# HOW RADIO PROGRAMS ARE SENT FROM THE STUDIO TO YOUR HOME

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NATIONAL RADIO INSTITUTE
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## How This Lesson Will Help You

LEARNING radio is much like building a skyscraper. Once the steel framework of a skyscraper is in place, the various floors of a skyscraper can be finished in any desired order. Likewise, once you become thoroughly familiar with the various radio parts and circuits which make up a complete modern broadcasting system, you will be in a position to study these radio parts and circuits faster.

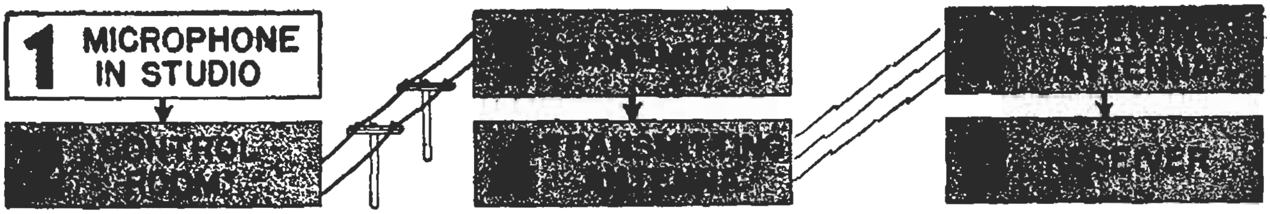
*Courtesy RCA Mfg. Co., Inc.* *Courtesy General Electric Co.*

**A radio program starts at a microphone which is usually located in a broadcasting studio. On special occasions, however, this microphone may be set up at any point to which man can travel—above, under or on the face of the earth. From this microphone, the program travels over a long and fascinating path to the loudspeakers of countless radio receivers. Somewhere along this path, there is a good-pay radio job awaiting completion of your training.**

Yes, our experience gained from many years of teaching radio has proved this to be true—that radio is *easiest to master* when you have a clear idea of how each study subject fits into the complete picture of radio.

This lesson takes you through the same broadcasting system you studied in the first lesson. Now, however, you will go through more slowly, so you have time to get acquainted with more of the *important* parts.

This detailed study of a radio broadcasting system will be your framework for the entire N.R.I. Course, regardless of what radio work you eventually choose. Even if you plan to follow radio receiver servicing or some other branch of radio dealing chiefly with receivers, a broad, general understanding of how radio programs are put on the air is essential to the completeness of your training.



**1 MICROPHONE IN STUDIO.** In radio, we start with sounds at the microphone, and must end up with reproductions of these same sounds at the loudspeaker. It is only logical, then, that you find out what sounds are like before you learn how microphones convert sounds into audio signals.

**What Is Sound?** When you strike a piano key, a small hammer swings against a wire inside the piano and makes that wire *vibrate.* If you touch the wire lightly, you will be able to *feel* these vibrations. Your ear can *hear* the vibrating wire even though many feet away, however, so these vibrations must travel through the air.

When you blow a whistle, the air inside and outside the whistle *vibrates.* Raindrops falling into a lake start many small *vibrations* both in the water and the surrounding air. The vocal cords in your throat *vibrate* when you speak or sing.

Since all these different vibrating materials produce sounds which can be heard, we can simply say that sound is *a vibration of any material at a rate which can be heard by human ears.* This vibrating material can be a *solid* object like wire, a *liquid* like water, or a *gas* like air.

**How Sound Travels.** Sounds produced by vibrating bodies must usually travel some distance before they reach human ears. Sound can travel through any gases, any liquids, and any solid objects which are elastic enough to vibrate. In other words, *sound can travel through anything which possesses the ability to vibrate.* Sound cannot travel through a vacuum, because there is nothing in a vacuum which can vibrate. This and other interesting characteristics of sound are illustrated in Fig. *1* (on next page).

Most of the sounds which we hear travel through air, which is a mixture of invisible gases and dust particles. Of particular interest to us as radio men is the way in which a loudspeaker sends sound through the air.

**How a Loudspeaker Produces Sound.** In an ordinary radio loudspeaker, we have a large paper cone which vibrates back and forth when the radio set is operating. This vibrating cone alternately pushes and pulls on nearby particles of air, thereby setting these air particles into vibration.

When the loudspeaker cone pushes air *forward,* it *compresses* the air particles, making them bump into other air particles which are farther away. These bump into still more particles, thereby giving a region of higher air pressure than normal. One of these higher-pressure regions begins traveling away from the loudspeaker each time the cone pushes forward.

When the cone moves backward, it leaves more room directly in front of itself for air particles, thus reducing the air pressure and creating a *partial* vacuum (a vacuum is a space having no air, and hence no pressure). Nearby air particles rush into this lower-pressure area, leaving a partial vacuum where they were. This lower-pressure region likewise travels outward in all directions from the cone of the loudspeaker.

Thus, a lower-pressure region begins traveling **away** from the loudspeaker each time the cone moves *backward*. This process repeats itself each time the cone moves forward and backward, which happens many times each second. The resulting regions of air pressure higher and lower than normal, traveling away from a sound source, are known as *sound waves*.

One thing we should definitely understand about sound is this: The vibrating particle of air which bumps into your eardrum and makes you hear the voice of a radio announcer did *not* travel all the way from the radio loudspeaker to you.

A sound wave made up of vibrating air particles can be compared to a wave moving across a lake on a windy day. This traveling wave is just a slow up-and-down vibration of water. The water particles stay in practically the same locations all the time, and only the vibrating or up-and-down action of water travels across the lake with the wind. Likewise, air particles in a sound wave merely move back and forth without getting very far. Each particle transfers its back-and-forth movement to the next particle, and these back-and-forth movements form *traveling* regions of higher and lower air pressure than normal.

**Speed of Sound.** Sound waves travel through air at a speed of approximately 1089 feet per second. This is slow in comparison to the 186,000-mile-per-second speed of radio waves, so you may be hearing the words of a radio announcer coming from your loudspeaker a split second before those sound waves reach persons at the rear in the studio audience.

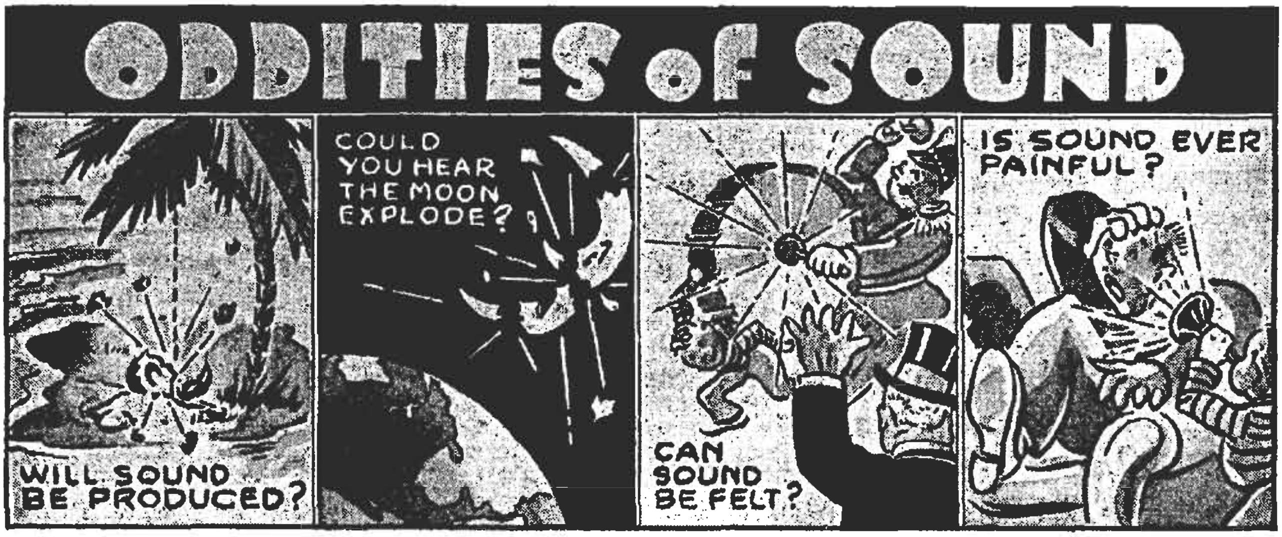


FIG. 1A. The radio scientist says *YES*, because he knows shattered pieces of coconut will vibrate *at a rate which can be heard by human ears.* The medical scientist says *NO*, because he defines sound as a vibration acting on and audible to human ears, and there are none on this uninhabited South Sea isle near the Equator.

FIG. 1B. No matter how violent an explosion of the moon might be, neither you nor any other person on this earth could hear the sound of the explosion. The reason is simply that sound travels only through materials which can vibrate, and there is nothing in the ethereal space between us and the moon—just vacuum.

FIG. 1C. When a large drum is struck vigorously, the stretched diaphragm of the drum vibrates in and out. This action alternately increases and decreases the air pressure in the vicinity of the drum, creating a sound wave which travels away from the drum. Your hand definitely *feels* the varying air pressure of this sound wave.

FIG. 1D. If some husky youngster should blow a large whistle or horn close to your ear, you would definitely agree that sound *can be painful* to the eardrum if sufficiently loud. This is why artillery men must stuff cotton into their ears or use special ear plugs when firing big guns during land warfare or naval maneuvers.

**How We Hear Sound.** The outer passage of the human ear is closed by a thin membrane called the *eardrum.* When the eardrum is set into vibration by sound waves which travel through air and enter the ear, the vibration is transferred through a series of small bones to a fluid in the inner ear, and through this fluid to the sensitive fibers of the hearing nerves. These nerves convey to the brain the sensation of sound.

**Wavelengths and Cycles.** If your sense of touch were sufficiently delicate, you could stand in the path of a sound wave and feel every variation above or below normal air pressure, just as is illustrated in Fig. *1C*. You would feel an *increase* in the pressure of the air, followed by a return to normal, a *decrease* from normal air pressure, and a return to normal again. This would repeat itself as long as the sound was being produced. Each complete *increase* and *decrease* in air pressure, corresponding to one complete vibration back and forth of the sound source, is known as a *cycle* of the sound wave (pronounced *SIGH-kull*).

If you could in some way stop a sound wave and make its variations in air pressure visible, you could take a yardstick and measure the distance between two adjoining higher-pressure regions of the sound wave. Your result would be the length of the wave, or the *wavelength* of that particular sound. Wavelengths of common sounds range from about one inch for the chirp of a cricket to about fifty feet for the booming sound of a bass drum.

**Frequency of Sound.** The number of complete back-and-forth vibrations which a sound source makes in one second of time is called the *frequency* of a sound. If you could count the number of vibrations the cone of a loudspeaker makes in one second, your result would be the *frequency* of the sound in *cycles per second.*

The lowest sound frequency which a person can hear is *about 20 cycles per second;* the highest is *about 20,000 cycles per second.* The higher the frequency, the more high-pitched or shrill the sound is to our ears.

The approximate range of frequencies which we can hear is thus *between 20 cycles and 20,000 cycles;* this range is called the *audible range.* Any frequency in this range is an *audio frequency,* abbreviated *a.f.* Of course, these figures represent the extreme limits of hearing, and the average person will have a somewhat narrower hearing range. Older persons, especially, have difficulty in hearing the higher audio frequencies.

Notice that we omitted the phrase "per second" after the frequency values in the previous paragraph. Radio men often do this, and no one is confused, simply because the only interval of time ever used with frequency in radio work is one second. Just remember that whenever you read "20 cycles" or any other value in cycles, the meaning is "cycles per second," unless some other meaning is definitely indicated.

**Radio Program Frequencies.** Most of the radio broadcasting systems in this country are designed to handle audio frequencies from about 80 cycles to about 5000 cycles. A few high-fidelity broadcasting stations handle frequencies up to about 10,000 cycles, while the new frequency modulation broadcasting systems (developed by Major E. H. Armstrong, and described later in the N.R.I. Course) handle audio frequencies from about 30 cycles to about 15,000 cycles. Increased frequency range makes programs seem more natural when heard with frequency modulation receivers.

**Audio Reminders.** You will encounter the terms *audio* and *a.f.* hundreds of times throughout this course. Just remember that they both mean the same in common usage, and both refer to *frequencies which can be heard.*

For example, take the audio signal in a receiver. It is strictly an electrical signal, and cannot be heard. Because it *is* an *audio signal,* however, we know it has the same frequency (the same number of cycles per second) as the original sound. By feeding this audio signal into a loudspeaker, we can make the nearby air vibrate at exactly this same frequency, and we can hear the resulting sound waves.

## The Microphone

As you have already learned, the purpose of a microphone in a radio system is *to change sound waves into audio signals.* The microphone does this job in two steps: *1.* It changes the sound waves into corresponding back-and-forth movements or *vibrations* of a flexible part; *2.* It changes these vibrations into *audio signals.*

**How Sound Waves Move a Diaphragm.** Every microphone has one flexible part which vibrates whenever sound waves hit it. This part is called the *diaphragm,* and is usually a thin, light-weight metal disc which is loosely mounted so it can be pushed back and forth by sound waves.

With the aid of a pencil, a length of paper tape, a telephone mouthpiece and a few small parts arranged as shown in Fig. *2A,* we can demonstrate how the diaphragm of a microphone acts when a sound wave comes along. (In this diagram, half of the mouthpiece is cut away to show the diaphragm.) The diaphragm and pencil are joined by a link and lever in such a way that the pencil moves to the *left* when the diaphragm is *pushed* by the increased-pressure part of a sound wave, and the pencil moves to the *right* when the diaphragm is *pulled forward* by the reduced-pressure part of a sound wave.

