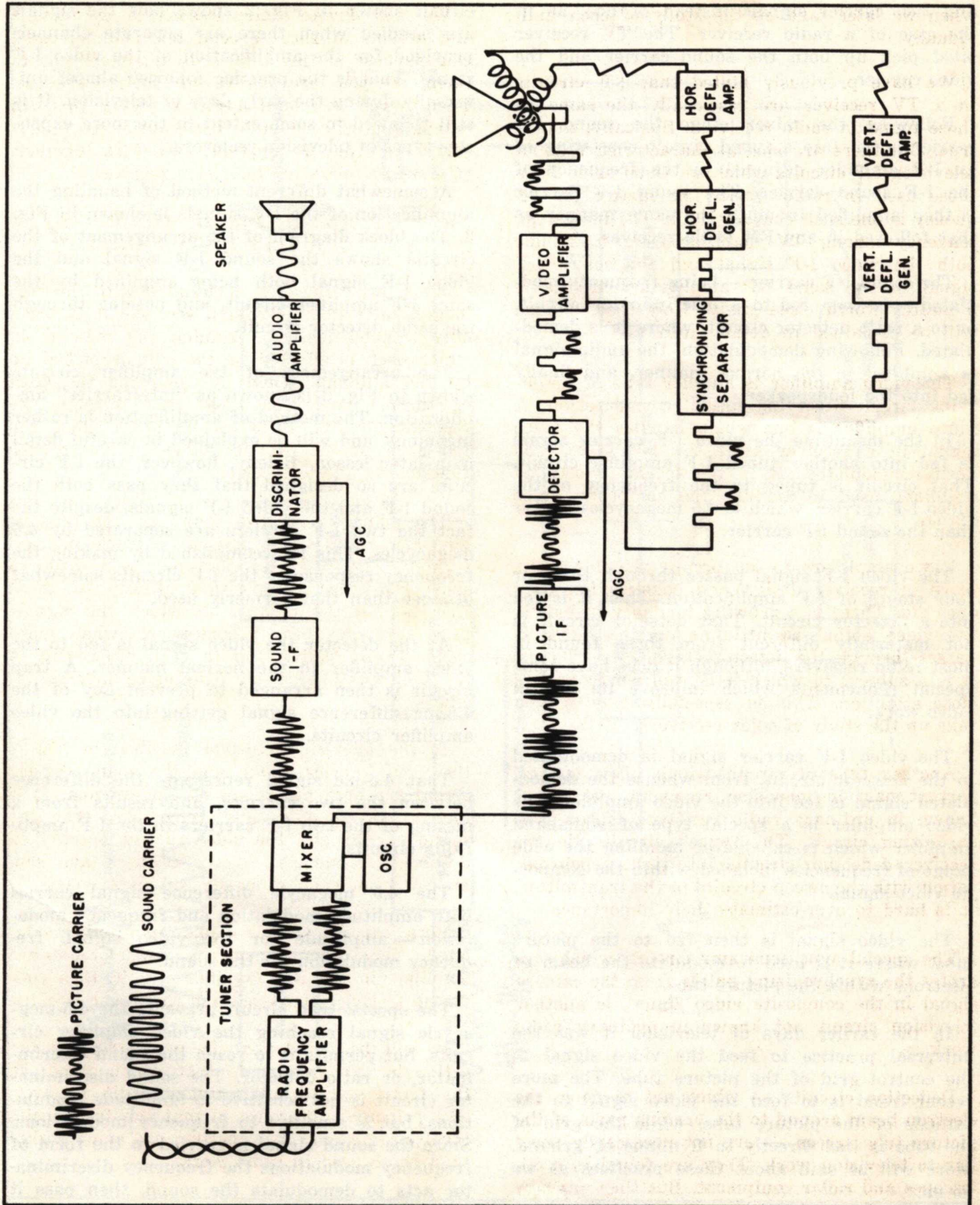


Figure 2. Block Diagram of TV receiver.

ling *two* carrier signals instead of one, as in the case of a radio receiver. The TV receiver *must* pick up both the sound carrier and the video carrier.

Following the mixer stage the sound I-F carrier is fed into a tuned circuit consisting of an I-F amplifier adjusted to the frequency of the I-F sound carrier. The sound I-F carrier is then amplified in much the same manner as that followed in any FM radio receiver.

The sound I-F carrier — being frequency modulated — is then fed to a discriminator circuit, or to a ratio detector circuit, where it is demodulated. Following demodulation, the audio signal is amplified in the normal manner, and finally fed into the loudspeaker.

In the meantime the video I-F carrier signal is fed into another tuned I-F amplifier circuit. That circuit is tuned to the frequency of the video I-F carrier, which is 4.5 megacycles *higher* than the sound I-F carrier.

The video I-F signal passes through three or four stages of I-F amplification. Then it is fed into a detector circuit. That detector circuit is not materially different from those found in most radio receivers, although it does have some special refinements which improve its use in video work.

The video I-F carrier signal is demodulated in the detector circuit, from whence the demodulated signal is fed into the video amplifier. The video amplifier is a special type of wide-band amplifier which is capable of handling the wide range of frequencies included within the composite video signal.

The video signal is then fed to the picture tube, where it is used to modulate the beam of electrons within the picture tube.

In the earlier days of television it was the universal practice to feed the video signal to the control grid of the picture tube. The more recent trend is to feed the video signal to the cathode of the picture tube, while the grid of the tube is tied directly to B minus or ground. More will be said about these practices as we go on.

The block layout of the television receiver

circuit shown in Fig. 2 shows how the signals are handled when there are separate channels provided for the amplification of the video I-F signal. That is the practice followed almost universally during the early days of television. It is still followed to some extent in the more expensive types of television receivers.

A somewhat different method of handling the amplification of the I-F signals is shown in Fig. 3. The block diagram of the arrangement of the circuits shows the sound I-F signal and the video I-F signal both being amplified by the same I-F amplifier circuit, and passing through the same detector circuit.

The arrangement of the amplifier circuits shown in Fig. 3 is known as "intercarrier" amplification. The method of amplification is rather ingenious, and will be explained in careful detail in a later lesson. Briefly, however, the I-F circuits are so designed that they pass both the sound I-F and the video I-F signals, despite the fact the two I-F carriers are separated by 4.5 megacycles. This is accomplished by making the frequency response of the I-F circuits somewhat broader than that formerly used.

At the detector the video signal is fed to the video amplifier in the normal manner. A trap circuit is then arranged to prevent any of the 4.5-mc difference signal getting into the video amplifier circuits.

That 4.5-mc signal represents the difference between the two carriers, and results from a mixing of the two I-F carriers in the I-F amplifying circuits.

The 4.5 megacycle difference signal carries both amplitude modulation and frequency modulation — amplitude for the video signal, frequency modulation for the sound.

The special trap circuit prevents the 4.5-megacycle signal reaching the video amplifier circuits, but permits it to reach the sound discriminator, or ratio detector. The sound discriminator circuit is not sensitive to amplitude modulations, but is sensitive to frequency modulations. Since the sound signal is carried in the form of frequency modulations the frequency discriminator acts to demodulate the sound, then pass it on to an audio amplifier. From there it reaches the loudspeaker.

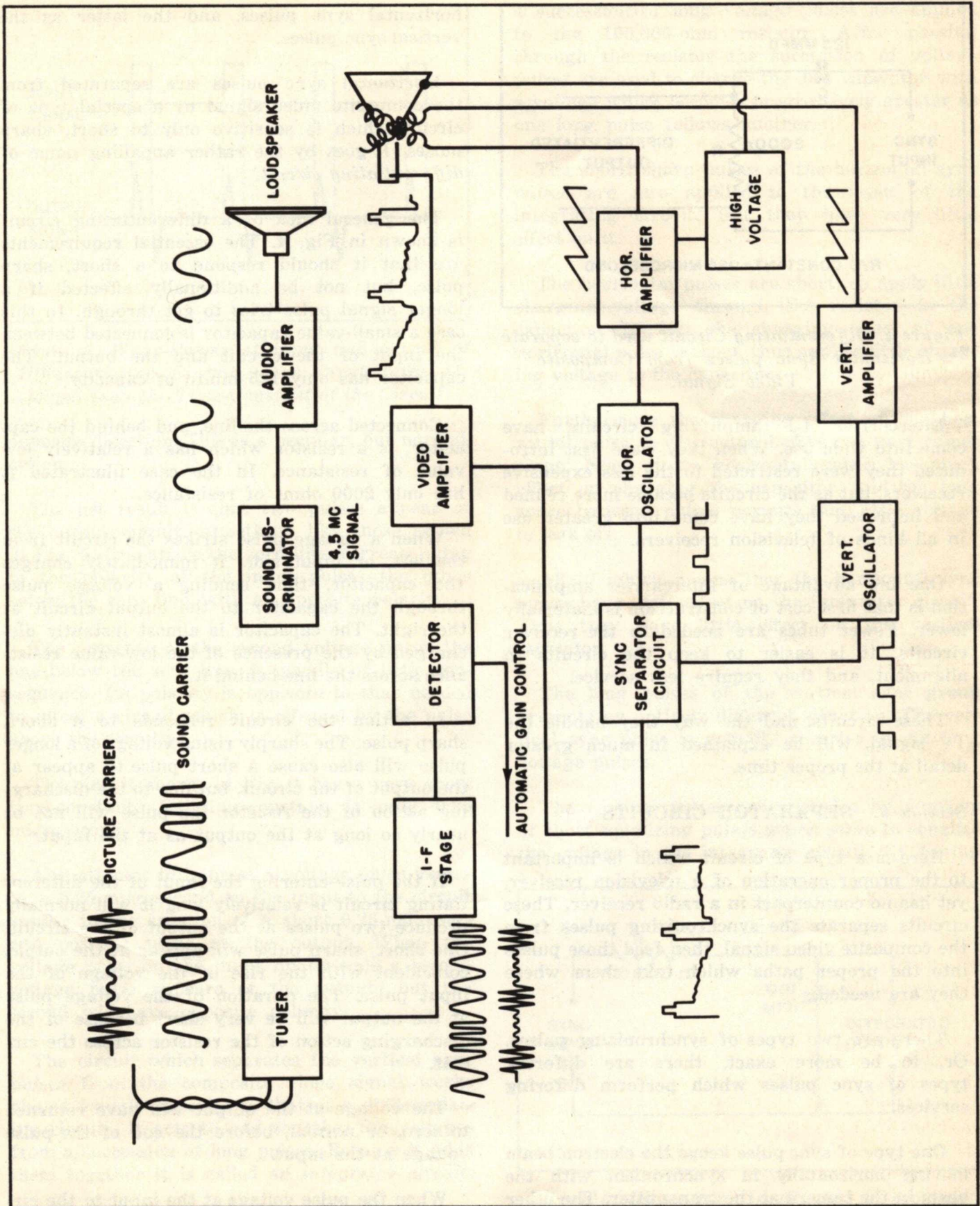


Figure 3. Block Diagram of TV receiver with Inter-carrier Amplification of I-F Signals.

