RADIO AND TELEVISION INSTITUTE INC.

Practical Home Training in All Branches of Radio, Television and Talking Pictures

GENERAL WORK SHEET 31

CHICAGO, ILL., U. S. A.

Factors that Control Radio Reception from Distant Stations

"That station is eighteen hundred miles from here."

No other thrill in radio is quite so pleasant and quite so satisfying as to turn a tuning dial, hear the music come in, and then to hear an announcer give the call letters which let you turn to your friends and mention some great distance over which those signals are coming to you.

Most set owners will state that they are entirely satisfied with local reception--but they don't fool anyone. Just let them get some far away station so its program can be heard with loud speaker volume and they will boast of the fact to everyone who will listen. "DX" reception, which means reception from great distances, is well worth while. Therefore, in this lesson, we are going to find out just what things give a receiver "sensitivity," the quality which makes "DX" possible.

Fig. 1.

RANGE OF A RECEIVER.

The range of a set means the number of miles away a transmitter may be and still produce satisfactory volume from a loud speaker. The range depends on any number of things in addition to the receiver's own ability. It depends on the power of the transmitting station and on the station's location, on the time of year, on the kind of weather, on the time of day or of night and on the kind of country between transmitter and receiver. Everything shown in Fig. 1 affects the receiving range.

Fig. 2.

With one receiver located in a closely built up city and another located out in the country, both being at equal distances from a transmitter as in Fig. 2, the set out in the country will have much better reception than the one in the city.

These effects are caused by absorption of the signal energy in the things through which the radio waves must pass. The waves don't care whether they give up their energy to a radio antenna or to mountains, trees, buildings and such things. The energy goes into whatever the waves strike first, part of it being absorbed there and the remainder passing on to any receivers within range.

Should you look at a Government weather map you would see drawn upon it lines something like those shown in Fig. 3. Some of these lines are called "isotherms." The isotherms are drawn through points having equal temperatures at any one time, joining these places together. Other lines, those shown in Fig. 3, are called "isobars." The isobars join places which have equal pressures on the barometer at one time. You know a barometer is an instrument which assists in foretelling the kind of weather we are to have by measuring the pressure of the atmosphere.

Now, it seems that radio transmission is better between two places, both near one isobar than it is between places located on different isobars. In Fig. 3 we might expect good reception between Minneapolis and Chicago because these two places are near one isobar. But reception between Denver and Chicago might be poorer because the radio waves between these latter cities would have to cross several isobars, cross several changes in barometric pressure.