If we let the point of the pencil rest on a length of paper tape, and pull this tape upward at a uniform speed while the sound wave of a pure whistled note is making the diaphragm vibrate, the pencil will trace on the paper a smooth wavy line like that appearing on the tape in Fig. *2A.*

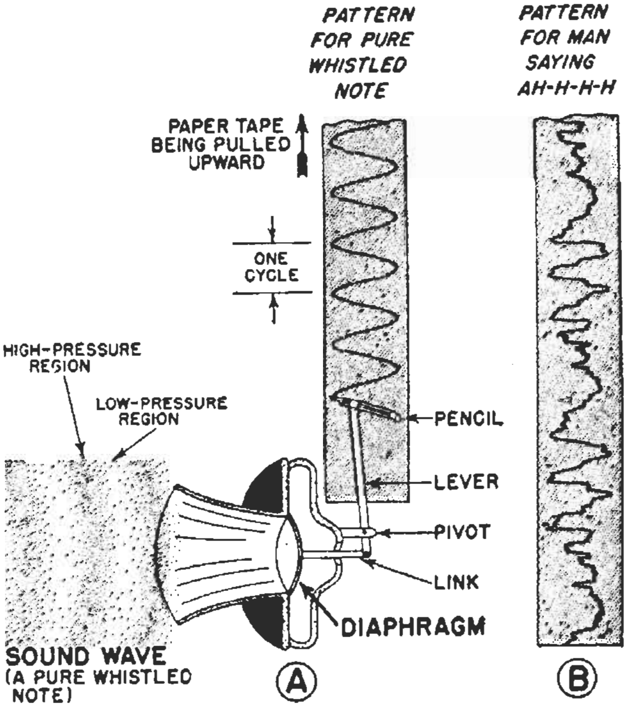


**FIG. 2. The simple diaphragm and lever mechanism shown here will trace on paper tape the manner in which a microphone diaphragm is moved back and forth by a sound wave.**

If the sound wave is produced by a man saying "ah-h-h-h," however, the pencil will trace on the paper a jagged pattern like that shown in Fig. *2B.* Each other type of sound will give a different pattern on the paper tape, and each pattern will represent the way in which the diaphragm and the source of sound are vibrating.

The one important thing for you to remember is that whenever sound waves hit the diaphragm of a microphone, *they make this diaphragm vibrate in the same way that the original source of sound is vibrating.*

**How a Diaphragm Produces Audio Signals.** Although all microphones start out by converting sound waves into vibrations of a diaphragm, many different types of microphones are used for changing diaphragm movements into audio signals. The important types in use today are the dynamic microphone, crystal microphone and velocity microphone. Condenser microphones and carbon microphones were once popular, but are now gradually fading out of the radio picture.

Let us assume that the microphone being used in the studio we are inspecting is a *dynamic microphone.* This is today one of the most widely used of all microphones, so an understanding of how it works will be sufficient until you come to the N.R.I. lesson which covers the other types of microphones.

The important features of a dynamic microphone are shown in a simplified manner in Fig. *3.* Sound waves enter the microphone through the holes in front, and make the thin circular metal diaphragm vibrate in the same way as the original sound source is vibrating.

Attached to the back of the diaphragm is a paper-thin bakelite *coil form* about half an inch in diameter. On this cylindrical form is a small coil of wire called the *voice coil,* made from insulated copper wire almost as fine as human hair. The voice coil has two flexible wire leads (pronounced *leeds*) which connect to the two wires of the *microphone cable.* The moving system of this microphone (the diaphragm and voice coil) is so light in weight that it vibrates readily even for faint sounds.

Surrounding the voice coil in Fig. 3 are the poles of a powerful *permanent magnet,* arranged in such a way that magnetic lines of force pass through this tiny coil at all times. Yes, that's all there is to a dynamic microphone —just a coil of wire mounted on a diaphragm, surrounded by a magnet, and connected to the two wires of the microphone cable.

When the diaphragm of a dynamic microphone is set into vibration by a sound wave, the voice coil moves in and out through the magnetic lines of force which exist between the poles of the permanent magnet. This movement of the voice coil *changes the number of magnetic lines of force* which pass through the coil, thereby inducing (producing) an *audio voltage* in the coil.

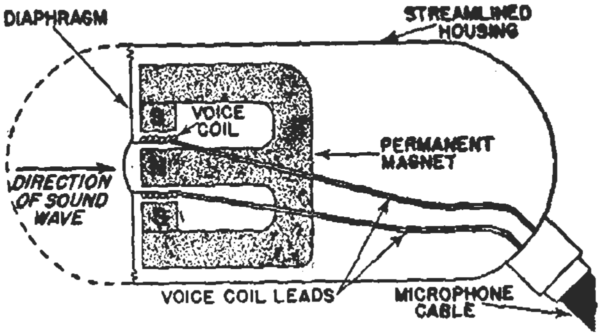


FIG. 3. Cross-section diagram of a typical dynamic microphone, showing the essential features which would be visible if we sliced vertically through the center of the microphone. When the voice coil of a dynamic microphone is moved in and out by sound waves, the number of magnetic lines of force which pass through the coil is changed, and therefore an audio voltage is induced in the coil. (The actual microphone appears in Fig. *6*.)

When the voice coil moves *into* the magnet, the voltage acts in one direction; when the coil moves *out of* the magnet, the voltage acts in the opposite direction. The voltage which the microphone puts out (called the *microphone output voltage*) thus reverses its polarity (direction) from instant to instant. A voltage which regularly reverses or *alternates* its polarity in

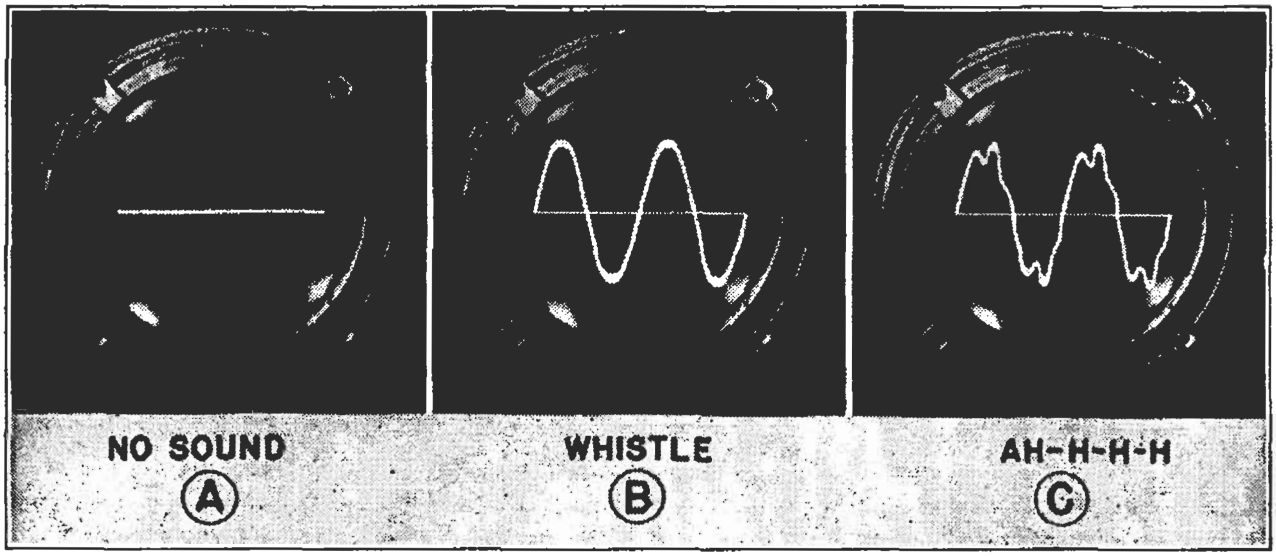


**FIG. 4. Patterns like these, traced on the screen of a cathode ray oscilloscope by a flying beam of electrons, show exactly how an audio voltage is varying. The weird, bright green fluorescent glow of the lines in these patterns is truly fascinating. (A fluorescent screen is one which glows when hit by electrons.) By using an oscilloscope to show how invisible voltages and currents are acting, radio engineers can pry into the secrets of radio circuits and actually see how adjustments or new parts affect performance.**

this manner is known as an *alternating current voltage* (abbreviated *a.c. voltage*).

The a.c. voltage produced by a microphone has exactly the same *frequency* as the original sound, because the voltage reverses in polarity each time the original sound source reverses its direction of motion. For this reason, the a.c. voltage which is generated in the voice coil of a dynamic microphone is generally called the audio voltage or *a.f. voltage.* Sometimes this audio voltage is simply called the *audio signal* or *a.f. signal.*

The *louder the sound,* the greater is the movement of the voice coil and the *stronger* is the audio voltage produced by the microphone.

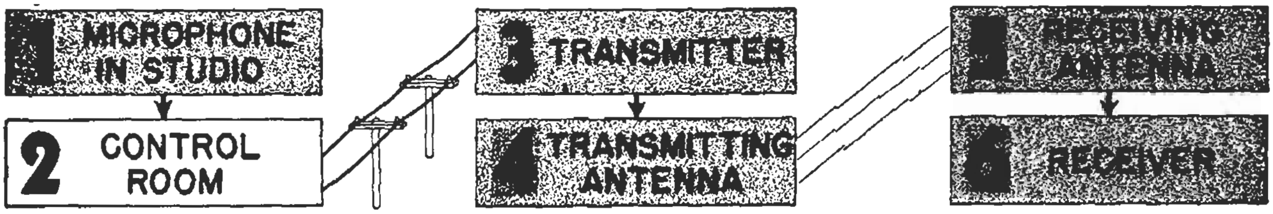
**Audio Voltage Patterns.** When radio men want to know how a particular audio signal voltage is varying, they sometimes use an electrical instrument called the *cathode ray oscilloscope* (pronounced *ah-SILL-oh-SKOPE*). In this instrument, the varying voltage is made to move a beam of electrons up and down across the white screen at the large end of a cathode ray tube. A bright greenish-white glow appears wherever the electron beam hits the chemical coating which forms this *fluorescent* screen (pronounced *FLEW-oh-RESS-sent*). A fluorescent screen glows *while* being hit by electrons.

When the audio signal voltage applied to an oscilloscope is zero (or when there is no sound), the electron sweeps horizontally from side to side continually, and "paints" on the screen the horizontal line shown in Fig. *4A*.

When we use an oscilloscope to look at the audio voltage produced by a pure whistled note, the audio voltage pattern shown in Fig. *4B* appears on the screen. Compare this with the pattern produced by the moving pencil in Fig. *2A*, and you will see that this audio voltage varies exactly in step with the movements of the microphone diaphragm. The horizontal line still shows faintly here, for the electron beam returns along this line while tracing the pattern over and over again. Each time the pattern crosses the horizontal line, the voltage drops to zero and reverses its polarity.

When we apply to an oscilloscope the audio voltage produced by a microphone while a man is saying "ah-h-h-h," the audio voltage pattern shown in Fig. *4C* appears on the screen. Comparing it with Fig. *2B*, we find again that the a.f. voltage of a microphone varies in step with the diaphragm movements.

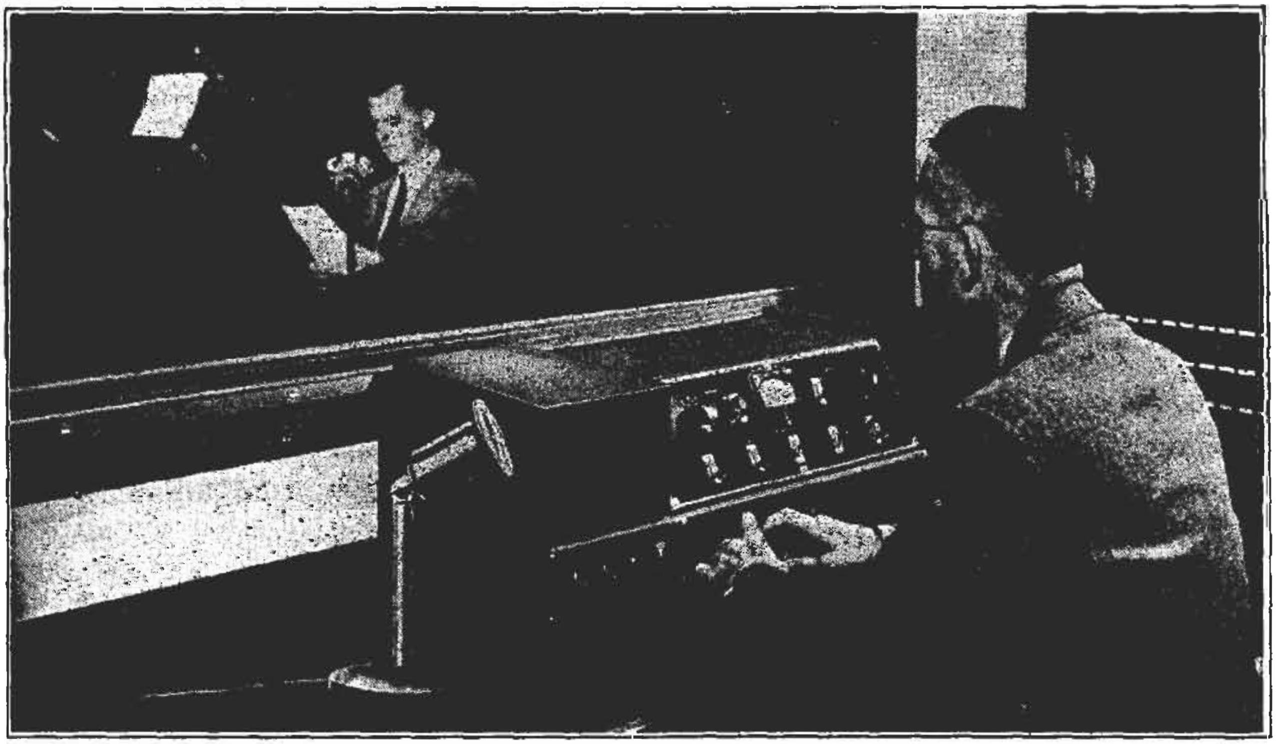
The audio voltage produced by a microphone makes electrons move back and forth through the microphone wires when a complete circuit is provided for the microphone by apparatus in the control room.