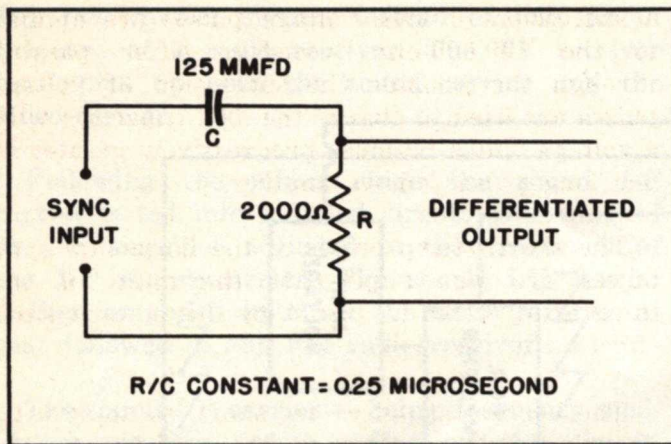


Figure 4. Differentiating Circuit used to separate Horizontal Sync pulses from Composite Video Signal.

Intercarrier I-F amplifying circuits have come into wide use. When they were first introduced they were restricted to the less expensive receivers, but as the circuits became more refined and improved they have come into greater use in all kinds of television receivers.

One big advantage of intercarrier amplification is that first cost of construction is materially lower. Fewer tubes are needed in the receiver circuits. It is easier to keep the circuits in alignment, and they require less service.

These circuits, and the way they handle the TV signal, will be explained in much greater detail at the proper time.

### Section 3. SEPARATOR CIRCUITS

Here is a type of circuit which is important to the proper operation of a television receiver, yet has no counterpart in a radio receiver. These circuits separate the synchronizing pulses from the composite video signal, then feed those pulses into the proper paths which take them where they are needed.

There are two types of synchronizing pulses. Or, to be more exact, there are differing types of sync pulses which perform differing services.

One type of sync pulse keeps the electron beam moving horizontally in synchronism with the beam in the camera at the transmitter. The other keeps the beam moving vertically at the correct instants of time. The first is referred to as the

horizontal sync pulses, and the latter as the vertical sync pulses.

Horizontal sync pulses are separated from the composite video signal by a special type of circuit which is sensitive only to short, sharp pulses. It goes by the rather appalling name of *differentiating circuit*.

The general idea of a differentiating circuit is shown in Fig. 4. The essential requirements are that it should respond to a short, sharp pulse, but not be additionally affected if a longer signal pulse tries to get through. In this case a small-value capacitor is connected between the input of the circuit and the output. The capacitor has only 125 mmfd of capacity.

Connected across the line, and behind the capacitor, is a resistor which has a relatively low value of resistance. In the case illustrated it has only 2000 ohms of resistance.

When a voltage pulse strikes the circuit from the left, or input side, it immediately charges the capacitor, thus sending a voltage pulse through the capacitor to the output circuit at the right. The capacitor is almost instantly discharged by the presence of the low-value resistance across the line behind it.

In action the circuit responds to a short, sharp pulse. The sharply rising voltage of a longer pulse will also cause a short pulse to appear at the output of the circuit, but due to the discharging action of the resistor the pulse will not be nearly so long at the output as at the input.

If the pulse entering the input of the differentiating circuit is relatively long it will normally produce two pulses at the output of the circuit. One short, sharp pulse will appear at the output coincident with the rise of the voltage of the input pulse. The duration of the voltage pulse at the output will be very short because of the discharging action of the resistor across the circuit.

The voltage at the output will have returned to zero, or normal, before the end of the pulse voltage at the input.

When the pulse voltage at the input to the circuit returns to normal it causes the voltage on the other side of the capacitor to go in the

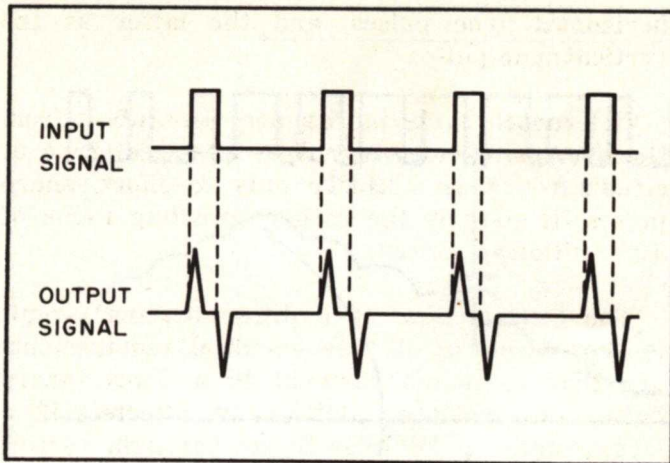


Figure 5. Wave-Forms at input and output of Differentiating Circuit when input pulse is longer than the Time-Constant of the Circuit.

opposite direction. This is a peculiar, but normal, action.

The net result is that *two* pulses appear at the output circuit, something like those shown in Fig. 5. One above the zero line, corresponding to the polarity of the input pulse; the other below the zero line, with an opposite polarity.

The presence of the second voltage pulse, the one below the zero line, is usually of little consequence. Its polarity is opposite to that needed to affect a circuit which is affected by the pulse above the zero line.

The circuit shown in Fig. 4 has a very short time-constant. Its time-constant is only 0.25 microsecond.

Any attempt to impress a voltage pulse longer than 0.25 microsecond on the input to the circuit results in the creation of a short 0.25-microsecond positive pulse at the output. When the voltage pulse on the input finally ends a second voltage pulse appears at the output; but the second will have opposite polarity.

The circuit which separates the vertical sync pulses from the composite video signal works almost exactly opposite to that of a differentiating circuit. It acts to *add together* the voltages from a succession of long pulses. Because it adds them together it is called an *integrator circuit*.

The elementary essentials of a simple integrator circuit are shown in Fig. 6. In that circuit

a succession of long voltage pulses are applied to the 100,000-ohm resistor. After passing through the resistor the succession of voltage pulses are used to charge the .001 capacitor with a voltage which becomes progressively greater as one long pulse follows another.

The short, sharp pulses of the horizontal sync pulses are also applied to the input of the integrating circuit. But they have very little effect on it.

The horizontal pulses are short, so apply little charging voltage through the resistor to the capacitor. In fact the charging effect of one horizontal pulse is short, thus applies little charging voltage to the capacitor.

Furthermore the charging effect of one horizontal pulse is dissipated before the next comes along. None of the horizontal pulses has much effect on charging the capacitor, and the long space between pulses permits that little voltage to leak off.

All of which means that the horizontal sync pulses have little effect on the integrator circuit. Thus they have little effect on the vertical oscillator.

The long pulses of the vertical sync group presents an entirely different situation. The vertical sync pulse is actually a series of six long voltage pulses.

The vertical pulses are preceded by a group of short equalizing pulses which serve to equalize the voltage in the integrator circuit. By having

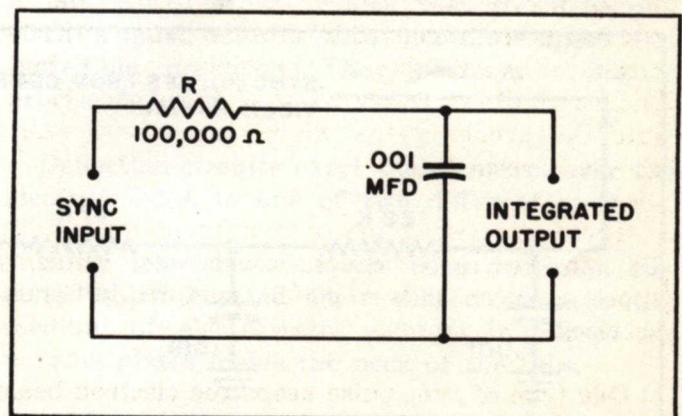


Figure 6. Integrator Circuit used to separate Vertical Sync Pulses from Composite Video Signal.