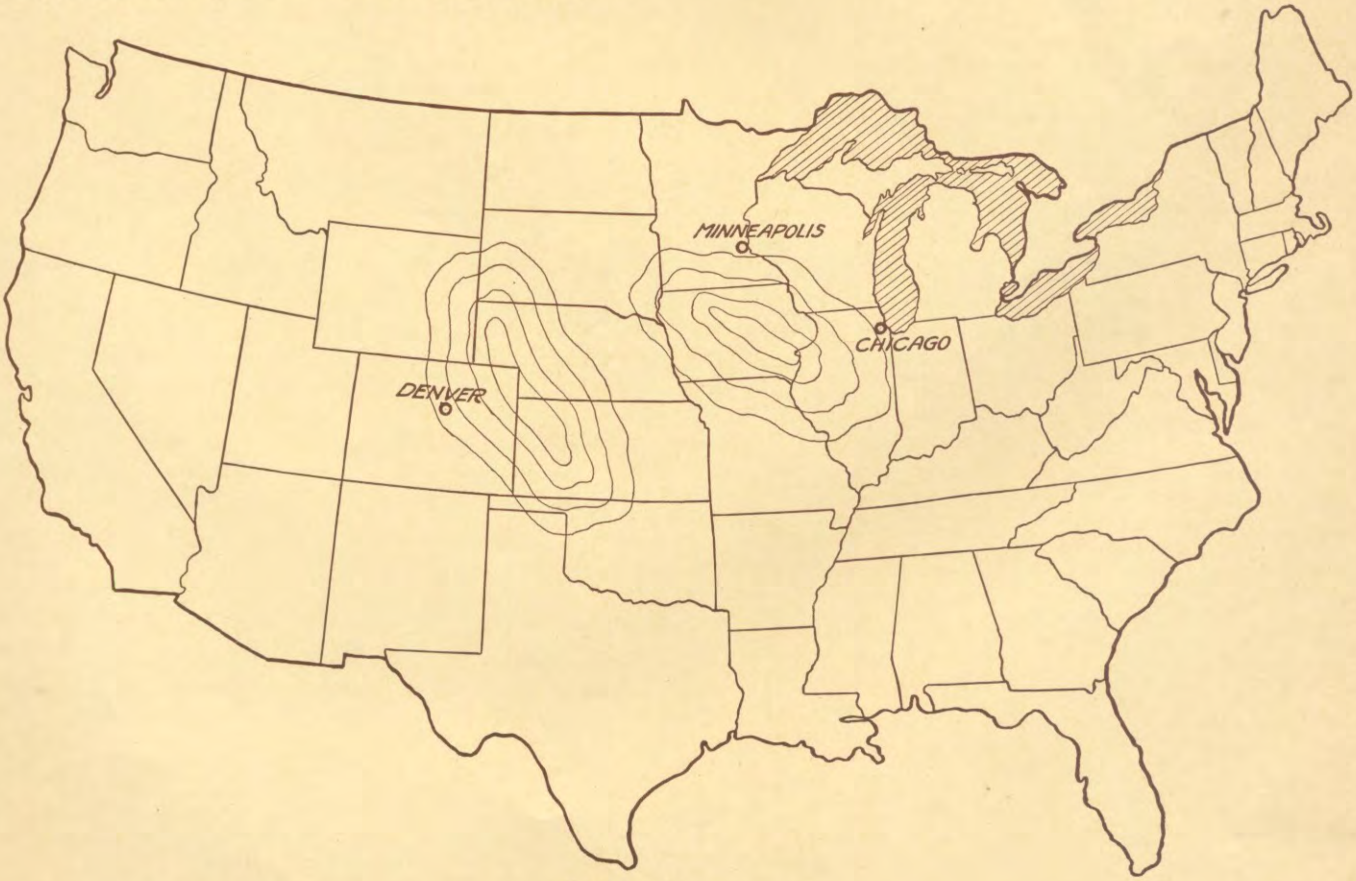

Fig. 3.

As you move farther and farther from a transmitter, the signals become weaker and weaker. As you move from a distance of say 10 miles to a distance of 50 miles the loss of strength is very rapid. As you get still farther away the strength continues to fall off, but not so rapidly. In Fig. 4 you can see a graph that shows approximately how the signal strength drops as the distance between transmitter and receiver increases. If you call the strength at 100 miles as equal to 100 per cent, then at

200 miles you will get a little less than 50 per cent or less than half the signal strength. The graph shows how the signal strength continues to fall with distance.

This drop in signal with increase of distance is caused by "attenuation" of the radio waves.

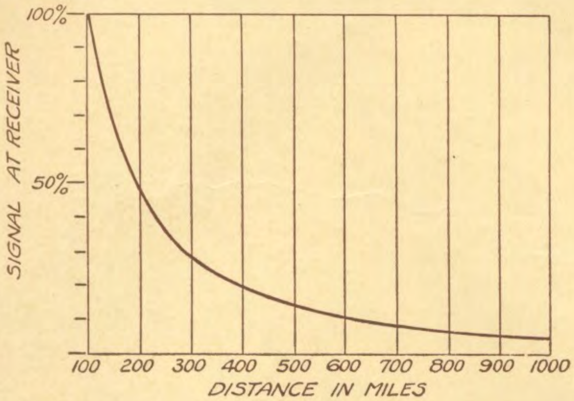

Fig. 4.