**2 CONTROL ROOM.** The audio signal voltage delivered by a microphone is so weak that it must be boosted a great deal before it can be sent over telephone lines to the transmitter. This building up of the signal voltage is done in the *control room,* under the watchful eye of the *monitor operator.*

The control room of a typical radio station is pictured in Fig. *5.* Let's imagine that we have just stepped into this room, and have asked the monitor operator to tell us about his work. His answer might run something like this:

"The audio signal travels through the microphone cable to this sound-proofed wall in front of me. The sig-



*Courtesy Western Electric Co.*

**FIG. 5. The monitor man in the control room watches the performers in the studio through a large glass window as he "rides gain." The small microphone at the left of the control unit is used principally for intercommunication between the monitor room and studio prior to a broadcast or during rehearsals, for the wall between the two rooms is sound-proof.**

nal is brought through the wall by means of a plug and outlet device on each side, after which it travels through another cable to this audio amplifier unit on my desk.

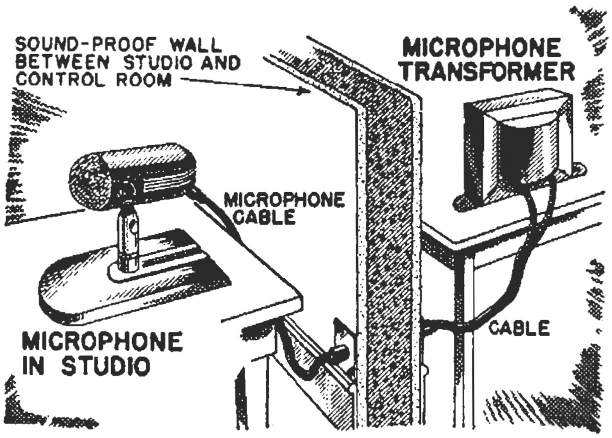


**FIG. 6. The first circuit in our studio-to-home radio system extends from the microphone in the studio to a microphone transformer in the audio amplifier which is located on the control desk in the control room.**

"Of course, there are other microphones in the studio, each feeding into my amplifier over a similar cable, plug and outlet path. Switches allow me to change instantly from one microphone to another during a broadcast, or use any combination of microphones when the program includes a dramatic production or music by a large orchestra.

"This heavy dual plate-glass window, built into the wall between the control room and the studio, blocks all sounds but allows me to watch the artists and the announcer while I 'ride gain' on the program. This is my most important duty; to 'ride gain' means to adjust the volume control here on the panel continually to compensate for excessive changes in the loudness of the program.

"For example, if I notice that the announcer is gradually moving away from the microphone, I gradually advance this volume control so the listeners cannot notice any change in the loudness of their program. If this meter in front of me indicates that the program is getting too loud, I immediately cut down the volume, to prevent overloading of the transmitter circuits. Overloading destroys the naturalness of the sound signal, and can even put the transmitter 'off the air' for a few moments because of the operation of automatic circuit-breaking switches which protect tubes and parts from burning out during overloads.

"But let's follow the audio signal as it enters this amplifier. The first thing it encounters is an iron-core transformer known as the *microphone transformer.* Notice that the two microphone wires go to the two terminals on the primary winding on this transformer (see Fig. *6*); this gives us a complete closed circuit over which electrons can travel.

"Here's the way I like to imagine that electrons are moving through the microphone circuit. I think of a necklace of balls strung end to end around the entire circuit, as on this diagram (see Fig. *7*). The lever of our microphone diaphragm mechanism (the same mechanism as in Fig. *2*) is attached to one point on the necklace.

**Using a cathode ray oscilloscope to see how the a.f. signal voltage in a radio set is varying.**

"Now, when a sound wave pushes down on the diaphragm, it makes the necklace end of this lever move upward, and the whole string of balls has to travel in the direction indicated by the arrows in Fig. 7.

"When the sound wave has pushed the diaphragm as far down as it can, both the diaphragm, the lever, and the necklace stop moving. Then, as the diaphragm moves backward due to its own springiness and to the pulling effect of the following lower-pressure region in the sound wave, the lever starts moving downward, and the entire necklace moves in the opposite direction to that shown by the arrows in Fig. 7.

"We thus have our necklace starting up gradually in one direction, increasing rapidly in speed, slowing down again as the diaphragm reaches the limit of its travel, stopping as the diaphragm stops, then reversing in direction and again repeating this increase and decrease in speed.

"You can compare the speed of this necklace to that of an automobile which you are driving back and forth continually between two points. You start up the car gradually as you leave one point, you travel at maximum speed when half-way between the two points, and you start slowing down before you arrive at the other point so as not to go past it.

"The actual electrons which make up an alternating current or signal current in a radio circuit move back and forth just like this imaginary necklace of balls. Of course, a piece of wire has millions of times as many electrons as there are balls in the necklace shown in Fig. 7, and there are no strings connecting the electrons together. But—whenever the electrons in a wire are acted on by an a.c. voltage, the electrons just move back and forth without getting anywhere, like the necklace of balls. That's all any audio signal *current* is—just a back-and-forth movement of electrons through the wires and parts of a circuit. The lower the frequency, the fewer back-and-forth movements there are per second.

"Here is a simplified circuit diagram which represents this first stage or section of our radio system (see Fig. *8* now). The audio signal current

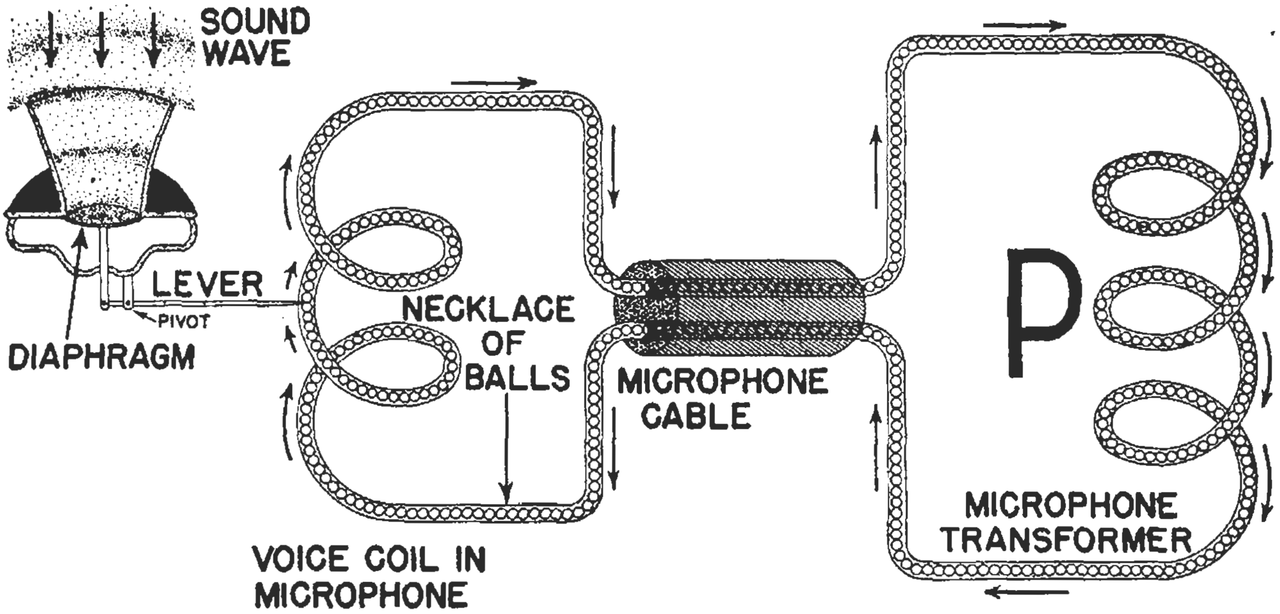


FIG. 7. To picture the way in which electrons move back and forth in a wire to make up an audio signal, think of a necklace of balls which is being moved back and forth through a circuit.

which flows through primary winding *P* of the microphone transformer causes an audio signal voltage to be induced in secondary winding *S* of this transformer. This audio voltage is several times stronger than the microphone voltage, because the microphone transformer secondary winding has more turns of wire than the primary.

"Notice that the stronger audio signal voltage which exists in secondary S acts upon the grid and cathode of the first a.f. amplifier tube, along with the d.c. voltage of the C battery which is in this same circuit. This first tube and its B battery together have amplifying ability, so a still stronger a.f. voltage is delivered to the primary of the second transformer in our circuit.

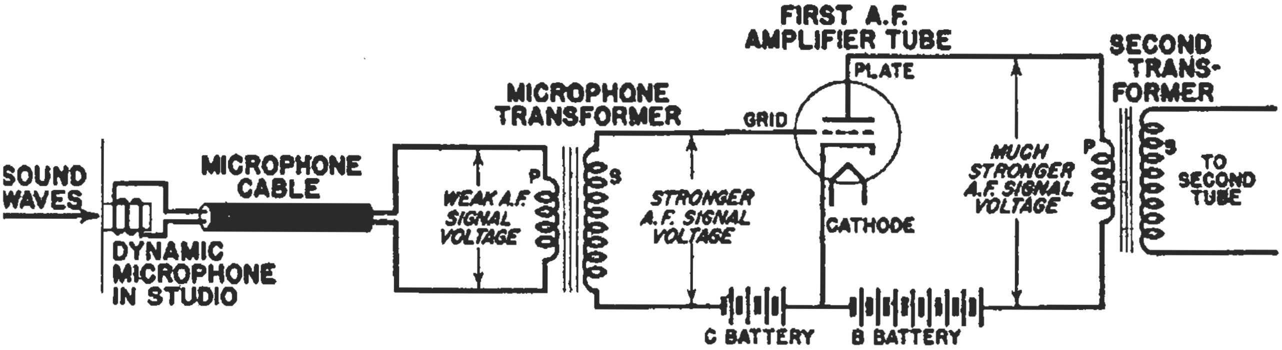


FIG. 8. Simplified circuit diagram showing the first part of the path taken by signals in traveling from the studio to your home. Only the most important parts of the circuit are shown here; the complete circuit will be taken up in later lessons.

"A microphone transformer and an amplifier stage acting together may amplify an a.f. signal voltage several hundred times, but even this is not enough. We must have many stages in this amplifier, with many tubes and transformers. Each stage steps up the signal voltage some more. Finally, we secure a strong enough voltage to send our signal over the telephone lines to the transmitter.

"There is just one more thing I must make clear before you leave the control room. Electrons do *not* move from one circuit to another in a radio system. The electrons in motion in a circuit remain in that circuit all the time. Each circuit is so planned, however, that the motion of the electrons in one circuit controls the motion of the electrons in the next circuit in the desired manner.

"To make this perfectly clear, let me redraw the circuit of Fig. *8* in such a way that each complete path for electrons is separate from the others (see Fig. *9*).

"The electrons which travel back and forth in the microphone circuit cannot get into the grid circuit . . . cannot get into any other tube circuit . . . and obviously cannot ever get into the transmitting antenna. Only magnetism, acting in the microphone transformer, links the microphone circuit with the grid circuit. It is magnetism which induces in our grid circuit the audio signal voltage which acts on the grid and cathode of the tube.

"You might at first think that the C battery would produce a continuous movement of electrons in one direction through the first grid circuit in Fig. *9*, but a little study will show why this does not happen.

"First of all, we learned in the previous lesson that the *negative* terminal of a battery tries to send electrons through the circuit to the *positive* battery terminal. With the C battery connected as shown, its negative terminal will try to make electrons flow *from* the grid *to* the cathode through the tube, so they will get to the + terminal of the C battery. No electrons can flow this way, however, because the grid does not emit any electrons. Electrons emitted from a heated cathode are the only ones which can bridge across the gaps between the electrodes of ordinary radio tubes.

"This is an idea well worth remembering, so let's repeat it in simpler form: When the grid of a vacuum tube is *negative*, there can be *no continuous flow* of electrons in the grid circuit.

"The electrons in the plate circuit are influenced by the grid circuit electrons, but there is no movement of electrons between the two circuits through the tube. We might think of these grid circuit electrons as traffic officers stationed on the grid wires of the tube, regulating the electron traffic which passes from cathode to plate in the plate circuit.

"Thus, you can see how a few electrons at the grid of a tube can control a much greater number of electrons in the plate circuit. In other words, a weak audio signal at the grid gives us a much stronger audio signal in the plate circuit. The stronger signal will behave exactly like the weak signal—that is, will have the same frequency.

"The B battery in the plate circuit is connected to make the plate *positive* with respect to the electron-emitting cathode, so the plate attracts electrons and we have a continuous electron flow from the cathode to the plate and around the complete plate circuit—a *d.c. plate current.*

"We thus have both a d.c. plate current and an audio signal flowing through the plate circuit at the same time. There is nothing unusual about this; the audio signal voltage in the grid circuit simply makes the d.c. plate current fluctuate above and below its steady value, and these *momentary changes* in the amount of electron flow (alternate increases and decreases) form the audio signal in the plate circuit.