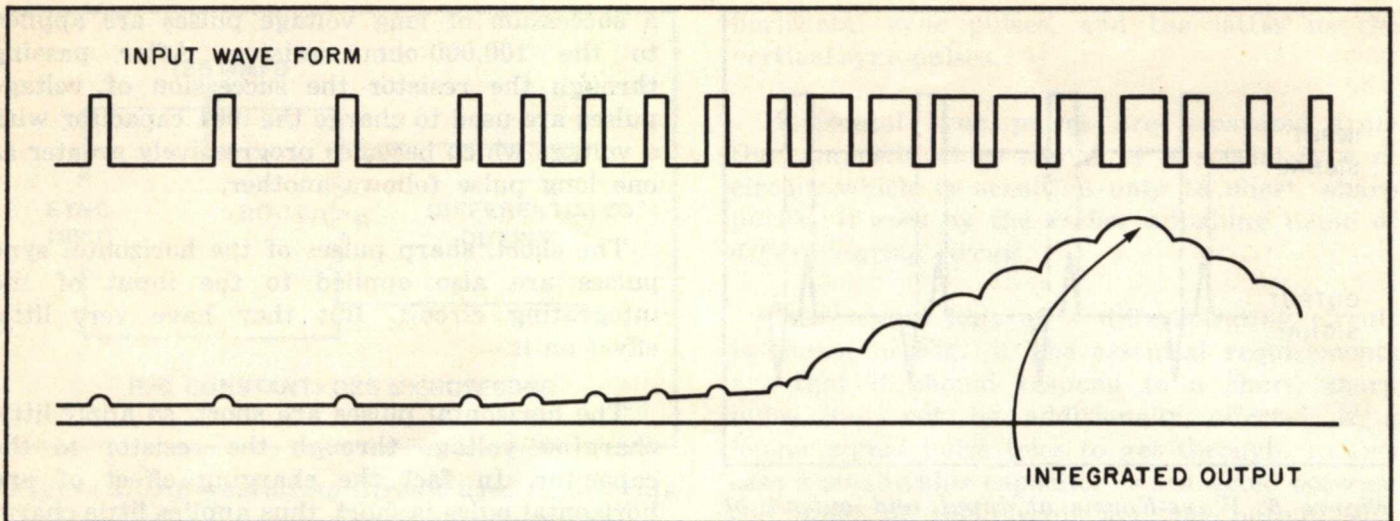


Figure 7. Input and output wave-forms at Integrator Circuit.

such a group of equalizing pulses appear just ahead of the vertical sync pulses it is possible to maintain the voltage on the capacitor at exactly the same level every time these vertical sync pulses arrive at the capacitor. This means that the vertical sync pulses always charge the capacitor to exactly the same level every time they appear.

It is rather interesting to note how the succession of vertical sync pulses build up a voltage on the capacitor. Fig. 7 makes that rather clear. The input pulses arrive at the integrating circuit in the form of regular voltage pulse wave-forms. The action of the integrator circuit changes that. The group of long pulses are added together to create a relatively high voltage across the capacitor.

The circuit shown in Fig. 6 is a decidedly

simple integrator circuit. Those used in actual television receivers are somewhat more complex.

Fig. 8 shows the type of integrator network used in at least one commercial television receiver. Others, using similar components, are used in other model receivers.

The values of the resistors and capacitors commonly used in TV integrator circuits have become so standardized that component manufacturers are now making printed circuits which include all those resistors and capacitors within a single unit. Such printed circuits reduce the number of components used in a television receiver, reduce the cost of its construction, and reduce the chance of error in wiring.

The internal circuitry of a widely used printed circuit unit for the integrator network is shown

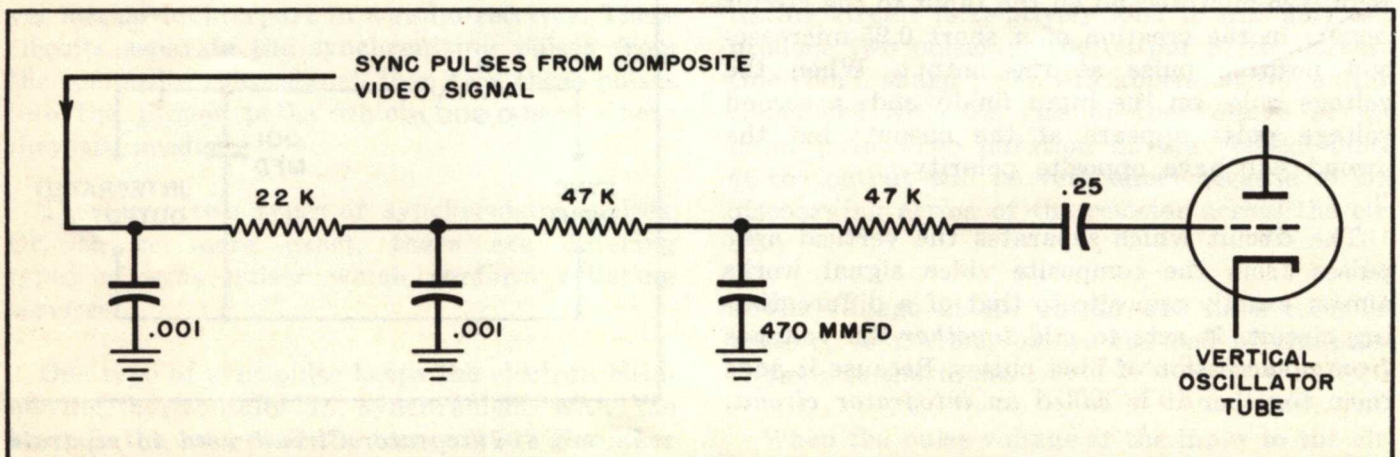


Figure 8. Typical Integrator Circuit used in a commercial TV receiver.

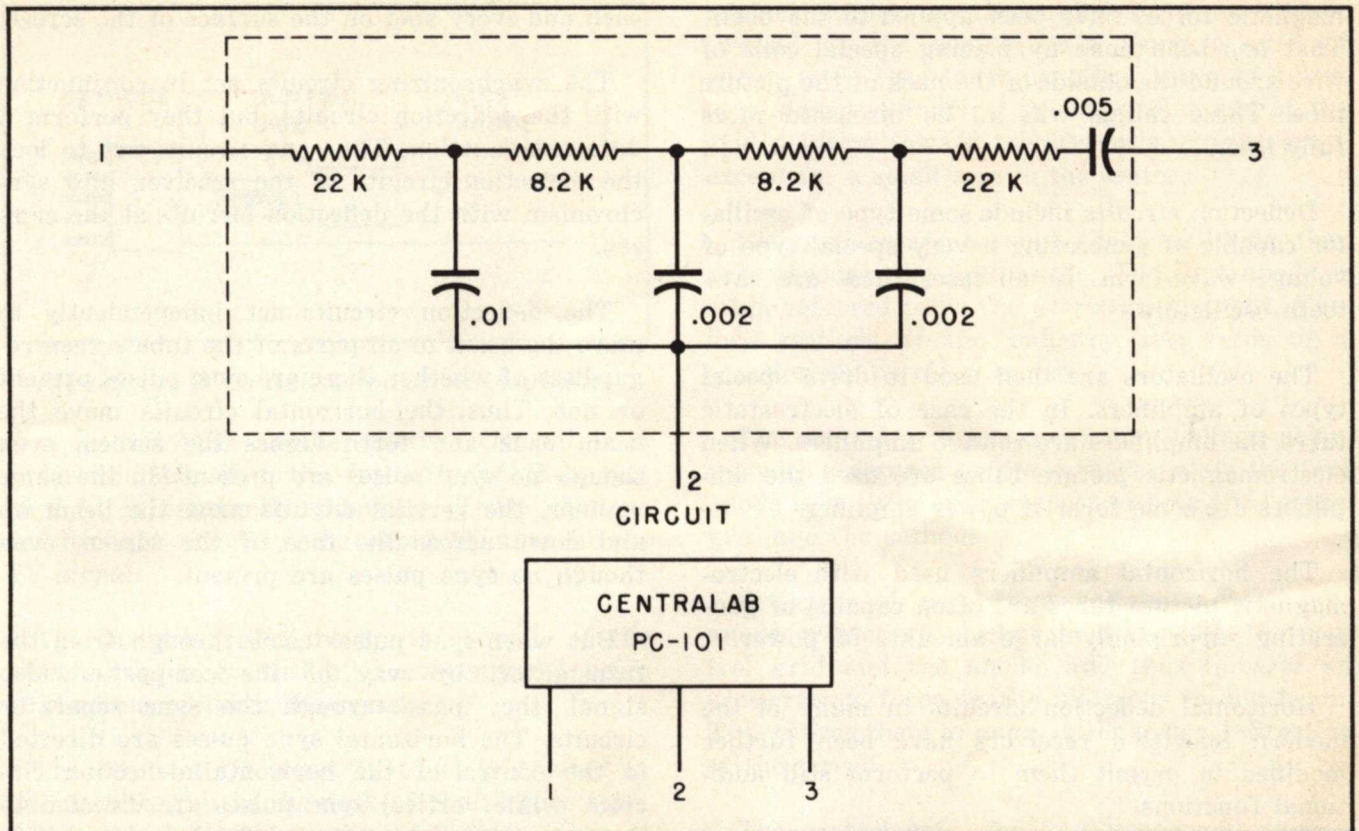


Figure 9. Circuit and appearance of Printed Circuit unit for Integrator Network.

in Fig. 9. There are four resistors and four capacitors within the network, which would normally mean making 16 wiring connections.

The 16 wiring operations are reduced to only three connections when the printed circuit unit is used.

#### Section 4. DEFLECTION CIRCUITS

We have neither the time nor the space to go into a full discussion of television deflection circuits in this lesson. Those circuits will be taken up and explained in lessons devoted solely to that subject.

Still, deflection circuits are not found in radio work, and those of you whose experience has been confined to radio servicing will find them new. You will also find them interesting.