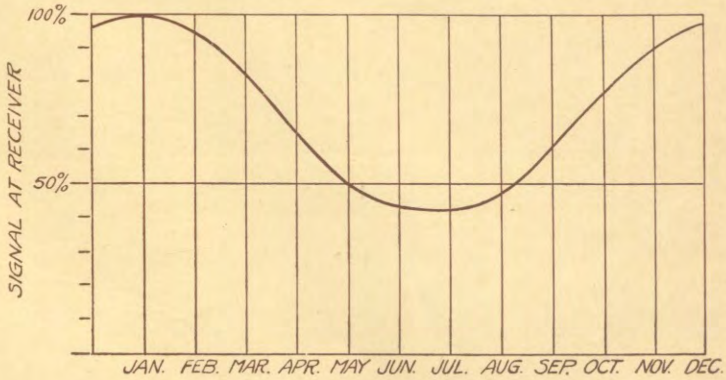

Fig. 5.

Radio reception is always better in cold weather than in warm. In our part of the world the best conditions come in January and the poorest in July. The curve in Fig. 5 shows how the signal strength varies with the seasons or with the months of the year. On the average, the ability of a receiving system is not half as good from May to August as it is during December, January and February.

Night reception is always better, so far as distance is concerned, than daytime reception. The curve in Fig. 6 represents about what you may expect in difference between daylight and darkness. Normally, the best reception will be had around midnight or shortly afterward. From early in the morning until evening commences, the reception from distant stations will be difficult.

EFFECT OF SIGNAL ON DISTANCE.

Transmitting stations are rated according to the power put into their antennas. Power is rated in watts, so we have stations of 1000 watts, of 5000 watts, of 10,000 watts and other wattages. In broadcast work stations of 500 watts power are among the smallest. Power of 5000 watts is quite common. The largest present day stations use 50,000 watts of power at certain times.

You might think that the range of a 5000-watt station would be five times that of a 1000-watt station, but you would be wrong. The service area of broadcasters varies approximately as the square root of their power ratings. The following list shows the distances over which fairly good service will be rendered by stations of several different powers:

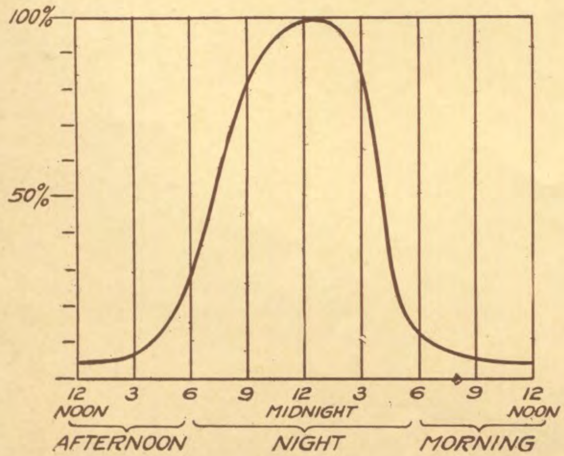

Fig. 6.

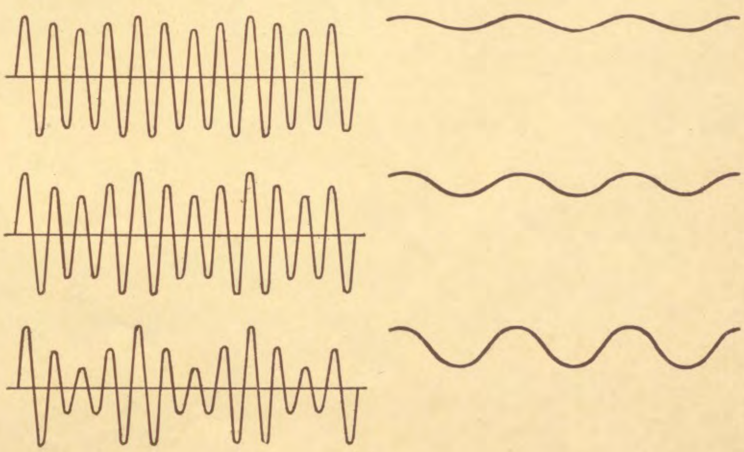

Fig. 7.

Station Power in Watts	Day Time Range	Night Time Range
500	10 miles	50 miles
1,000	35 "	200 "
5,000	75 "	400 "
10,000	100 "	600 "
25,000	160 "	1000 "
50,000	225 "	1300 "

From this table you can see that a station's power must be increased by about five times in order to double its distance range or service area.