"The B battery provides the additional power needed to make the audio signal in the plate circuit stronger than the signal in the grid circuit. In fact, no tube can generate electrical power; it merely utilizes the power from a voltage source in such a way as to amplify or strengthen a signal.

"It is this audio signal flowing through the primary of the second transformer (Fig. 9) which induces an audio signal voltage in the secondary of the transformer (in the second grid circuit).

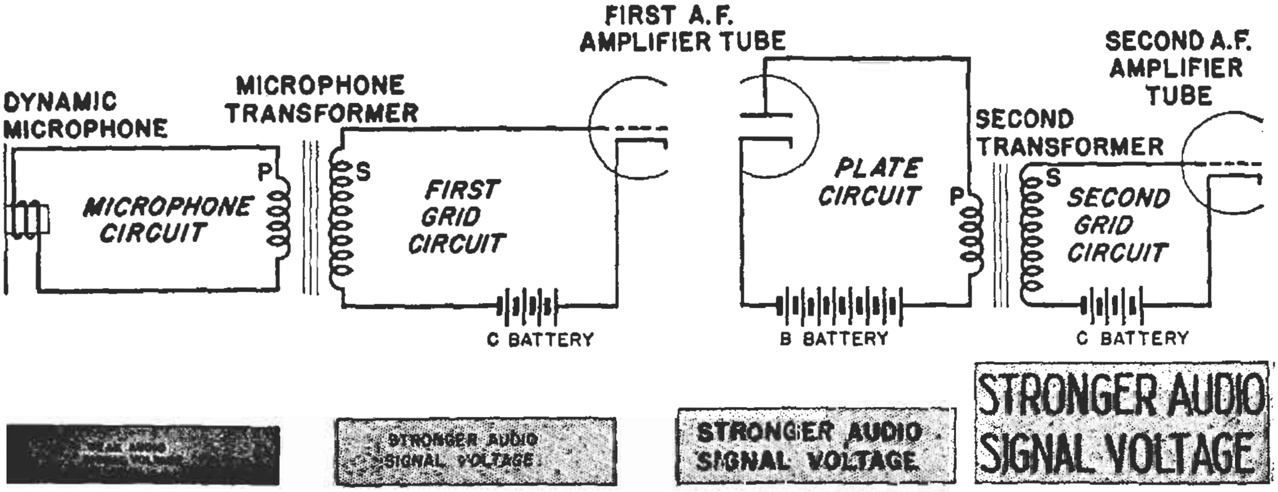
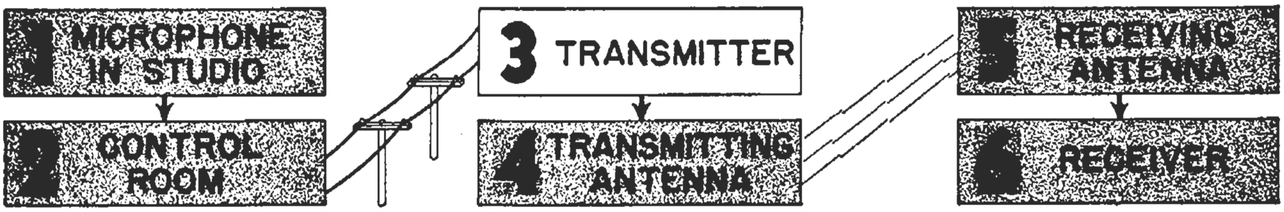


FIG. 9. This diagram shows that electrons in the microphone circuit cannot possibly travel through the other circuits of a radio system. It is the *effects* of these electron movements which are transferred from circuit to circuit to give increasingly stronger signals.

"Each other circuit in this audio amplifier likewise has its own set of electrons and its own audio signal. Tubes and transformers make electrons in one circuit act upon electrons in the next circuit, and thus we secure the desired increasingly stronger audio signal in each succeeding circuit."



**3 TRANSMITTER.** We leave the monitor operator in his control room, and follow the audio signal through the telephone lines which run to the transmitter.

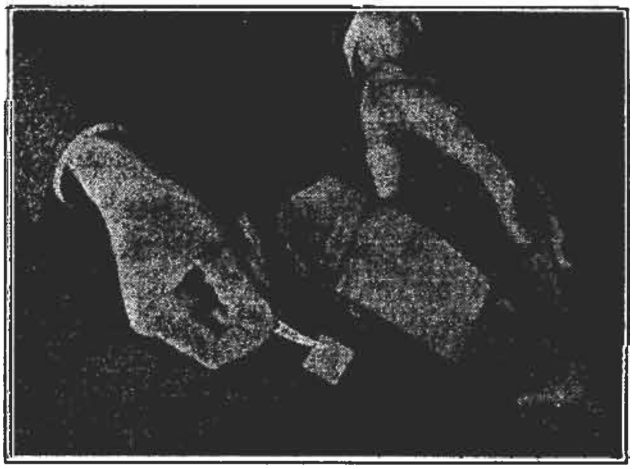
By the time the audio signal has arrived at the transmitter, its voltage (strength) has dropped considerably due to the long trip through the telephone line. This is why the audio signal is sent through several more voltage-boosting a.f. amplifier stages after it reaches the transmitter.

**R.F. Carrier Signal.** No matter how strong we make the audio signal voltage, however, it will not produce radio waves when fed into the transmitting antenna. The only thing that will produce radio waves which will "go places" is a high-frequency signal. This required higher frequency is known as a *radio frequency,* and is abbreviated *r.f.* A radio frequency signal is usually higher than 100,000 cycles per second, whereas, you will remember, an audio frequency signal is rarely higher than 15,000 cycles.

A radio frequency signal can be used to *carry* an audio signal through space. When used in this way, the r.f. signal is called the *r.f. carrier signal.* Each radio station in the United States is assigned a definite carrier frequency value by the Federal Communications Commission.

**Crystal Oscillator.** The r.f. carrier signal for a modern broadcast transmitter is produced by a special radio vacuum tube circuit known as a *crystal oscillator.* This circuit contains three important radio parts which we have not yet taken up—a crystal, a variable tuning condenser and an r.f. transformer. It is the crystal which produces the r.f. carrier signal, so we will first see what the crystal is like.

**The Crystal.** A modern radio transmitter is kept on its assigned carrier frequency by a carefully ground piece of natural quartz crystal about one inch square, which is known to radio men as a *crystal.* One of these finished crystals is shown in Fig. *10,* alongside a block of natural quartz from which radio crystals of



*Courtesy General Electric Co.*

FIG. 10. A quartz crystal slab which is ready for use in a broadcast transmitter is here held by tweezers alongside a piece of quartz as found in its natural state.

this type are cut. Natural quartz is mined in South America, in Brazil.

**Frequency of a Crystal.** When a piece of quartz crystal is jarred or tapped, it will vibrate like a strip of stiff spring steel. Each crystal has its own natural frequency of vibration, which depends upon the thickness of the crystal. For example, a crystal one-fifth of an inch thick has a natural vibration frequency of about 600,000 cycles.

A vibrating crystal has another peculiar characteristic—it produces an a.c. voltage between its faces whenever it vibrates. This a.c. voltage has the same frequency as that at which the crystal is vibrating. Still more interesting is the fact that we can reverse this characteristic—we can make the crystal vibrate by connecting it to an a.c. voltage source.

**Crystal Oscillator Circuit.** A simplified version of a crystal oscillator circuit is shown in Fig. *11*. The crystal is connected between the grid and cathode of the tube, while the B battery and a *tuning circuit* are connected between the plate and cathode.

The coil in the tuning circuit is the primary winding of an *r.f. transformer*, which consists simply of two coils of wire wound side by side or one over the other on a length of paper or fiber tubing called a *coil form*. There is no iron core inside the coil form.

The variable condenser consists of two sets of metal plates, insulated from each other. One set of plates is fixed. The other set is mounted on a shaft which turns or rotates in such a way that its plates can be meshed any desired amount with the fixed plates. (Two sets of plates are meshed when they fit between each other without touching.)

When the crystal oscillator circuit of Fig. *11* is operating properly, the crystal is vibrating at its natural frequency. Since this is generally higher than 100,000 cycles, it is a *radio frequency*. The resulting weak *r.f. voltage* produced by the vibrating crystal acts between the grid and cathode of the tube. The tube and its B battery boost the strength of this r.f. signal, just as in an audio amplifier stage, so we have a stronger r.f. signal voltage in the plate circuit.

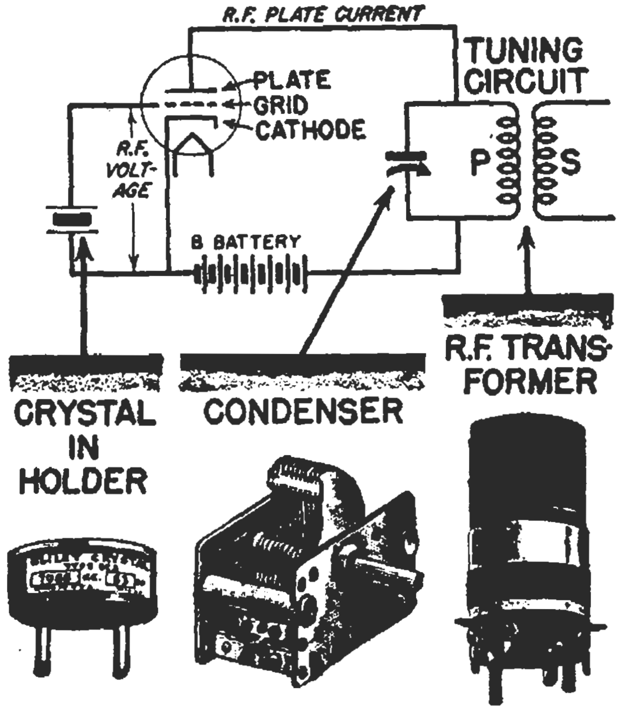


**FIG. 11. Simplified diagram of a crystal oscillator circuit, with illustrations of the three parts you have not yet studied. Only the more important parts are shown, because the other parts will be taken up in later lessons. Thus, by-pass condensers are omitted, and no C supply is shown. The condenser is a *tuning* condenser.**

Some of the r.f. signal voltage in the plate circuit feeds back through the tube and gives the crystal a little "push" during each cycle of vibration. A small part of the power obtained from the B battery thus serves to keep the crystal vibrating. The explanation of how the signal feeds back comes later in your Course.

By rotating the shaft of the variable condenser, the tuning circuit can be adjusted for best possible operation of the crystal oscillator. Maximum r.f.

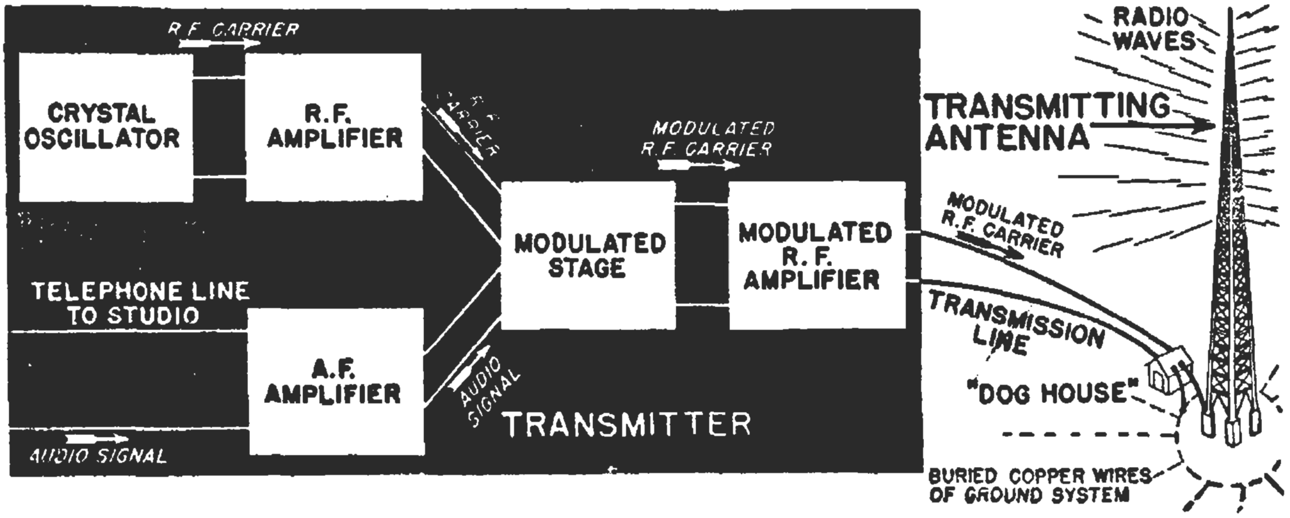


FIG. 12. All the main sections of a broadcast transmitter are shown here, along with the basic connections to the transmitting antenna.

current then flows through the coil of the tuning circuit, and this current induces a maximum r.f. voltage in the secondary of the r.f. transformer, for transfer to the next section of the transmitter. This r.f. voltage is still much too weak for broadcast purposes, however, so this r.f. carrier signal must be sent through a number of r.f. amplifier stages to build up its strength.

**R. F. Amplifier.** At this point, a "picture" of the main sections of a complete transmitter will help you to understand how the audio signal and the r.f. carrier get together. This picture is given in the block diagram in Fig. *12*.