There is something intensely fascinating about the manner in which the electron beam in the picture tube is taken in hand by the influence of the deflection circuits, and caused to do those things expected of it. The deflection circuits are assigned the duty of seeing that the

electron beam reaches each of the many thousand spots on the screen at exactly the right instant of time it should be there.

Should the electron beam reach any given spot on the screen a few microseconds late, or a few microseconds early, the scene reproduced on the screen will not be the one viewed by the camera. In all probability the scene reproduced on the screen will not represent anything at all. All of which means that the deflection circuits must operate with incredible speed and incredible precision. They perform a highly precise function.

Deflection circuits exert their control over the electron beam in one of two different methods.

Early television receivers used deflection circuits which exerted their control through the medium of electrostatic voltages impressed on parallel plates inside the neck of the tube.

As picture tubes grew progressively larger a different kind of deflection came into existence. Instead of electrostatic voltages being applied to the electron beam inside the tube, electro-

magnetic forces have been applied to the beam. That has been done by placing special coils of wire around the outside of the neck of the picture tube. These things will all be discussed more fully later.

Deflection circuits include some type of oscillator capable of generating a very special type of voltage wave-form. In all cases these are saw-tooth oscillators.

The oscillators are then used to drive special types of amplifiers. In the case of electrostatic tubes the amplifiers are voltage amplifiers. When electromagnetic picture tubes are used the amplifiers are some form of power amplifier.

The horizontal amplifiers used with electromagnetic picture tubes are often capable of generating surprisingly large amounts of power.

Horizontal deflection circuits in many of the modern television receivers have been further modified to permit them to perform still additional functions.

In some cases special types of circuits are included in the deflection circuit to boost the B plus voltage for the use of certain tubes.

Even more common is the practice of using the collapsing voltage in the horizontal output transformer, during the "flyback" period, to generate the extremely high voltage needed by the final anode of the picture tube. This has now become so common it is almost a universal practice.

#### Section 5. CONTROLLING MOVEMENT OF THE BEAM

Some degree of confusion often exists concerning deflection circuits and sync circuits.

It should be kept clearly in mind that the function of the deflection circuits in a television receiver is to move the electron beam around over the face of the picture tube screen. The horizontal deflection circuits move the beam back and forth from one side to the other. The vertical circuits move it up and down from top to bottom.

The interaction between the two deflection circuits makes it possible for the beam to touch

each and every spot on the surface of the screen.

The synchronizing circuits act in conjunction with the deflection circuits, but they perform a different function. The sync circuits act to lock the deflection circuits of the receiver into synchronism with the deflection circuits at the camera.

The deflection circuits act independently to move the beam to all parts of the tube screen regardless of whether there are sync pulses present or not. Thus, the horizontal circuits move the beam back and forth across the screen, even though no sync pulses are present. In the same manner, the vertical circuits move the beam up and down across the face of the screen, even though no sync pulses are present.

But when sync pulses come through from the transmitter, by way of the composite video signal, they pass through the sync separator circuits. The horizontal sync pulses are directed to the control of the horizontal deflection circuits, while vertical sync pulses are directed to the control of the vertical deflection circuits.

In that manner the deflection circuits of the receiver are locked into synchronism with the transmitter deflection circuits.

All of these circuits will be discussed in greater detail in other lessons. We are merely introducing them at this time.

#### Section 6. IMAGE ON THE PICTURE TUBE

Before proceeding with our discussion of the many circuits in a television receiver which are different from those found in radio or other electronic devices we will take a few minutes to examine the image on the picture tube. We will examine the things which contribute to its existence, and look into the many circuits which make that image possible.

Technical information needed to create the image is supplied by the TV signal receiver through the antenna.

We must never lose sight of the fact that the image on the screen of a picture tube is created by a fast-moving pin-point of light. Since the intensity of that pin-point of light corresponds at one instant with one picture element and the

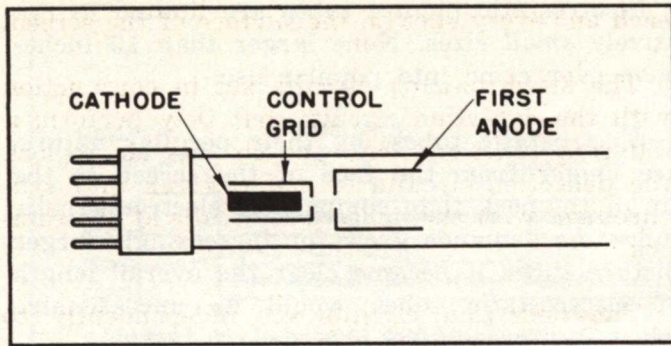


Figure 10. Where electron beam originates.

next instant with another picture element it is understandable that the intensity of that spot of light is constantly changing. Those changes are brought about by the rapid changes in the TV signal.

The pin-point of light on the screen of the picture tube is created by a concentrated beam of electrons striking the screen.

The beam of electrons, in turn, is created in the electron gun in the neck of the picture tube. Differences in the intensity of the beam result in differences in the brilliance of the screen from one tiny area to another. One tiny spot on the screen is caused to be brilliant because the beam at that spot is intense. An adjacent area is dark because the beam is weak.

Those differences in the intensity of the beam are brought about by the action of the control grid in the picture tube. The control grid is a part of the electron gun. Changing voltages in the TV signal are applied directly to the control grid.

It is always interesting to examine into the way the electron gun creates that beam. It is neither desirable nor necessary for us to examine into all those details at this time, but we can take a quick peek at the more obvious actions.

Something of the arrangement of the various elements composing the electron gun can be seen by studying Fig. 10. That is not a pictorial diagram, nor does it pretend to include all the necessary parts in an electron gun. But it does help visualize the action which takes place in the neck of the tube where the electron beam originates.

The cathode is heated by a wire filament in a

manner similar to other types of vacuum tubes. Instead of the control grid being a grid of wires, as is true in many other types of tubes, it is almost cylindrical in shape. The end of the grid pointing toward the screen is almost closed, except for a small hole in the center.

Electrons escape through that small hole, then pass through the first anode. The first anode is often referred to as the *accelerating anode*. Various sections of the industry also refer to it occasionally by other names.

The control grid has a negative voltage polarity with reference to the cathode, while the first anode is positive with respect to both the control grid and the cathode.

Presence of a positive voltage on the first anode creates an electric field between the control grid and the anode, and thus imparts an accelerating force to the electrons in the beam. This causes them to move in the general direction of the screen.

The control grid, the first anode and various other elements inside or outside the neck of the tube act upon the beam of electrons. The beam is focused, controlled, and manipulated. Considerable energy is created within the electron beam due to the fact the individual electrons attain an extremely high velocity while moving from the electron gun to the screen.

When the electrons in that beam strike the screen the kinetic energy in the fast-moving electrons is changed into light energy. That causes the screen to *fluoresce*, or become light, at the point where the electrons strike it.

As the electron beam recreates one picture element after another on the screen of the picture tube it is moved from one position to another by the influencing forces of the deflection circuits.

The difference in the brilliance of one picture element from that of another is brought about by the influence of the control grid on the strength of the electron beam. The voltage on the control grid is negative with respect to the cathode. It is not usually sufficiently negative to fully prevent the passage of electrons from the cathode to the screen, but the presence of the negative voltage on the control grid restrains the movement of the electrons to some extent.

By varying the strength of the negative voltage on the control grid from one instant to the next it is possible to control the degree of brilliance of the many thousand picture elements on the screen. That varying negative voltage is the TV video signal.

The exact manner in which the beam is caused to move from one position to another on the screen is determined by the peculiar characteristics of the individual tube. If the picture tube uses what is called electrostatic deflection the beam is influenced by varying voltages which appear between the various deflection plates within the neck of the tube.

The top drawing in Fig. 11 provides a rough outline of the essentials of an electrostatic picture tube. The beam is brought into existence within the electron gun in the extreme end of the picture tube neck. The electrons in the beam are accelerated to high speed by the various other elements. Finally, as the beam passes between the two pairs of deflection plates it is deflected upward or downward, or to one side or the other, depending on the voltages which happen to be present there at any given instant.

The several electrostatic fields which are present within the neck of the tube serve to focus the beam so the electrons are bunched into a very small area at the point where they strike the screen. The essential features of the actions described here become more clear when the upper illustration in Fig. 11 is carefully studied.

The glass surface inside the flaring bulb of the picture tube is coated with black conductive material. (Except for the actual screen surface.) It is a black substance with the trade name *aquadag*. Electrical contact is made with the aquadag by means of a special high-voltage connection through the glass envelope of the tube. See Fig. 11.

Applying high voltage to the aquadag provides the final accelerating force needed to speed up the moving electrons in the beam to the velocity necessary to make the phosphors on the screen fluoresce when the electrons in the beam strike the screen. The voltage applied to the aquadag, or final anode, varies from one type of tube to another. It ranges from around 6000 volts for the smaller electromagnetic tubes to 16,000 volts or more, for larger tubes.

Electrostatic picture tubes are limited to relatively *small* sizes. None larger than 10 inches have ever come into popular use.

Electrostatic tubes, by their peculiar nature, are longer from the face of the screen to the tip of the neck than comparable electromagnetic tubes. As demands grew for increasingly larger picture tubes it became clear the overall length of electrostatic tubes would be unreasonable when the screen sizes exceeded 10 inches.

Another limiting factor was the voltage. An electrostatic tube requires an abnormally high voltage on the final anode, and unusually high deflecting voltages on the deflecting plates. These high voltages pose very serious problems for design engineers.