The range of a station depends on many things besides its power in watts. Among the more important things is the amount of modulation put on the carrier wave. In Fig. 7 I have represented three different radio waves, one slightly modulated, another having greater modulation and the third quite deeply modulated.

Back in one of the very first lessons I told you how the audio frequency changes are combined with the carrier wave. The change in height or voltage of the carrier waves represents the changes in the audio frequency signal put on the carrier. The audio frequency changes for the three carriers in Fig. 7 are shown off toward the right hand side of the drawing. You can see that the changes in the audio part of the top wave are not very pronounced, are not very strong. You also see that the changes of the middle wave are stronger and those of the bottom wave are very strong. The bottom wave will cause a receiver to deliver much more volume than the other two.

STRENGTH OF THE SIGNAL.

So far we have been considering the things outside of the receiver itself which have a bearing on the reception from distant stations or on the volume which the set will deliver when tuned to any station. Now we are going to look into the receiver and find out what can be done to make it more sensitive so that it will amplify a given antenna signal to a greater degree.

In such an investigation we naturally commence with the signal coming to the antenna. The stronger this signal, the greater will be the volume from any kind of set. The signal strength is measured as the "field strength."

When we first studied the action by which radio waves are sent out we found that they spread away from the transmitter aerial as lines of force. These lines are in the form of two kinds of field, the electromagnetic field and the electrostatic field. The electromagnetic field consists of lines like those from a coil and the electrostatic field consists of lines like those between the plates of a condenser. The electromagnetic field dies away quite rapidly but the electrostatic field spreads out and out to great distances. The strength of this field is measured in microvolts per meter or sometimes in millivolts per meter. A microvolt is the one millionth part of a volt and a millivolt is the one thousandth part of a volt. The meter about which we are now talking is a measure of length equal to about thirty-nine and one-third inches, a little more than one yard. Now I will explain what is meant by this measure of field strength.

You remember that the antenna and ground shown at the left hand side of Fig. 8 are like the two plates of the big condenser shown at the right--also that the radio waves of the radio field comes along and makes a difference of voltage between these two plates. We went over all that in the early part of the course.

Then we can assume that the plates of the condenser in Fig. 9, representing the antenna-ground system of a set, are separated by a distance of one meter. A radio field is acting upon these plates and is producing a field between them. This field means a charge on the condenser plates and this charge, like any other charge, is measured in volts difference of potential between the plates. If, with the one meter separation, the field produces a potential difference of one volt, then the field strength is one volt per meter. If the difference is 1/1000 of a volt then the field strength is one millivolt per meter. Should the potential difference be one millionth of a volt the field strength is one microvolt per meter.

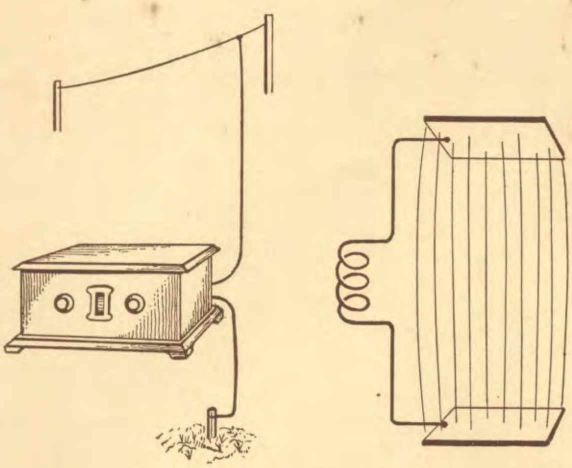

Fig. 8.

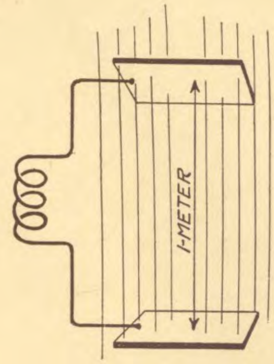

Fig. 9.

Fig. 10.