You will recognize the crystal oscillator and the a.f. amplifier immediately, for you have already studied these sections. The *modulated stage* is the highly important one which combines the audio signal and the r.f. carrier signal to produce the modulated r.f. carrier signal. The *r.f. amplifier*, located between the crystal oscillator and the modulated stage, boosts the r.f. output voltage of the crystal oscillator. The *modulated r.f. amplifier* is the most interesting of all sections, for it contains huge air or water-cooled output tubes which strengthen the modulated r.f. carrier signal sufficiently so it can be fed over the transmission line and through the *dog house* to the huge steel transmitting antenna tower.

Even in a moderate-size broadcasting station, one or more vacuum tube stages are required in the r.f. amplifier. These are all essentially alike, so only the first r.f. amplifier stage is shown in Fig. *13*. Its operation is the same

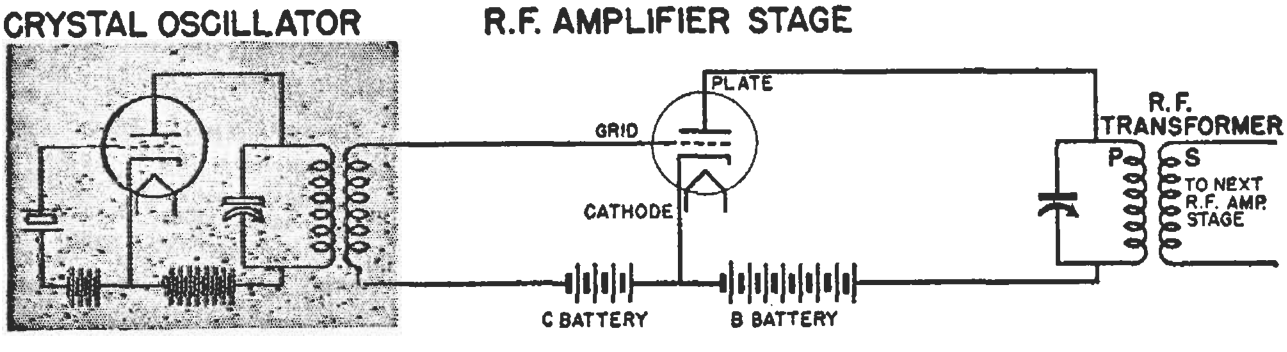


FIG. 13. Simplified circuit diagram of the first r.f. amplifier stage in a transmitter, with its connections to the crystal oscillator.

as that of an a.f. amplifier stage, except that an r.f. voltage instead of an a.f. voltage is applied between the grid and cathode of the tube and causes the plate current to vary at an r.f. rate. Remember that it is the B voltage source which furnishes to each stage the electrical power required to boost the signal strength.

The r.f. plate current flowing through primary *P* of the r.f. transformer in Fig. *13* induces a strong r.f. voltage in secondary *S*, which is in the grid circuit of the next r.f. amplifier stage. The final r.f. amplifier feeds its r.f. voltage into the grid circuit of the *modulated stage*.

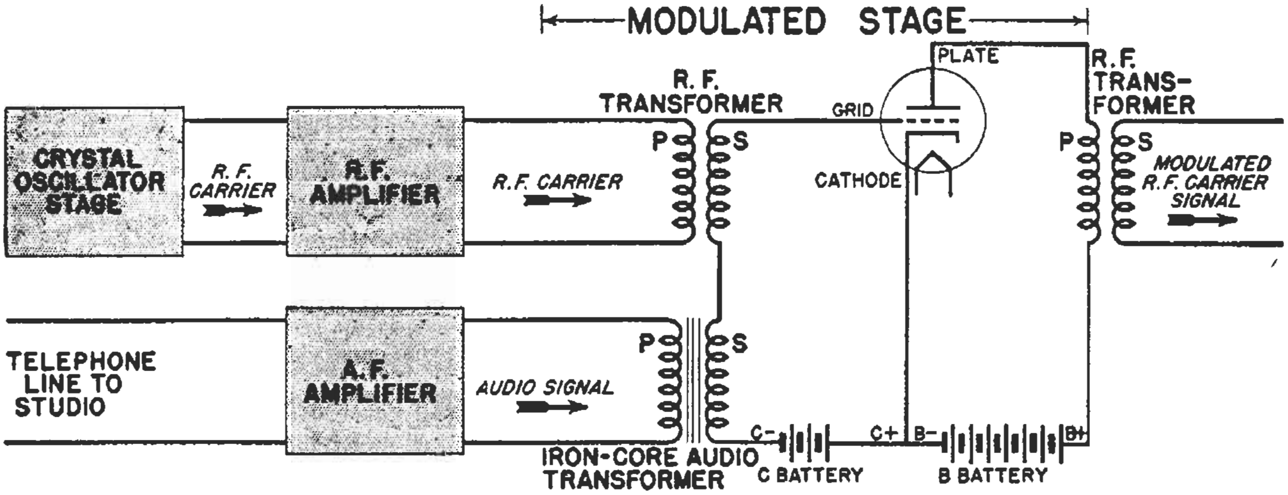


FIG. 14. Simplified circuit diagram of the modulated stage in a radio transmitter. This stage places the audio signal on the r.f. carrier, so as to give a modulated r.f. carrier signal.

**Modulated Stage.** The next stage we are to investigate is known as the *modulated stage,* because in this stage the r.f. carrier is modulated (made to vary) in the same way that the audio signal is varying. As you can see from the diagram in Fig. *14,* the modulated stage contains only one more part than is in an r.f. amplifier stage. This part is an iron-core audio transformer like those you have already studied. The audio transformer transfers the audio signal from the audio amplifier to the grid circuit of the modulated stage, while the first r.f. transformer in Fig. *14* takes the r.f. carrier signal and transfers it also to the grid circuit of the modulated stage.

We thus have an r.f. carrier voltage and an audio voltage acting on the grid of the tube in the modulated stage, in addition to the usual C battery voltage. As a result, we have in the plate circuit a modulated r.f. plate current—an r.f. plate current which increases and decreases in strength in step with the audio signal.

This signal-combining action is so important in a broadcast transmitter that it is well worth repeating as a single easy-to-remember sentence:

The *modulated stage* of a transmitter combines the *audio signal* with the *r.f. carrier signal* to give the *modulated r.f. carrier signal.*

With a cathode ray oscilloscope, the laboratory man can show exactly how each of the signal voltages in the modulated stage is varying. This gives a clearer idea of how the audio signal "rides" on the r.f. carrier, for we see an action which otherwise would have to be imagined because it is invisible.

In Fig. *15A* we see the pattern for the signal voltage which is fed into the modulated stage. It is much like that shown in Fig. *2B* for the "ah-h-h-h" sound.

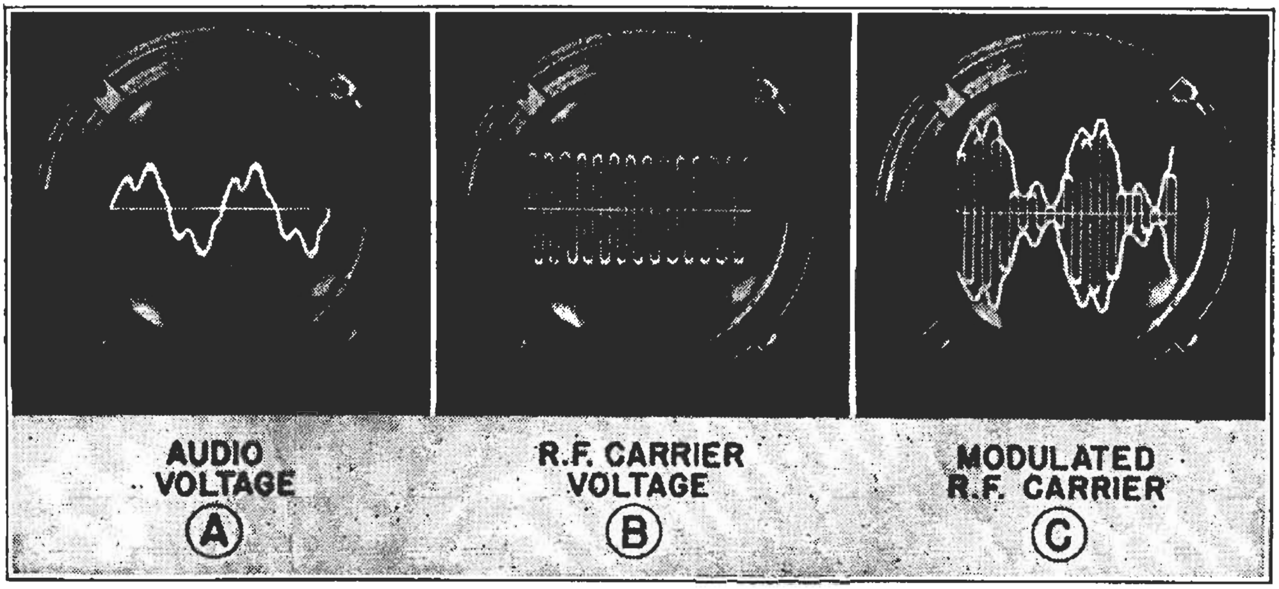


**FIG. 15. These three patterns give the complete story of the modulated stage in a transmitter, as it would appear on the screen of a cathode ray oscilloscope.**

In Fig. *15B* is the pattern for the r.f. carrier voltage which is also fed into the modulated stage. Its loops are close together because, as you will remember, this r.f. voltage reverses its polarity many more times per second than does an audio voltage.

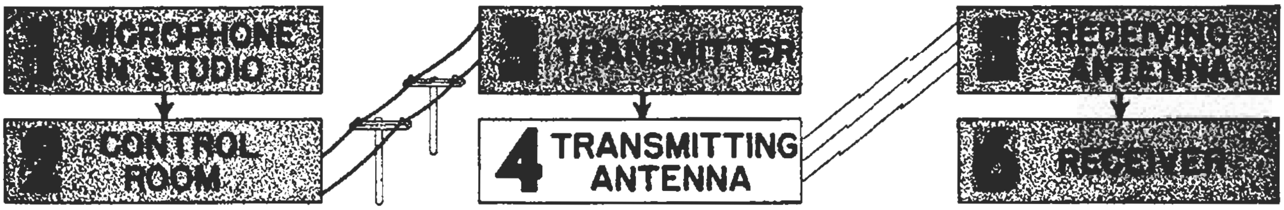
The most interesting pattern of all is Fig. *15C,* which shows how the *modulated* r.f. carrier voltage, which we obtain from the modulated stage, is varying in strength from instant to instant. The farther the pattern swings above and below the horizontal line at a particular instant, the greater is the strength of the signal at that instant. The pattern of our audio voltage is clearly recognizable both above and below the horizontal zero-voltage line, proving definitely that our radio program is still present at the output of the modulated stage. Thus do electrons in a cathode ray oscilloscope tube make it possible for us to find out what electrons in other circuits are doing.

The modulated r.f. plate current flows through primary *P* of the second r.f. transformer in Fig. *14,* and induces in secondary *S* the desired *modulated r.f. voltage.* At last we have an audio signal "riding" on an r.f. carrier—the required combination for producing radio waves which will carry radio programs for long distances through space.

In low and medium-power transmitters, the modulated r.f. carrier signal is often fed directly to the transmitting antenna without additional amplification.

In large transmitters, however, the modulated signal is usually fed into a *modulated r.f. amplifier.* This contains one or more amplifier stages much like the r.f. amplifier stage you have already studied, except that now we are using much larger tubes.

Our signal acquires more power (more strength) each time it passes through an amplifier. In a large broadcast transmitter, the huge vacuum tubes in the modulated r.f. amplifier stage handle so much signal power and take so much power from the B voltage source that the tubes must be cooled either by blower fans or by a circulating water system. This is particularly true of the final tubes in the transmitter; these must handle the government-assigned output power of the transmitter, which for most U. S. broadcast stations is some power value between 250 watts and 50,000 watts. (A *watt* is a unit used for measuring quantities of electric power. The antenna of a 100-watt station gets the same quantity of power as does a 100-watt lamp bulb.)



## 4 TRANSMITTING ANTENNA.

The modulated r.f. carrier signal at the output of a radio transmitter is fed to the transmitting antenna tower over a special two-wire transmission line which runs through the tuning house or "doghouse," essentially as was illustrated in Fig. *12*. One of the transmission line wires goes to the base of the huge steel antenna tower. This tower is insulated (electrically separated) from the earth by means of insulators. The other transmission line wire goes to a network of buried copper wires which radiate outward for hundreds of feet from the tower like the spokes of a wagon wheel. These wires serve as the *ground* connection.

The transmitting antenna tower and the nearby ground area together act like a tuning circuit containing a coil and condenser. This means that maximum signal current will flow through the antenna tower when the tower is tuned exactly to the r.f. carrier frequency of our transmitter.

An antenna can be tuned to a definite frequency simply by adjusting the height of the antenna tower. Engineers figure out the height which will approximately give the desired tuning, then build the tower and provide at its top a telescoping metal pipe or mast which can be adjusted to increase or decrease the height of the antenna.

The tuning house or doghouse may contain an r.f. transformer with a condenser placed across each of its coils so as to provide two additional tuning circuits. These insure that the antenna will receive the maximum possible amount of signal power from the transmission line.

Remember, our modulated r.f. carrier signal in the transmitting antenna is simply a combination of our desired audio signal and its r.f. carrier.

**Producing Radio Waves.** In the previous lesson, you learned that whenever electrons *move* through a wire, they produce a *magnetic field* around the wire.