Electromagnetic tubes can operate on much lower final anode voltages than comparable electrostatic tubes. But such tubes require several external parts not needed by electrostatic picture tubes. They require, for example, a magnetic deflecting coil around the outside of the neck of the tube, and some means to anchor and position the coil.

They also need some type of external focus magnet. At least this is true of many types of electromagnetic tubes. Some of the newer electromagnetic deflection picture tubes are employing electrostatic focus inside the tube.

The lower illustration on Fig. 11 provides a pretty good idea of the essential parts of an electromagnetic picture tube using external focus magnet. Such tube is much shorter from front to back than a comparable electrostatic deflection picture tube, and employs much lower voltages on the anodes. All of which simplifies many of the problems of the design engineer.

Another lesson has been devoted to the more precise details concerning the construction and operation of various types of picture tubes. This will give you the information you need now.

## Section 7. ANTENNA SIGNAL

The antenna signal, the way it is picked up by the antenna, the way it is handled by the transmission line, and the things which are done to it in the tuner section of the TV receiver, are all highly technical subjects. We can let ourselves

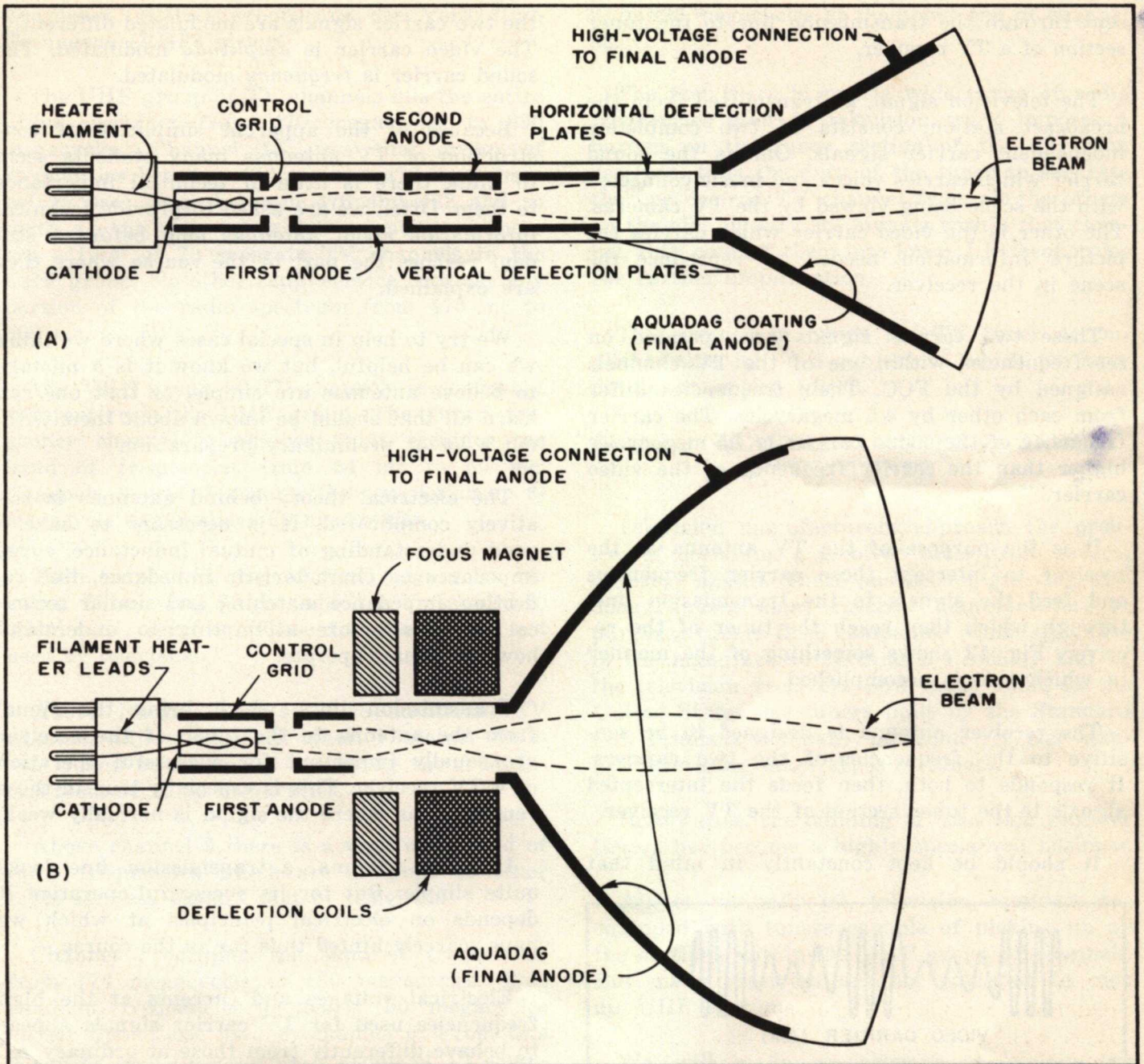


Figure 11. Electrostatic and Electromagnetic picture tubes.

in for a lot of grief by trying to explain all the actions which involve the antenna signal before we are ready to understand those things.

Each of those subjects will be taken up in turn, and explained. Entire lessons are devoted to some of them. In some cases we devote one or more lessons to the job of preparing you to understand the material.

To the inexperienced eye there is little about television which appears more simple than an

ordinary TV antenna, unless it is the transmission line which connects the antenna to the receiver. Yet the electrical principles which cause an antenna to operate are exceedingly complex. To really understand how to obtain the best performance from a TV antenna it is necessary to first understand those basic electrical principles.

But that does not keep us from taking a good look at the television signal as it appears at the time it is intercepted by the antenna and

sent through the transmission line to the tuner section of a TV receiver.

The television signal, as transmitted from the broadcast station, consists of two completely independent carrier signals. One is the sound carrier which carries voices and music connected with the scene being viewed by the TV cameras. The other is the video carrier which carries the picture information needed to reproduce the scene in the receiver.

These two carrier signals are operated on set frequencies within one of the TV channels assigned by the FCC. Their frequencies differ from each other by 4.5 megacycles. The carrier frequency of the sound carrier is 4.5 megacycles higher than the carrier frequency of the video carrier.

It is the purpose of the TV antenna at the receiver to intercept those carrier frequencies and feed the signals to the transmission line, through which they reach the tuner of the receiver. Fig. 12 shows something of the manner in which this is accomplished.

The receiver antenna is designed to be sensitive to the frequencies of the two carriers. It responds to both, then feeds the intercepted signals to the tuner section of the TV receiver.

It should be kept constantly in mind that

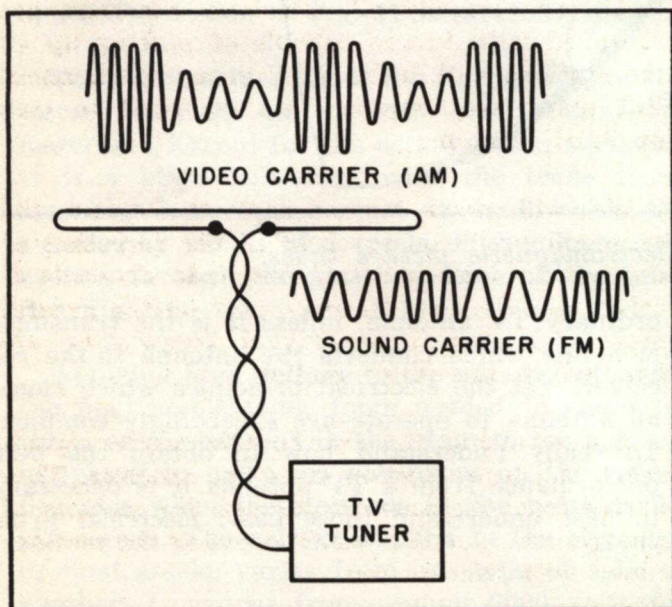


Figure 12. Signal Wave-Forms at antenna and tuner.

the two carrier signals are modulated differently. The video carrier is *amplitude* modulated. The sound carrier is *frequency* modulated.

Because of the apparent simplicity of construction of TV antennas many students seem to think there is little of technical importance to them. Often we are asked to provide technical information about antennas long before a student reaches the part of the course where they are explained.

We try to help in special cases where we think we can be helpful, but we know it is a mistake to believe antennas are simple, or that one can learn all that should be known about them without a lot of preliminary preparation.

The electrical theory behind antennas is relatively complicated. It is necessary to have a good understanding of mutual inductance, surge impedance or characteristic impedance, line reflection, impedance matching and similar technical subjects before attempting to understand how antennas operate.

Transmission lines which bring the signal from the antenna to the tuner of the receiver are equally important for successful operation of a TV receiver. This is especially true in those remote areas where the signal is normally weak.

Like an antenna, a transmission line looks quite simple. But for its successful operation it depends on electrical principles at which we have scarcely hinted thus far in the course.

Electrical voltages and currents at the high frequencies used for TV carrier signals appear to behave differently from those at ordinary AC power line frequencies. Before one can understand how a TV carrier frequency signal can pass through a transmission line it is first necessary to understand how those high frequency signals behave. Acquiring such knowledge is not always simple nor easy.

While we do not pretend to explain the technical background of antenna signals at this time, we can look into some very practical aspects of how these signals are handled.

There are more than eighty channels assigned for television use by the FCC. These are divided into two groups of channels, the Ultra High

Frequency (UHF) group, and the Very High Frequency (VHF) group.

The UHF group of TV channels fills the entire radio spectrum from 470 megacycles to 890 megacycles. Channel 14 uses that group of frequencies between 470 mc and 476 mc; channel 15 uses those between 476 and 482 and so forth all the way up to 890 megacycles. There are a total of 70 separate TV channels in the UHF group. No other radio service occupies any portion of the radio spectrum from 470 mc to 890 mc.