In Fig. 10 the condenser plates are separated by a distance of two meters. Now there is twice the voltage difference between the two plates. The field strength in Fig. 10 is the same as that in Fig. 9 because, of course, separating the antenna and ground plates doesn't make any difference in the radio field which is passing by. But the greater separation between the plates in Fig. 10 allows us to take advantage of more of the field, to enclose more of it between the plates, and consequently we have a greater potential difference between them.

The condenser plates in Figs. 9 and 10 represent the antenna and ground. The distance between the plates represents the electrical height or the effective height of the antenna. The greater this height the greater will be the voltage difference produced between antenna and ground with a given field strength.

The actual voltage produced in the antenna system is equal to the effective height of the antenna in meters multiplied by the field strength in volts, millivolts or microvolts.

The greater the potential on the antenna, the more current will flow in the antenna circuit. The amount of current which actually flows in the antenna circuit depends on the impedance of the antenna system. You recall that impedance is the combined effect of resistance and reactance. We can get rid of the reactance by tuning the antenna circuit to resonance at the frequency we wish to receive--then we will have left in the antenna circuit only its high frequency resistance.

With the antenna tuned to resonance, the current induced in its circuit is equal to the antenna voltage divided by the high frequency resistance. Here we are dealing with currents so small that we have to make measurements in millionths of amperes or in microamperes.

The sensitivity of a receiver is measured according to the number of microvolts per meter field strength it requires to produce a loud speaker signal of certain definite volume. Receivers built a few years ago required about 50 microvolts per meter to produce a signal which was just audible, which you could just hear distinctly. The latest receivers will produce just as much volume from the speaker with a field strength of only five microvolts per meter. That is the progress that has been made just recently and it is one of the reasons why there is always a market for the newer sets--this year's receivers are always so far ahead of last year's that there can be no comparison between their performances.

SENSITIVITY OF THE RECEIVER.

From what I have just told you about the current produced in the antenna circuit you realize that the less we can make the high frequency resistance of the antenna, the more current will be produced. The loud speaker volume depends on the current in the antenna circuit.

The high frequency resistance of the antenna is lessened by using large wire, by properly soldering all joints, by using high grade insulators properly placed, by making a good connection to a first class ground--in fact, by observing all the rules I gave you in the lessons on antennas. It's practically certain that within a mile of where you're sitting this minute there are many receivers from which the owners might get double the present volume if you were to do no more than fix up their antennas.

The sensitivity of the receiver depends on the amount of amplification it provides. As you learned, greater amplification is secured with coils of high inductance and tuning condensers of small capacity than with small coils and large condensers. Here too, we find a use for the "optimum coupling" about which I told you in another lesson. The optimum coupling transfers the greatest possible power from one circuit to the following circuit.

The greater the number of amplifying stages, the greater will be the total amplification and the greater the sensitivity. This applies both to radio frequency stages and to audio frequency stages. Tubes having high amplification factors or having a high "mu" will also add to the sensitivity.

One of the most important things to care for in increasing the sensitivity is to build all the parts so that the high frequency resistances are as low as possible. This means that we must use the highest grade insulation throughout, must properly proportion the parts and must use all the tricks of design and construction about which I will tell you as we come again to a study of coils, condensers and tubes.

Even after the receiver is designed and built there is a whole lot to be done by the service man in maintaining sensitivity. Dirty contacts on tubes, loose and dirty terminal connections of wires, dust and grime in general--all these are enemies of sensitivity and must be prevented if any set is to do its best work. In Fig. 11 I have indicated some of the things which affect sensitivity.