In addition to this, electrons have their own *electric fields,* consisting of *electric lines of force* which represent the *directions* in which electrons will repel or attract other charged objects.

When the electron flow through a transmitting antenna changes in amount or direction, both the electric and magnetic fields of the electrons will travel out in all directions from the tower at the speed of light. These moving electric and magnetic fields make up the *electromagnetic waves* which are known as *radio waves.*

During intervals of silence when no audio signal is produced by the microphone in the studio, the only signal which reaches the transmitting antenna is the r.f. carrier alone. We call it the *unmodulated* r.f. carrier signal, because it has no modulation (no audio signal riding on the r.f. carrier).

When an unmodulated r.f. carrier signal is being supplied to a transmitting antenna by a broadcast transmitter, the electron flow in the antenna tower is changing in direction and amount many hundred thousand times per second, essentially as indicated by the r.f. carrier voltage pattern in Fig. *15B*. As a result, electric and magnetic fields which also vary in much this same way are being produced continuously by the transmitting antenna. These electric and magnetic fields travel off into space as radio waves.

Here is the important fact to realize —only the magnetic and electric fields leave the transmitting antenna. The electrons stay right in the antenna tower at all times.

When the microphone is picking up sound waves and producing audio signals, the r.f. carrier signal is *modulated* with an audio signal. The maximum strength of the electric and magnetic fields then varies from instant to instant much as in Fig. *15C*, because the electron flow in the antenna tower is now varying in strength in this manner. A radio wave therefore varies in strength from instant to instant in such a way that it still carries the same radio program we traced through the transmitter stages.

When radio waves leave a transmitting antenna tower, they travel up into the sky as *sky waves*, and along the ground as *ground waves*. Those waves which go up into the sky are not lost, however; about 50 miles above the earth there are layers of electrons and gas particles which can bend or reflect radio waves back to the earth.

All long-distance radio reception, in short-wave bands as well as the broadcast band, is by means of sky waves. Ground waves give the best reception, but have a range of only about 100

*Courtesy Chicago Tribune & WGN.*

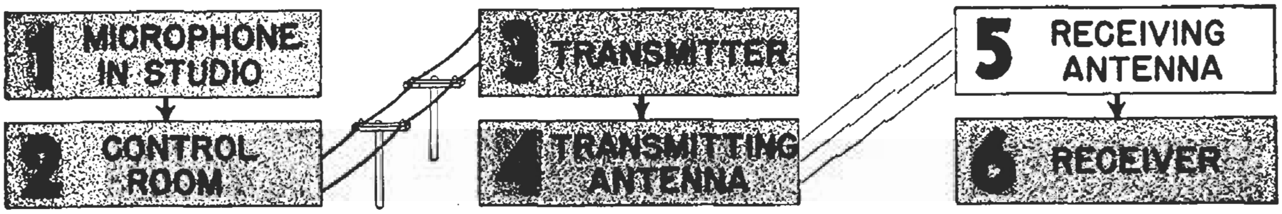
*Courtesy Station WFOY.*

**Left:** Famous 750-foot high steel transmitting antenna of radio station WGN in Chicago. A single porcelain insulator supports the 65-ton weight of the tower.

**Right:** Self-supporting 200-foot high steel tower of station WFOY, located in a salt-water marsh near St. Augustine, Florida. The dog house (tuning house) is directly under the tower, with a catwalk running from it to the transmitter.

miles at the most. Transmitting antennas for broadcast and police radio stations are designed to send out a high proportion of ground waves, while antennas for short-wave stations are designed to send out chiefly sky waves.

This completes the first chapter of our story of radio; in the next chapter, we discover how the receiving antenna and receiver reverse the entire transmitting process and give us sound waves again.



**5 RECEIVING ANTENNA.** When a radio wave arrives at a receiving antenna, the electric and magnetic fields of this radio wave make the free electrons in the antenna wire move back and forth *along the wire* at exactly the same frequency as that of the r.f. carrier in the transmitter. One electron transfers its motion to the next through collision, so the electrons in the receiving antenna move back and forth in the same way as the electrons in the transmitting antenna. The result is a modulated r.f. current in the receiving antenna, like the current in the transmitting antenna but much weaker. The farther the radio waves have to travel, the weaker is the receiving antenna current.

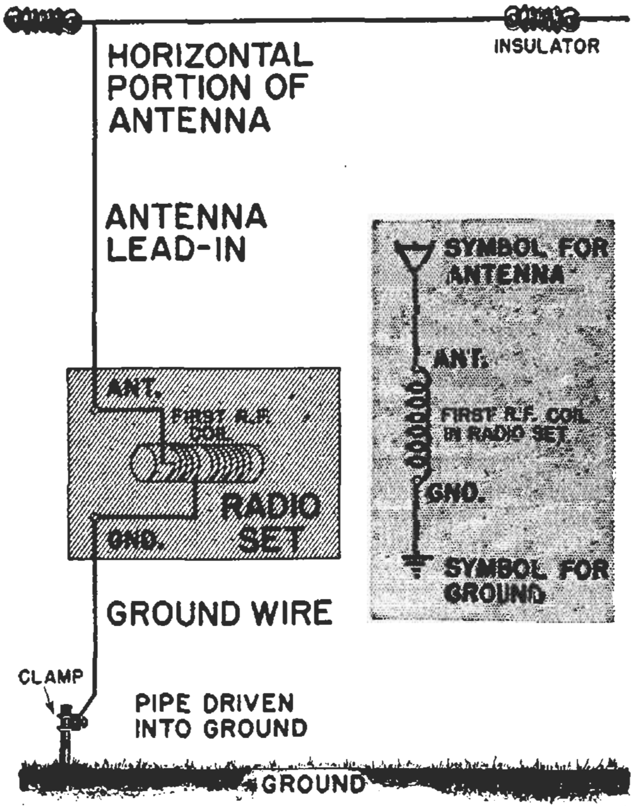


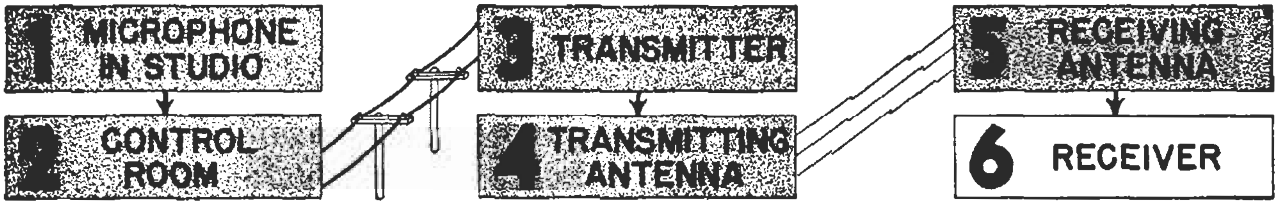
FIG. 16. Simple receiving antenna system, showing path from antenna to ground for modulated r.f. currents set up in the antenna by radio waves. Symbols used by radio men for the antenna and ground are shown at the right.

The circuit for this modulated r.f. current is from the antenna down to the receiver, through the first r.f. coil, and then to the ground, as shown in Fig. *16*.

The farther the receiving antenna is from the transmitting antenna, the weaker will be the radio wave by the time it reaches the receiving antenna, and the weaker will be the resulting modulated r.f. current in the antenna.

Each receiving antenna has a natural frequency of its own, at which the antenna current is the strongest for a given radio wave. Changing the length of the antenna changes its "best-results" frequency.

For ordinary broadcast band reception of entertainment programs, we pay little or no attention to the length of a receiving antenna. It is only when best possible reception of distant short-wave stations is desired that we begin measuring antenna lengths.



**6 RECEIVER.** Two types of receivers are in general use today. The simpler of these is the *tuned radio frequency receiver*, commonly referred to as a *t.r.f. receiver.* The other type is the *superheterodyne receiver,* which is now the leader because its special circuits give superior results. Naturally you will prefer to take up first the simpler of these receivers, so we will consider only t.r.f. receivers now.

As the diagram in Fig. *17* indicates, a t.r.f. receiver has only four sections, having the following purposes:

*1.* The *r.f. amplifier,* which builds up the strength of the signal from a desired station, and also keeps out undesired signals.

*2.* The *detector,* which separates the audio signal from the r.f. carrier.

*3.* The *audio amplifier,* which builds up the strength of the audio signal.

*4.* The *loudspeaker,* which converts the audio signal into sound.

**R.F. Amplifier.** If a radio man glances at the simplified circuit in Fig. *17* he says immediately that our t.r.f. receiver has two r.f. amplifier stages, with three tuning circuits. The two r.f. amplifier stages boost the strength of the desired modulated r.f. carrier signal a tremendous amount. The three tuning circuits keep back all other modulated r.f. carrier signals which may be present in the receiving antenna, and also do their share toward boosting signal strength. (Signals from hundreds of different stations, some weak and some strong, may be present in a receiving antenna at any one time.)

The three tuning circuits in Fig. *17* are $L_1$-$C_1$, $L_2$-$C_2$ and $L_3$-$C_3$. (In radio, we use the letter $C$ to represent a condenser, and the letter $L$ to represent a coil. When there is more than one coil or more than one condenser,

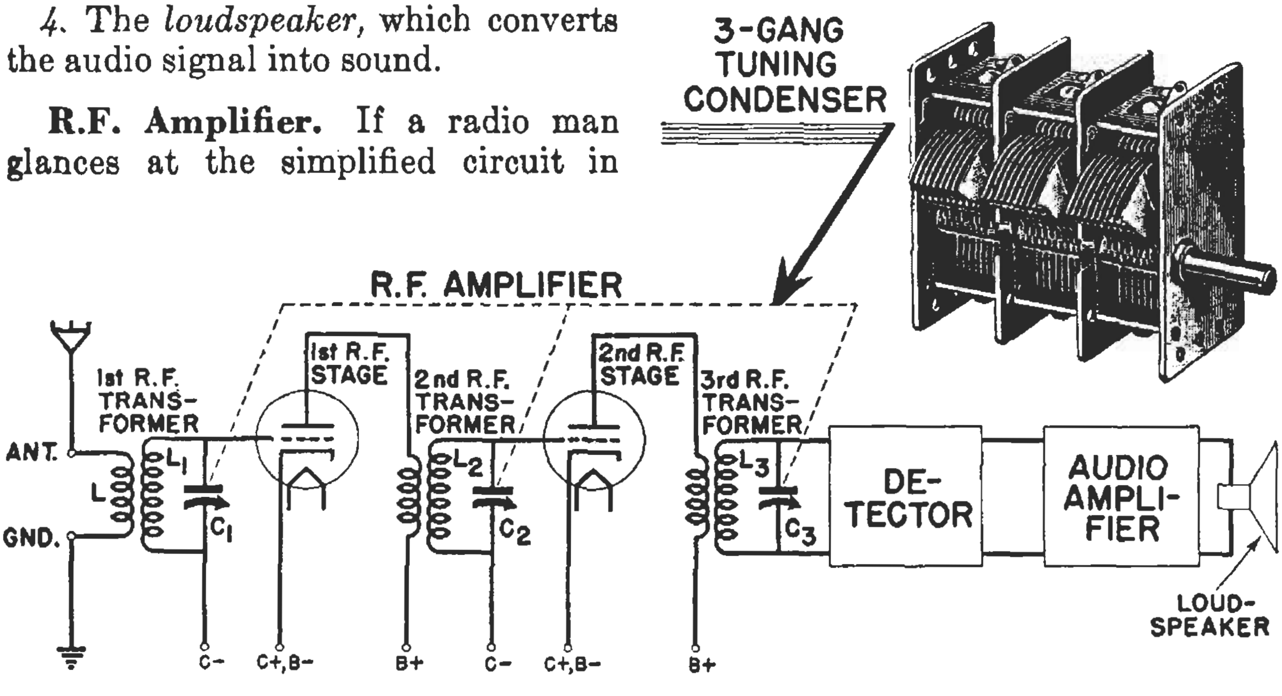
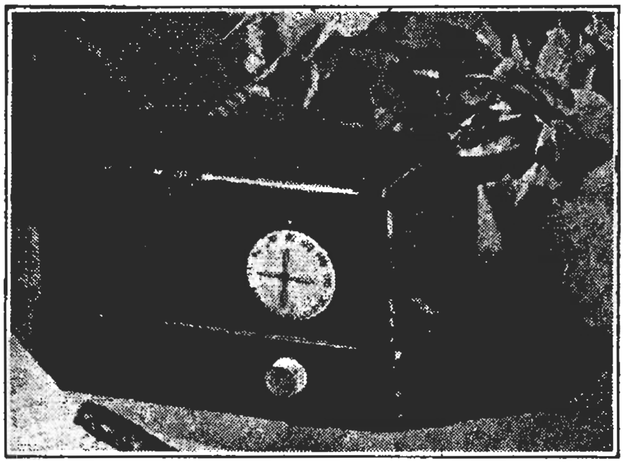


FIG. 17. Circuit arrangement of a typical t.r.f. receiver, with the two-stage r.f. amplifier circuit shown in simplified form. All d.c. circuits are completed through the power supply, which is not shown. All paths for signal currents are completed through condensers and other parts, which have been omitted here to simplify the diagram.



Courtesy General Electric Co.

**Typical tuned radio frequency (t.r.f.) receiver. This set has five tubes, and uses circuits very similar to those which serve as examples in this lesson. Stations are tuned in with the large dial-knob, while the set is turned off or on and the volume is adjusted with the smaller knob.**

numbers are used after the letters to distinguish between the similar parts.) Each tuning circuit contains a coil and a condenser. The condensers are shown separately in the diagram in Fig. *17,* but in the actual receiver these three condensers are combined into a single unit like that shown at the upper right in the diagram. The dotted lines connecting together the three tuning condenser symbols indicate that these condensers are on the same shaft and tuned by the same knob.