The VHF group of TV channels is somewhat different from the UHF group. The lowest frequency channel is number 2. It occupies the band of frequencies from 54 mc to 60 mc. Channels 3 and 4 occupy the two adjacent 6-megacycle bands above 60 megacycles.

Then there is a gap of four megacycles between 72 mc and 76 mc which are assigned to other radio services. Those frequencies are not used by television.

Above 76 mc there are two additional TV channels adjacent to each other. These are channels 5 and 6; channel 5 occupying the frequencies from 82 to 88 megacycles.

Above channel 6 there is a very wide band of radio frequencies which are assigned to other radio services besides that of television.

Channel 7 occupies the band of frequencies from 174 megacycles to 180 megacycles. This band of frequencies is nearly 90 megacycles higher than those used by channel 6. From this it can be seen that the VHF group of TV channels can be sub-divided into two other groups, the "low-band" group of channels 2-6, and the "high-band" group of 7-13.

All the frequencies up to 216 megacycles are occupied by the other VHF television channels. They are channels 7 through 13.

From this it can be seen that there are 12 television channels in the VHF group, and 70 television channels in the UHF group. This vast group of television channels covers an extremely wide range of radio frequencies; they range from 54 megacycles, at the low end of channel

2, to 890 megacycles at the upper end of channel 83.

The fact there is such a wide range of radio frequencies used in television work imposes a burden on the tuner section of the television receiver. It is the duty of the tuner to separate the one desired TV channel from all the others on the air, amplify the signals within that channel, then convert them into lower I-F frequencies for further amplification.

The manner in which the TV tuner accomplishes this job is a subject to which we later devote an entire lesson.

### Section 8. HANDLING ANTENNA SIGNAL IN THE TUNER

Television manufacturers approach the problem of designing a receiver tuner from several different angles. There has been a growing tendency among many receiver manufacturers to purchase tuners from companies which specialize in the manufacture of tuners. Probably half of the television receivers now being built in the United States use tuners built by the Standard Coil Products Company, but some receiver manufacturers use other types of tuners.

In any case, the building of television receiver tuners has become a highly specialized business.

All, or virtually all, television receivers are equipped with tuners capable of picking up all the stations within the VHF group of channels. But many receivers are not equipped to pick up UHF stations.

We will make no attempt to explain the technical problems involved in the reception of the various high and low frequency channels at this time. We want to touch only on the general manner in which the signal frequencies are handled in the tuner section.

A study of Fig. 13 shows how the carrier signals reach the tuner section from the antenna. They arrive from the antenna through the medium of the transmission line which connects the receiver tuner with the antenna.

The carrier frequencies shown arriving at the tuner section in Fig. 13 correspond to those used



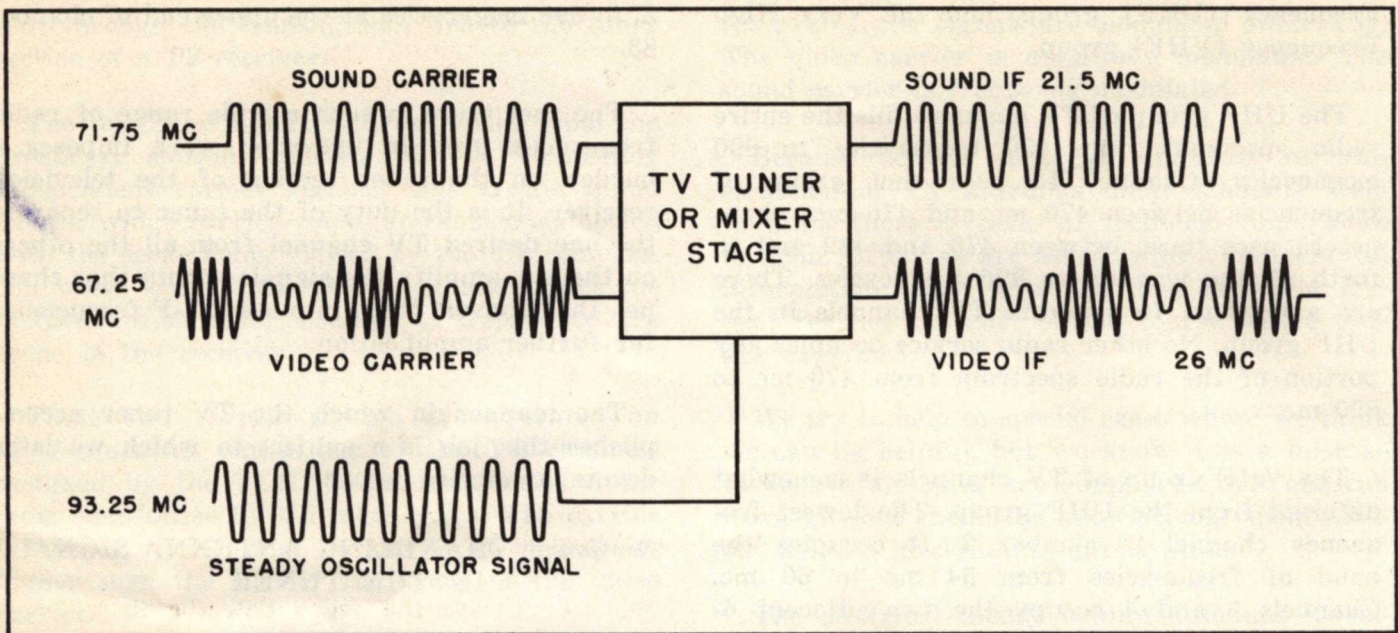


Figure 13. Frequencies of Carrier Signals from antenna changed in Tuner.

by TV broadcast stations assigned channel 4. The sound carrier is operating on a frequency of 71.75 megacycles, the video carrier on 67.25 megacycles. Careful observation discloses these two carriers operate on frequencies 4.5 megacycles apart, but both are within the frequency limits provided for stations operating on channel 4.

The exact manner in which the carrier signals are handled within the tuner section differs from one type of tuner to another. Some amplify the RF carrier signals before they are mixed with the signal from a local oscillator; others do not.

In either case, the RF carrier signals are mixed with a local oscillator signal somewhere within the circuits of the tuner section.

A local oscillator signal operating on a frequency of 93.25 megacycles is shown as being mixed with the carrier signals in Fig. 13. This is a typical action, especially in the older types of television receiver tuners.

The oscillator signal has a fixed, unmodulated frequency. When it mixes with the sound carrier it provides an I-F frequency of 21.5 megacycles. This results from mixing the 93.25 megacycles of the oscillator with the 71.75 megacycles of the sound carrier. The 21.5 megacycles I-F signal represents the difference between these two signals.

The fixed frequency of the local oscillator is also heterodyned against the 67.25 megacycles of the video carrier. The result of this mixing is another I-F signal. It is the 26-megacycle signal of the video I-F shown in Fig. 13.

From all this it can be seen that we now have two I-F signals instead of the one I-F signal to which we are accustomed in radio work. You should also note, and keep in mind, that those two I-F signals have frequencies 4.5 megacycles apart. We keep repeating this because it is important, and we want to impress it on your mind.

In this particular instance we are dealing with I-F frequencies of 21.5 megacycles and 26 megacycles. These are frequencies which have been widely used throughout the television industry, especially up to about 1953.

Since that time there has been an increasing tendency within the industry to use higher I-F frequencies than those described here. Many of the more modern receivers are using I-F frequencies in the neighborhood of 40 to 45 megacycles.

Using higher I-F frequencies in the I-F stages of a television receiver has both advantages and disadvantages. Under ordinary circumstances there would not be the same amount of gain per stage when using the higher frequen-

cies, and theoretically it should be harder to control the radiation of the oscillator signal from the antenna.

Good engineering design, and improved amplifier tubes, have enabled the manufacturers to obtain virtually the same amount of gain at the higher frequencies as they had at the lower ones. One big advantage is that I-F frequencies of 40 to 45 megacycles do not cause as much interference as was true of the lower I-F frequencies.

The lower frequencies fell into radio bands where they caused a lot of interference, and harmonics of the I-F signal could get into other nearby TV receivers and create annoying interference there. Furthermore, short-wave radio signals operating in the 21 megacycle bands frequently caused TV interference.

I-F frequencies between 40 and 45 megacycles do not cause serious interference with other services, even when part of the I-F signal is radiated. But careful design, and careful shielding, has reduced most of the radiation. Furthermore, an I-F signal of 40 to 45 megacycles does not cause serious interference in other nearby TV receivers. This is because the harmonic relationship is such that any interference which does occur is not noticeable on nearby receivers. Nor is it so easy for a 40-megacycle radio signal to reach the TV I-F circuits.

In the earlier days of television it was the regular practice to feed the sound I-F signal to special sound I-F amplifier stages, while the video I-F signal was fed to special video I-F amplifiers. That practice is still followed to some extent, especially in the more expensive television receivers.

But there is a growing tendency among manufacturers to use what is called *intercarrier* amplification, in which both the sound and video I-F signals are amplified by the same circuits. There is little purpose in trying to explain at this time how intercarrier amplification is accomplished, but it will all be explained to you in due time.

### Section 9. I-F AMPLIFIER AND DETECTION ACTION

There is not nearly so much gain in the I-F stages of a television receiver as in comparable

radio circuits. The I-F circuits in a radio are tuned to very narrow bands of frequencies, thus great gain can be brought about in each stage of amplification. The I-F circuits in a television receiver are different. They must be tuned so broadly that a range of frequencies more than 4 megacycles wide can get through. This means the amplifying ability of each stage is greatly reduced.