When we tune in a program with the tuning knob, we are actually adjusting all three condensers at the same time so they will tune all of the tuning circuits automatically to the carrier frequency we desire to receive, and at the same time reject the undesired signals.

In the early days of radio, single-control tuning was unknown. Each tuning circuit had its own separate tuning condenser. To tune in a station, it was necessary to adjust all of the tuning knobs, one at a time. Some sets had as many as five tuning condensers, each with its own knob, so it was quite a feat to tune in a station in those days.

Getting back to our own t.r.f. circuit in Fig. *17*, the antenna signal current flowing through coil $L$ induces a signal voltage in the first tuning circuit, $L_1$-$C_1$. The tuning circuit transfers this weak voltage to the grid and cathode of the first r.f. tube (the C battery, not shown, completes the circuit from $C-$ in the tuning circuit to $C+$ at the cathode).

As a result of the amplifying ability of the tube and its B voltage source, the modulated r.f. signal current flowing in the plate circuit of the first r.f. stage is much stronger than the antenna signal current. In Fig. *18* is a rough sketch showing this first r.f. stage as it might be drawn by a radio man.

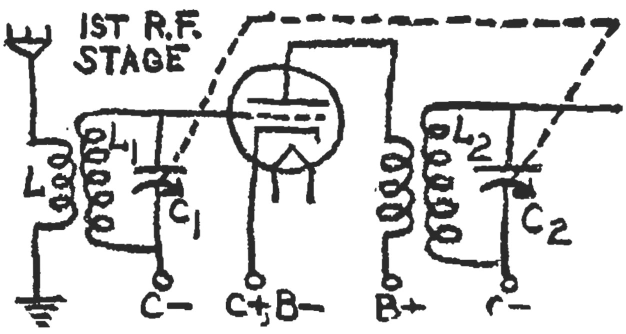


FIG. 18. The first r.f. stage of Fig. *17* is redrawn here as a guide for you to follow in preparing the rough sketch called for in Question 9. Your sketch can be even rougher than this; just be sure it shows the circuit correctly.

The second r.f. amplifier stage and the two remaining tuning circuits provide still more boosting of our signal, so that the signal voltage in tuning circuit $L_3$-$C_3$ is strong enough to be handled by the detector.

For the present, it is sufficient to understand that the r.f. amplifier in a t.r.f. receiver accepts and *steps up the voltage of a desired radio signal,* and also *keeps out undesired signals.* By using a sufficient number of tuned stages, complete rejection of undesired stations can be obtained.

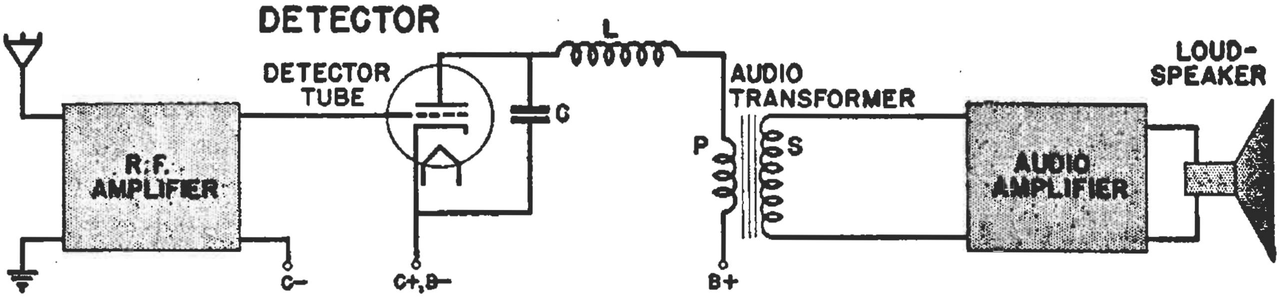


FIG. 19. Simplified detector circuit of a t.r.f. receiver.

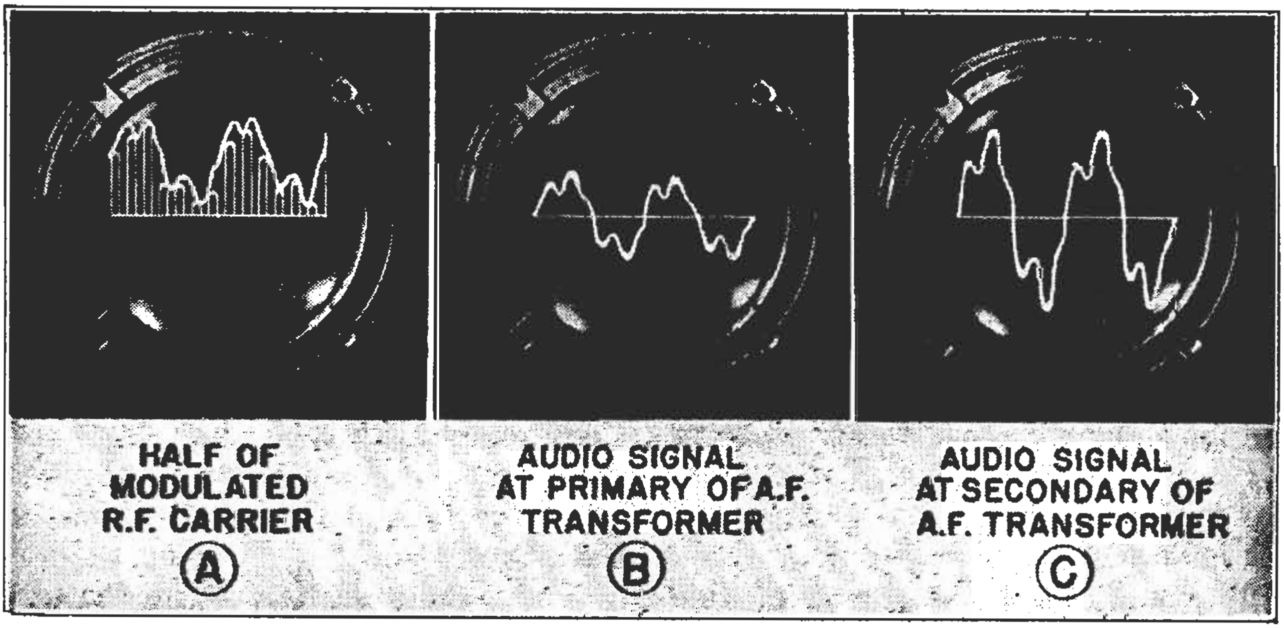
**The Detector.** Now that the modulated r.f. signal has been built up sufficiently in strength, the r.f. carrier signal is no longer needed; in fact, we must get rid of the r.f. carrier now, so it will not interfere with the operation of the remaining stages. We separate the audio signal from its r.f. carrier with a vacuum tube operated in a special manner in the *detector* stage. A simplified version of one common type of detector circuit is shown in Fig. *19*.

The modulated r.f. current which we feed into the detector is an alternating current, and its pattern on the screen of a cathode ray oscilloscope would be exactly the same as the modulated r.f. carrier pattern shown in Fig. *15C* for the transmitting antenna.

The detector tube allows the input signal voltage to act on the grid in one direction only. This has the effect of cutting off one entire half of this signal pattern, because it allows only half of each alternating current cycle to affect the plate current of the detector tube.

The signal pattern at the output of the detector tube would therefore be as shown in Fig. *20A*. This pattern represents a d.c. voltage which is always acting in the same direction, but is varying in value from zero to a maximum at an r.f. rate (many hundred thousand times each second). The maximum value at each instant is determined by the *audio signal*.

The job of getting rid of the r.f. variations in the detector output signal is taken care of by two simple radio parts, condenser *C* and coil *L*.


HALF OF MODULATED R.F. CARRIER Ⓐ

AUDIO SIGNAL AT PRIMARY OF A.F. TRANSFORMER Ⓑ

AUDIO SIGNAL AT SECONDARY OF A.F. TRANSFORMER Ⓒ

FIG. 20. Here is the story of how the audio signal is separated from its carrier in the detector stage of a t.r.f. receiver, as presented by patterns on the screen of a cathode ray oscilloscope.

The values (electrical characteristics) of these two parts are so chosen that condenser *C* lets r.f. signals pass through but blocks audio signals. Coil *L,* on the other hand, lets the audio signal pass through but blocks the r.f. signals. Together these two parts force r.f. signals to take the path through *C* from the plate to the cathode of the detector tube, and this is the end of the r.f. signal so far as our receiver is concerned.

The signal current which gets through coil *L* and also flows through the primary of the audio transformer in Fig. *19* is the *audio signal* we want. Its pattern is shown in Fig. *20B,* and is simply the pattern of Fig. *20A* with the vertical lines of the r.f. signal removed.

The audio transformer has more turns on its secondary than on its primary, and consequently it steps up the audio signal as well as transfers it to the next section, the audio amplifier. The pattern of our strengthened audio signal at the secondary of the audio transformer is shown in Fig. *20C.* Notice that this strengthened signal swings much farther above and below the horizontal zero line than does the signal in Fig. *20B;* this indicates the increased *strength* of the signal.

We thus secure from our detector circuit an audio signal like the original signal produced by the microphone. The one important fact to remember is that the detector in a radio receiver *separates the audio signal from its r.f. carrier.*

**The Audio Amplifier.** The audio output signal of the detector stage in a receiver is strong enough to operate headphones, but is usually too weak for loudspeaker operation.

We build up the strength of this audio signal in exactly the same way that we build up the strength of the microphone output signal in the transmitter, by means of audio amplifier stages using vacuum tubes.

A t.r.f. receiver may have one, two or even more a.f. amplifier stages; the more stages there are, the greater will be the audio signal power fed to the loudspeaker and the louder will be the maximum volume obtainable from the receiver. The last audio amplifier stage is often called the *output stage.*

The iron-core transformer which transfers the audio signal from the output stage to the loudspeaker is called the *output transformer.* The connections are shown in Fig. *21.*

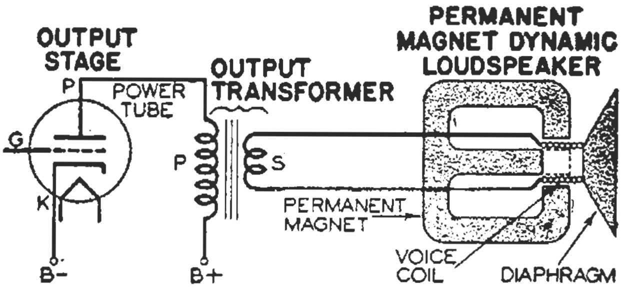


**FIG. 21. Here is a simplified version of the very last stage in a radio receiver. It connects the power tube (the last tube in the audio amplifier) to the loudspeaker.**

The output transformer is usually mounted directly on the loudspeaker, simply because this is a convenient position, but you will occasionally encounter sets which have the output transformer on the chassis.

For the present, all you need to know about the output transformer is that it supplies the correct signal voltage to the loudspeaker without too greatly affecting the operation of the output stage. Later, you will learn more about output transformers—why they are needed, why they are step-down transformers, and how they can affect the tone quality and volume of a receiver.

**The Loudspeaker.** The newest type of loudspeaker, known as a *permanent magnet* (p.m.) *dynamic loud-*

*speaker,* consists essentially of three parts: a powerful *permanent magnet,* a paper *cone,* and a *voice coil.* The voice coil is mounted at the center of the paper cone and is located between the poles of the permanent magnet, as indicated at the right in Fig. *21*.

When audio frequency current is sent through the voice coil of a p.m. dynamic loudspeaker, a magnetic field is produced by the coil. This magnetic field reacts with the magnetic field of the permanent magnet, with the result that the voice coil moves either in or out. Since the diaphragm is attached to the coil, the diaphragm moves also.

The movements of the voice coil correspond exactly to the variations in the audio current passing through the coil, and consequently the diaphragm vibrates at audio frequencies and produces sound waves.

The sound waves produced by the loudspeaker are the same kind as those which acted on the microphone in the radio studio. They vary in the same manner and affect our ears in the same way, so we hear at the receiver the very same sounds which are in the studio. No wonder people say it is the *magic* of radio which transfers sounds thousands of miles in a split second!

A p.m. dynamic loudspeaker is similar to a dynamic microphone. In fact, in most intercommunication systems employed in factories and stores, a special loudspeaker of this type also serves as a microphone. The talk-listen switch automatically connects the loudspeaker to the input of an audio amplifier for microphone operation, and to the output of the audio amplifier for loudspeaker operation.

The loudspeaker is the only part in a radio receiver which moves continually, and even its motion cannot be seen because it is so fast. In fact, all the signals in a radio system travel faster than a bolt of lightning.

Even though you can't see radio receiver parts move like parts in a locomotive or a threshing machine, you will soon be able to visualize plenty of action in radio circuits. As you become more familiar with the tubes, transformers, resistors, condensers and other parts used in radio, you will find yourself thinking of electrical actions in these parts—actions more exciting and more rapid than in any man-made engine. Radio will become *alive,* and you will develop an *enthusiasm* which makes your radio job a pleasure rather than a chore.

**Volume Control.** The average radio receiver, when tuned to a local station, is capable of producing far more volume than is required by listeners in homes. Furthermore, people like to vary the loudness of a radio program to suit the occasion; they want much more volume for a news broadcast than for background music which accompanies the conversational chatter of a dinner party. For these reasons, every radio receiver has a device which serves as the volume control. It is adjusted by a knob or lever on the front panel of the receiver.