Few, if any, modern television receivers have less than *three* stages of I-F amplification. Some have more. In fact, four stages are quite common.

The final stage of I-F amplification feeds into the video detector circuit.

In many ways the video detector in a television receiver is closely similar to the diode detector which is so common in radio receivers. Some of the circuits associated with it are different; they are more broadly tuned, they are differently loaded, and there are other minor differences. But essentially, they are much the same.

A study of Fig. 14 provides a pretty good idea of the video signal wave-forms as they are applied to the video detector, and as the video signal leaves that circuit. The action of the video detector is to separate the composite video signal modulation from the video I-F carrier signal. This is very similar to the action of a diode detector in a radio receiver.

Most of the modern television receivers incorporate some form of Automatic Gain Control (AGC). This circuit operates much the same as the AVC circuit in a radio, and serves very much the same purpose.

The AGC circuit tends to prevent the signal becoming stronger or weaker from instant to instant, and thus causing the picture on the receiver to become alternately light and dark. Irregular reflections are one of the principal causes of such irregular brilliance on the picture. Such irregular reflections occur when portions of the transmitted TV carrier signal are reflected from a fast moving body. Reflections from an airplane are typical of what we are describing.

As an airplane moves swiftly through the sky television signals are reflected from its surface.

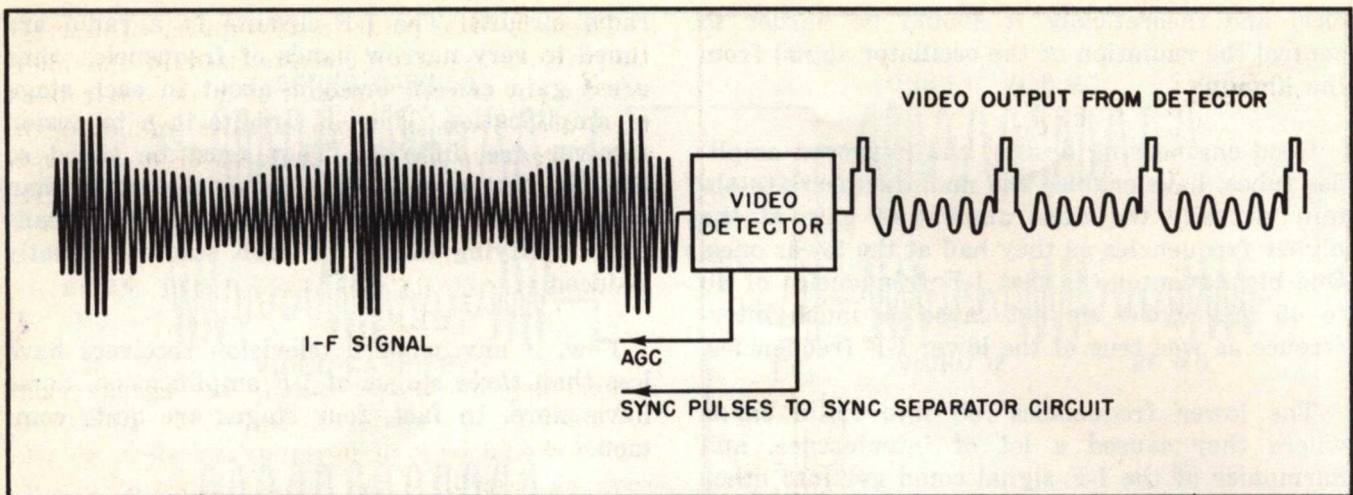


Figure 14. Signal wave-forms at Video Detector.

Because the airplane is constantly changing position the signals which are reflected from its surface will alternately reinforce those moving directly from the transmitter to the receiver, then the signals will oppose each other. The net result is that the signal at the antenna of the receiver will be strong one instant, then weak the next. See Fig. 15.

When an automatic gain control circuit is incorporated in a television receiver it tends to hold the signal strength at the detector to a more constant level. This is done by changing the bias on the RF and IF amplifying tubes as the strength of the signal varies. When the signal is coming in strong a higher negative bias voltage is placed on the control grids of the amplifier tubes, thus reducing their amplifying ability. When the signal strength weakens, some of that negative bias is removed; and the tubes become better amplifiers.

AGC voltage is usually tapped off at the video detector as indicated in Fig. 14. Some receivers incorporate special types of AGC circuits which are designed to meet special conditions. These subjects will be discussed in greater detail as we progress.

Synchronizing pulses needed to lock the receiver deflection circuits into synchronism with those in the transmitter are often tapped off at the video detector. This is indicated in Fig. 14.

In some cases the sync pulses are tapped off a later stage, one of those in the video amplification section.

## Section 10. TV POWER SUPPLIES

Television receivers need *two* types of power supplies.

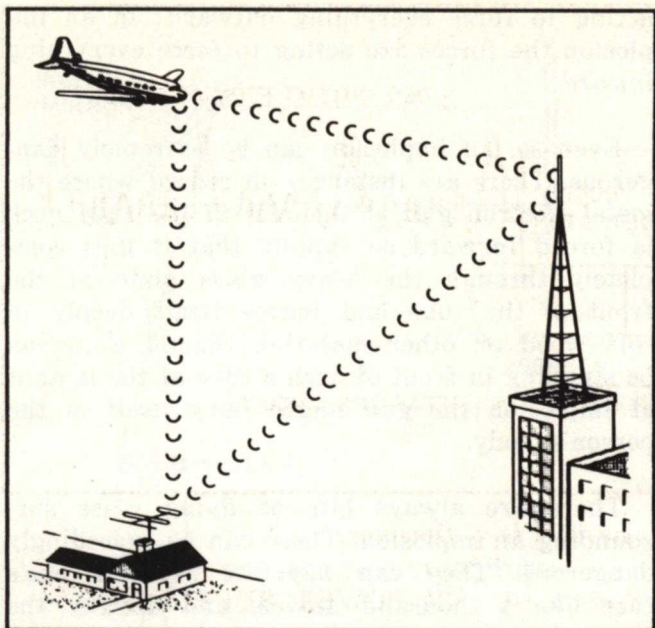
One is called the *low-voltage* power supply. It is similar in most respects to those commonly used in radio receivers and other types of electronic devices. Its purpose is to supply the filament voltages needed to properly heat the cathodes of the various amplifier tubes, and the B plus voltages needed for the anodes and screen grids of those tubes.

Television receivers also use a second power supply which is generally referred to as the *high-voltage* power supply. Its purpose is to supply the extremely high voltage needed to operate the final anode of the picture tube.

We cannot hope to mention all the various items of interest associated with television power supplies, but we can mention a few things which are of immediate interest to you.

The low-voltage power supply varies from one model receiver to another just about as much as is true of power supplies used in radio receivers. Possibly, somewhat more so.

There are full-wave vacuum tube-rectifier type power supplies employing a heavy power transformer and a rectifier tube on the general order of the 5U4. The 5U4, and improved modifications of that tube, are widely favored by television manufacturers because of their power handling ability.



*Figure 15. Constantly changing position of plane causes length of reflected path to change from instant to instant.*

Many television power supplies use two 5U4 tubes so there will be ample power for the various amplifier tubes in the circuit.

Other manufacturers favor half-wave power supplies using selenium rectifiers and high-capacity electrolytic capacitors. These types of power supplies are usually found in the less expensive television receivers, although some of the largest manufacturers of supposedly fine receivers also favor this type power supply.

Despite these variations the fact still remains that the low-voltage power supply in a television receiver is not materially different from that used in radio receivers.

High-voltage power supplies for television receivers introduce types of circuits not found in radio receivers. These are the circuits which generate the voltages ranging up to many thousands of volts which are required for the proper performance of picture tubes.

The exact amount of high-voltage needed by a television receiver depends on the type of picture tube used in it. Modern direct-view picture tubes require voltage ranging from some 6000 volts to almost 20,000 volts. Projection tubes require voltages ranging up to 50,000 volts; some even requiring as much as 100,000 volts.

There is little point in attempting to describe the various types of circuits used in the high-voltage power supply circuit of modern television receivers. Some of those circuits employ principles we have not previously covered. But each will be taken up in turn, and explained in careful detail.

### Section 11. CARE IN HANDLING PICTURE TUBES

Perhaps this is not exactly the proper place to mention this subject. But it is something which should be kept in mind, and since we will soon be describing the various types of picture tubes it seems appropriate to mention the matter here.

Direct-view picture tubes, the types found in the vast majority of home television receivers, have a relatively large surface area. This is especially true of the larger size picture tubes.

Pressure of the air on the surface of these tubes becomes very great, far greater than most people realize.

We are not normally aware of it, but the fact remains there is air pressure on us amounting to approximately 15 pounds per square inch of surface. That is the pressure of air at sea level. That does not seem like a great deal, but when the surface area of an evacuated body becomes quite extensive the pressure on that body is very great.

The one evacuated body with which most of us have had most experience is the common incandescent lamp bulb. Such a bulb has a relatively small surface area, in terms of square inches, therefore the pressure on its surface never becomes very great. Nevertheless, most of us have had the experience of dropping and breaking such a lamp bulb, and hearing the rapid inrush of air into the evacuated space.

Consider, then, the pressure which is present on the surface of a television picture tube which has such a radically increased amount of surface area — even for a small picture tube. See figure 16.

A small 10-inch picture tube, now virtually obsolete except for portable receivers, has a surface area of about 250 square inches. Multi-

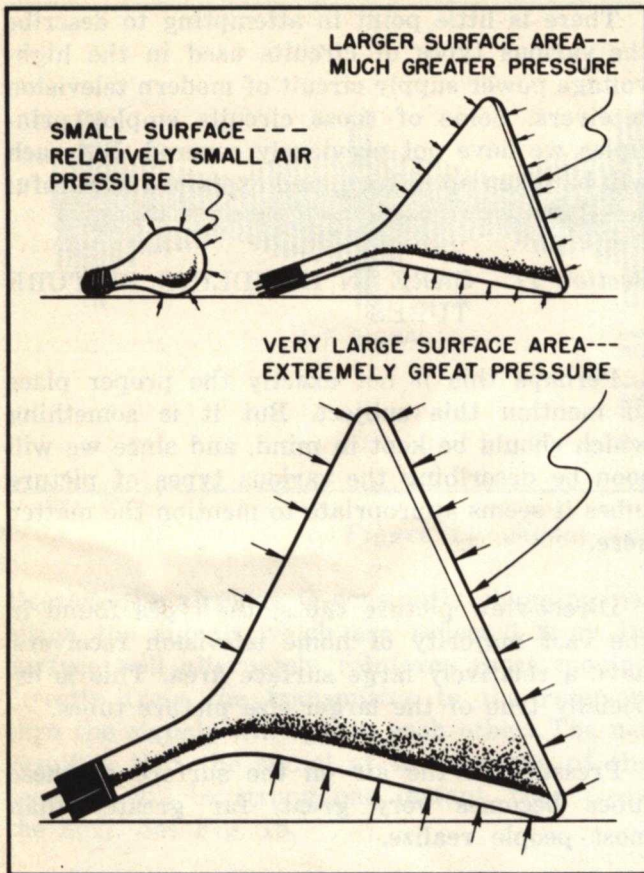


Figure 16. Comparative sizes of tubes, and air pressures on them.

plying 250 inches by 15 pounds per square inch discloses the fact there is a total pressure on the surface of that small picture tube amounting to 3,750 pounds. It is hard to believe such tremendous pressure is present on what appears to be such a small surface area, but figures don't lie.

It is because of the great pressure which is always present on the comparatively fragile glass body of a picture tube that it is necessary to exercise caution whenever tubes are handled.

Manufacturers warn against attempting to pick up a picture tube by grasping the neck of the tube. Such action places a strain on the glass where the neck joins the flaring bulb of the tube. There is always danger of subjecting the glass to sufficient strain so it breaks.

Breakage of the glass envelope of an evacuated picture tube results in what is known as an "implosion." An implosion is the direct opposite of an explosion. In an explosion there are forces

acting to force everything outward; in an implosion the forces are acting to force everything inward.

Even so, an implosion can be extremely dangerous. There are instances on record where the metal electron gun at the rear of the tube neck is forced forward so rapidly that it flies completely through the heavy glass plate at the front of the tube and buries itself deeply in soft wood or other material. Should a person be standing in front of such a tube at the instant of implosion the gun might bury itself in the person's body.

There are always bits of flying glass surrounding an implosion. These can be exceedingly dangerous. They can flay the skin of one's face like a thousand knives, and destroy the eyes. Other unexpected dangers, often of a freakish nature, are occasionally disclosed after an accident involving an implosion.

It is never safe to permit an old picture tube to lie unused around a shop or other place where uninformed persons have access to it. Special tools are available for breaking the seal at the end of the neck, and thus permitting air to enter the tube. Another practice followed by many is to place the old tube in a large carton, then the neck of the tube is broken by striking it with a piece of metal.

The present tendency to turn in old picture tubes in exchange for new ones, so the old ones can be rebuilt, requires that the old one not be seriously damaged. However, old tubes can be easily rendered harmless, and still permit them to be rebuilt, by breaking the neck close to the base of the tube.

Placing a metal wire around the neck of the tube, then heating it electrically, is a favorite method used by many to make such old tubes harmless.

Another is to remove the base, then break the small exhausting tip under it.

## Section 12. PROJECTION PICTURE TUBES

The American public has given a hearty endorsement to direct-view types of television receivers. In so doing they have turned a cold shoulder to the projection-type receivers.

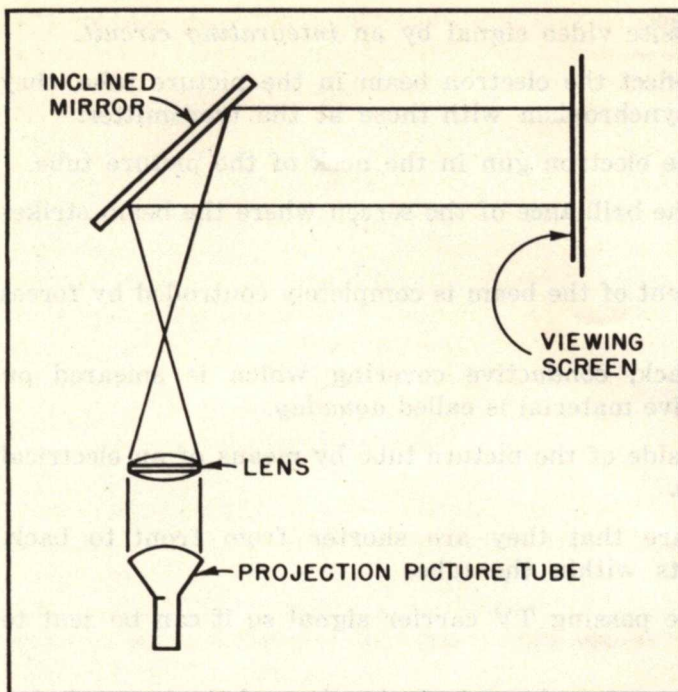


Figure 17. Projection of TV picture onto special Viewing Screen.

Nevertheless, projection type receivers are used in some places. Probably the greatest use of projection-type receivers is in theaters, and similar places where a very large screen is needed.

Projection type receivers require more com-

plicated circuits than direct-view receivers, and must provide radically higher anode voltages for the projection tubes. As stated earlier, voltages ranging up to 100,000 volts are not uncommon.

Several systems for projecting television images have been used, but the drawing in Fig. 17 gives a good idea of the system most widely favored.

The extremely high cost of the complicated lenses and mirrors has prevented projection types of television receivers achieving a high degree of popularity in the United States. Relatively few have found their way into actual use in homes, although some have been installed in public places.

Projection receivers are in a class by themselves. They employ circuits not generally found in the more common types of direct-view television receivers. A full explanation of projection receivers would be practically a course by itself.

Since there are so few such receivers in common use, and they are usually serviced by the manufacturer's own representatives, there seems little reason to discuss them very extensively. There are too many other things of more immediate practical benefit to you to spend your time on something that can have little value to you.

#### NOTES FOR REFERENCE

Many circuits used in television receivers are closely similar to those used in radio receivers and other electronic devices.

In addition to circuits which are similar to those used in radio, there are a number of others in TV receivers which are different from anything found in radio.

Sync separator circuits are very important in TV receivers, but are not used in radio receivers.

A television receiver must be capable of picking up, amplifying, and handling two entirely separate RF carrier signals. One is the sound carrier, which handles the voice and other audio sounds; the other is the video carrier, which carries the picture information needed to reproduce the scene viewed by the camera.

The frequency of the sound carrier and that of the video carrier are separated from each other by 4.5 megacycles.

Some TV receivers employ separate amplifying systems for sound I-F signal and the video I-F signal. Others use a single I-F amplifying system for both sets of signals.

Sync pulses, needed to synchronize the horizontal deflection circuits at the receiver with those at the transmitter, are separated from the composite video signal by means of a special circuit called a *differentiating circuit*.

Vertical sync pulses are separated from the composite video signal by an *integrating circuit*.

Sync pulses from the transmitter are not used to deflect the electron beam in the picture tube, they merely act to lock the deflection oscillators into synchronism with those at the transmitter.

The electron beam in a picture tube originates in the electron gun in the neck of the picture tube.

Varying the intensity of the electron beam varies the brilliance of the screen where the beam strikes it.

When using an electrostatic picture tube the movement of the beam is completely controlled by forces which are exerted upon it from *inside* the tube.

The final anode of a picture tube consists of a black, conductive covering which is smeared on the inside of the glass of the tube. That conductive material is called *aquadag*.

High voltage is applied to the aquadag on the inside of the picture tube by means of an electrical connection through the glass envelope of the tube.

Advantages of the electromagnetic picture tubes are that they are shorter from front to back, and require smaller voltages on the active elements within the tube.

The purpose of a receiver antenna is to intercept the passing TV carrier signal so it can be sent to the tuner section of the receiver.

The antenna signal is brought from the antenna to the tuner through the medium of the transmission line.

Electrical and physical characteristics of a transmission line are carefully controlled so its *characteristic impedance* will match that of the receiver tuner and that of the antenna.

Mismatch of the impedances between the antenna and the transmission line can result in a very much reduced signal. Mismatch also introduces "ghosts".

An impedance mismatch between the transmission line and the tuner of the receiver can create "line reflections" and ghosts, and also seriously weaken the strength of the signal.

The tuner separates the desired TV carrier signal from all the others "on the air", mixes it with a local oscillator signal, and converts it to a much lower I-F frequency signal.

Automatic Gain Control (AGC) circuits in television receivers hold the picture strength to an even level, and prevent fluctuation between extreme darkness and extreme brightness when the level of the signal changes.

The low-voltage power supply in a TV receiver is not much different from those used in radio receivers, and other electronic devices.

High-voltage power supply circuits in TV receivers are intended to provide the extremely high voltages needed by the picture tube for proper operation.

Extreme care should be used when handling picture tubes to prevent them breaking or "imploding". Used picture tubes and new ones are equally dangerous so long as they contain a high vacuum inside.

## NOTES

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