When you turn down the volume of a radio receiver by rotating the volume control knob counter-clockwise, you are simply reducing the strength (voltage) of the signal which is being transferred from one point to another in the receiver. When you advance the volume control all the way, for reception of a distant or foreign station, you are simply using the full signal-boosting ability of the receiver.

**On-Off Switch.** Another control which you will find in every radio receiver is an *on-off switch* or *power switch.* This switch turns off the receiver by disconnecting it from the power line or other source of power. Assuming that our t.r.f. receiver operates from an a.c. power line, this switch would be located on the front panel of the receiver and would be connected into one of the leads of the receiver power cord.

Oftentimes the volume control knob also operates the on-off switch. Turning this knob a slight amount clockwise clicks on the switch, and further turning increases the volume.

**Power Pack.** An a.c. power line provides only an a.c. voltage, but the tube electrodes in a receiver require d.c. voltages like those obtainable from batteries. In order to change the a.c. line voltage into the various d.c. and lower a.c. voltage values required by the tubes, a special vacuum tube stage known as the *power pack* is needed in every receiver which operates from an a.c. power line.

Although receivers may have different types of power packs or may operate directly from batteries, you will find that all receivers—aircraft sets, auto radios, portable receivers, and others—have essentially the same signal circuits. This is indeed fortunate, for it means that you need to study only a limited number of signal circuits.

The vacuum tube used in a power pack is known as a *rectifier tube*. Its job is to convert the a.c. voltage into a *pulsating* d.c. voltage, which always acts in the same direction even though it rises and falls in value. Condensers and a coil acting together in a *filter circuit* smooth out the variations in this pulsating d.c. voltage, so as to give the *pure* (unvarying) d.c. voltage required by the tubes.

The other important duty of the power pack is to provide the correct low a.c. voltage for each tube filament. In your very next lesson, you will study several ways in which this is done.

**Avoiding Distortion of Sound.** The sound as reproduced by the loudspeaker of a radio receiver will be identical with the original sound picked up by the microphone in the broadcasting studio *only* if our audio signal varies in exactly the same way at all points on the long path between the studio and the home. One improper adjustment or one defect anywhere along this path can destroy the faithfulness of reproduction of the sound, making repairs necessary. This unnaturalness of a radio program coming from a loudspeaker is called *distortion*.

**Your Duty.** As a radio serviceman, it would be your duty to maintain the receiver end of this radio broadcasting chain in perfect condition. As a communications expert, you would be intrusted with the care of the transmitter end.

The only part of the radio signal path which is completely out of the hands of radio men is the space between the transmitting and receiving antennas. Here nature produces electrical storms which cause static interference. In addition, the reflecting layers high in the stratosphere shift up or down from time to time and cause fading of radio signals. But even these natural enemies of radio are gradually being conquered by radio engineers, with improved circuits, improved equipment, and a greater knowledge of radio.

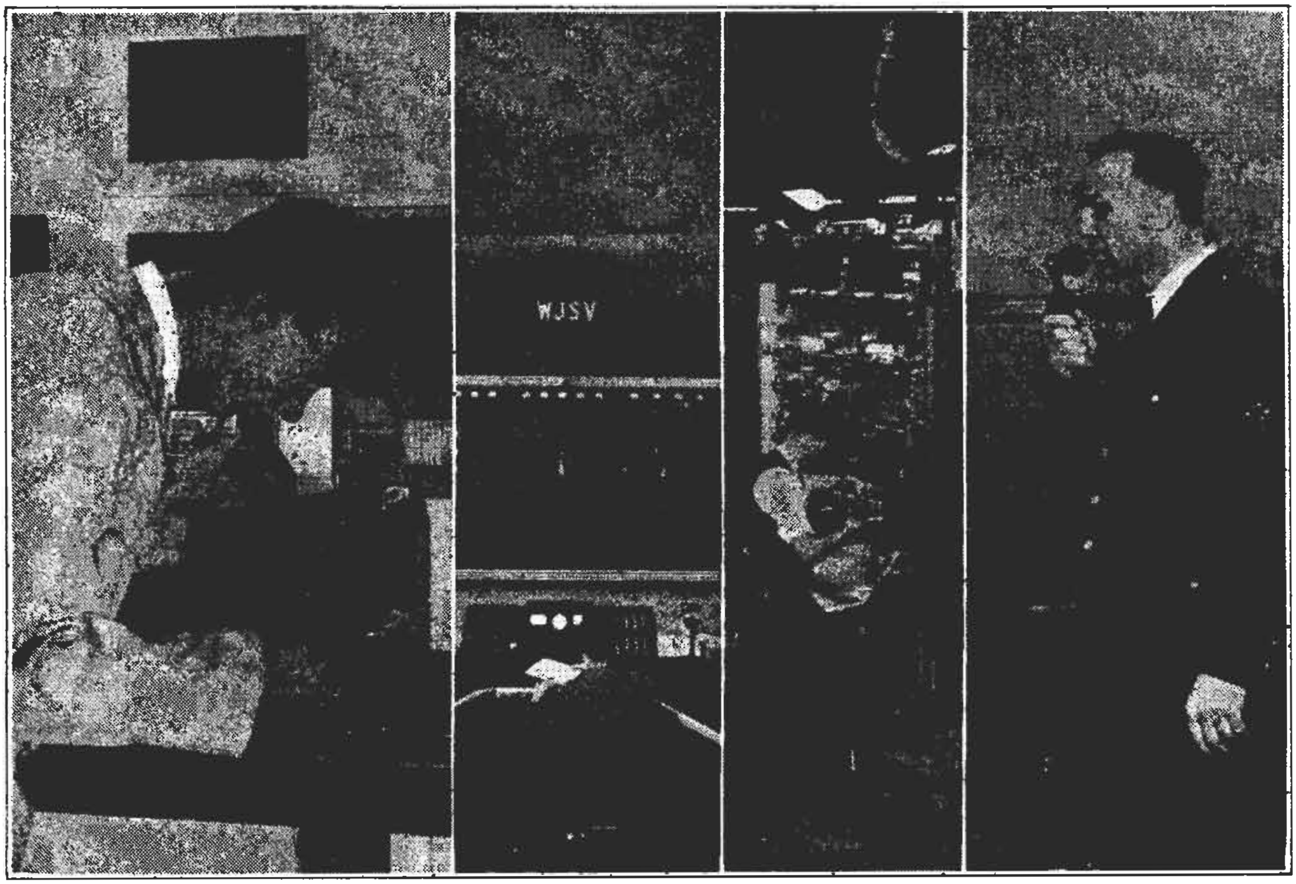
# A Review

A brief review of the process of sending and receiving a radio broadcast will tie together in your mind the various steps involved in sending a sound radio program from the studio to your home.

Starting at the studio, the performers produce sound waves. These are picked up by the microphone and converted into an audio signal having the same characteristics as the sound waves. This audio signal travels through the microphone cable to the control room, where it is amplified many times by vacuum tube amplifier stages.

The amplified audio signal is then fed over telephone lines to the transmitter proper, which may be many miles from the control room and studio. The audio signal undergoes additional amplification at the transmitter before it is fed into the modulated stage. A radio frequency carrier voltage, produced by a crystal oscillator and amplified by various r.f. amplifier stages, is also fed into the modulated stage.

The modulated r.f. carrier signal of the modulated stage is amplified further by r.f. amplifier stages, and the resulting strong modulated r.f. carrier signal is then fed to the transmitting antenna. The electrons vibrating in the transmitting antenna under the influence of this modulated r.f. carrier current produce vibrating electric and magnetic fields which travel out through space as radio waves.



RADIO RECEIVER SERVICEMAN

BROADCAST OPERATOR

FACTORY TECHNICIAN

AIRCRAFT RADIO OPERATOR

**Here are four important radio jobs for which this lesson gives essential background information.**

At a receiver location, the free electrons in the receiving antenna wire are set into vibration at the frequency of the radio waves. The result is a very weak modulated r.f. carrier current in the receiving antenna. This is amplified thousands of times by the r.f. amplifier stages in the receiver, after which the signal is sent into the detector.

The detector stage separates the audio signal from its r.f. carrier, and feeds only the audio signal into the audio amplifier. The audio amplifier in turn delivers a strong audio frequency current to the loudspeaker; this current causes the loudspeaker diaphragm to push and pull against the surrounding air, creating sound waves which are a true reproduction of the sound produced by the performers in the broadcasting studio.

## Looking Ahead

You have now obtained enough knowledge of radio to give you the necessary foundation for one of the most fascinating careers in the world —RADIO. Best of all, you didn't have to wade through fifteen or twenty lessons to get this information. You secured your foundation knowledge from just two lessons, because the N.R.I. Course gives you only *what you really need.*

You have now passed a real milestone, and you are certainly entitled to a satisfying feeling of accomplishment. At the same time, you have prepared yourself for the next milestone, which is a fascinating study of individual radio parts, circuits and meters. Here you will take up circuit details which were purposely saved for this next lesson, and study many other interesting arrangements of radio parts which are sometimes used in place of the circuits already studied.

In the next lesson you get a wealth of practical information about meters, which are the most valuable tools of all for radio men. You will learn exactly how meters are used in real radio circuits, and how they tell you what the invisible electrons and radio signals are doing in your circuits. The ease with which you master this next lesson will be additional proof of how much you have learned in such a short time.

You will also learn about practical battery connections such as are used in portable receivers, and about different ways of changing voltages from one value to another.

With the confidence and "feel" of radio you have already developed, you will be anxious to start the next lesson as quickly as possible. Therefore, turn back to the first page now and take care of those last few steps in the Study Schedule, so you can start on the next lesson while the important facts of the first two lessons are still fresh in your mind.

# Lesson Questions

**Be sure to number your Answer Sheet 2FR-5.**

**Place your Student Number on every Answer Sheet.**

***Send in your answers for this lesson immediately after you finish them.*** **Doing this insures that the graded answers will reach you while the subject matter is still fresh in your mind, and you will get the greatest possible benefit from our speedy personal grading service.** ***Never hold up a set of lesson answers.***

1. What is the approximate range of frequencies (the lowest and highest) which can be heard by human ears? 10.-20,000

2. What is the important purpose of a microphone? to Broadcast [illegible]

3. Write on your answer sheet the missing words which will correctly complete this statement:

   When the voice coil of a dynamic microphone moves in and out between the poles of the permanent magnet, an audio voltage is induced in the coil because the number of__________________________________ which pass through the coil is being changed.

4. Do the electrons in the voice coil of a dynamic microphone ever get into the transmitting antenna?

5. Name the two important signals which are combined in the modulated stage of a broadcast transmitter to produce the modulated r.f. carrier signal.

6. What *two kinds of fields* make up the radio waves (electromagnetic waves) which travel away from a transmitting antenna in all directions?

7. Is the modulated r.f. current in the receiving antenna STRONGER, WEAKER, or the SAME IN STRENGTH as the modulated r.f. current in the transmitting antenna? (*Only one of these three possible answers is correct. Write down on your answer sheet the one which you think is correct.*)

8. What are the *two* purposes of the r.f. amplifier section of a t.r.f. receiver?

9. Make a rough pencil or pen sketch of the simplified circuit given in Fig. *18* for the first r.f. stage of a t.r.f. receiver. (*Any convenient size will do.*)

10. What stage in a t.r.f. receiver separates the audio signal from its r.f. carrier signal?

# STUDY SCHEDULE NO. 2

**By dividing your study into the steps given below, you can master this part of your N.R.I. Course quickly and thoroughly. Check off each step when you finish it.**

☑ 1. **Read:—How This Lesson Will Help You..........................Page 1**

☐ 2. **Microphone in Studio..........................Pages 2-8**

Read once at an ordinary rate, then re-read slowly so you clearly understand what sound is, how it is produced, how it travels, what frequencies it includes, and how a microphone changes sound into audio signals. Answer Lesson Questions 1, 2 and 3 on page 29 now.

☐ 3. **Control Room..........................Pages 8-13**

Read the first time at your usual reading speed, then re-read slowly to secure a clear understanding of what an audio signal is and how the strength of a weak audio signal is boosted by the audio amplifier in the control room. Answer Lesson Question 4 now.

☐ 4. **Transmitter..........................Pages 13-18**

This is information which is included to complete your picture of a radio system. Let your own interests determine how much time to spend on this section; one thorough reading will ordinarily be sufficient. Answer Lesson Question 5 now.

☐ 5. **Transmitting Antenna..........................Pages 18-20**

Here is more information which you need to read only once. You should, however, get at least a general idea of what radio waves are. Answer Lesson Question 6 now.

☐ 6. **Receiving Antenna..........................Page 20**

You can master this short section in a short time and get a satisfactory understanding of how the receiving antenna feeds signal currents down to the receiver. Answer Lesson Question 7 now.

☐ 7. **Radio Receiver..........................Pages 21-26**

This is a highly important section both for servicemen and communications men, so read it slowly at least three times. A clear general idea of how a simple tuned radio frequency receiver changes antenna signals into sounds will help you to master later lessons, because basic receiver circuits are to be found in all types of radio equipment. Answer Questions 8, 9 and 10 now.

☐ 8. **A Review..........................Pages 27-28**

Read the review slowly several times to refresh your memory on the most important points covered in this lesson. A single reading will be enough for the "Looking Ahead" section, which is a short discussion of the practical radio information you are going to get from the next lesson and how much you have already obtained.

☐ 9. **Mail Your Answers for Lesson 2FR-5 to N. R. I. for Grading.**

☐ 10. **Start Studying the Next Lesson.**

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