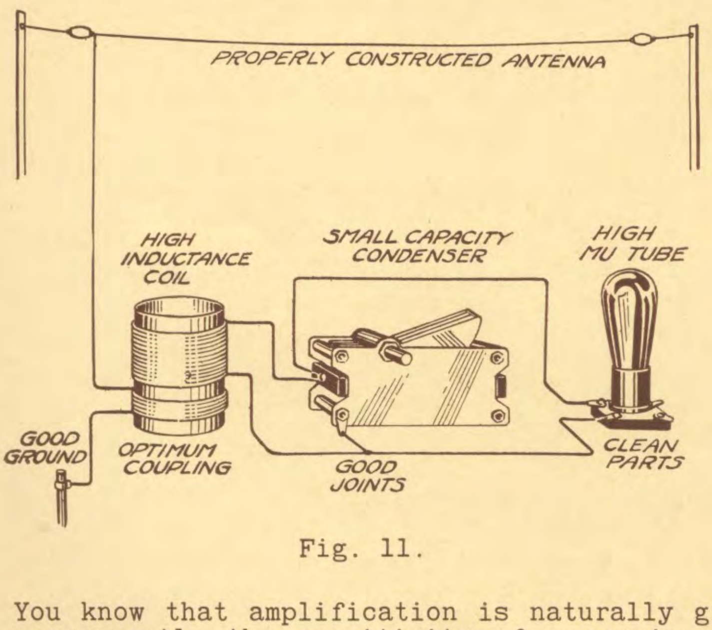

Fig. 11.

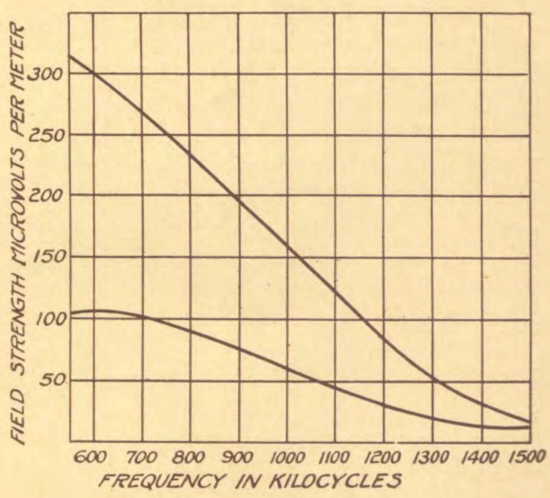

Fig. 12.

You know that amplification is naturally greater at high frequencies than at low, consequently the sensitivity of a receiver is also naturally greater at the high frequencies. In Fig. 12 you can see some typical sensitivity curves for different receivers. The sensitivity is measured in the number of microvolts per meter needed to produce audible volume at the different frequencies used in broadcasting. The upper curve shows the sensitivity of a poorly designed receiver. At the low frequencies this set needs a strong input; for example, at 600 kilocycles the field strength has to be 300 microvolts. Then, at the highest frequencies, the set is very sensitive, needing at 1500 kilocycles only about 12 microvolts to give an equal volume.

The lower curve shows the sensitivity of a modern, well designed and well built receiver. Here a field strength of about 100 microvolts per meter is needed at the lowest frequencies and a strength of about 8 microvolts at the other end of the band. The ideal sensitivity would mean a straight line calling for the same field strength at any point in the frequency band to produce a uniform output in volume.

These curves of Fig. 12 show the sensitivity with the receivers operated to the very best advantage. Proper tuning is more difficult with some receivers than with others. Some people can get a great deal more from a set than others can get with all conditions the same. Experience with one receiver generally lets the operator do better work than can be done by someone else handling the set for the first time.

ANTENNA COUPLING.

The degree of coupling between a coil in the antenna circuit and a coil in the first tuned circuit has a lot to do with sensitivity. The closer the coupling, up to the optimum point, the greater the sensitivity.

The antenna circuit always has a fairly large amount of high frequency resistance. There are so many parts in this circuit and they are placed in such unfavorable positions that a real low resistance circuit cannot be had. When this high resistance antenna circuit is closely coupled to the first tuned circuit, the resistance affects that tuned circuit and the receiver is not selective. Consequently we generally have to use a rather loose coupling for the antenna in spite of the fact that this makes us lose some strength.

On many receivers you will find two or more terminals marked "Antenna." One will be marked "Short Antenna" and another "Long Antenna." It is intended that a long antenna, one of fifty feet or more, shall be connected to the "long antenna" terminal while a shorter antenna shall use the other terminal. These terminals are connected as shown in Fig. 13. The antenna and ground act like a condenser, so placing the small fixed condenser in series with them makes the capacity of the antenna system less than when this condenser is not in the circuit. Connecting a long antenna to its proper terminal has the effect of shortening the electrical length and capacity, therefore, the antenna which is really long is made to act about like the one which is short.

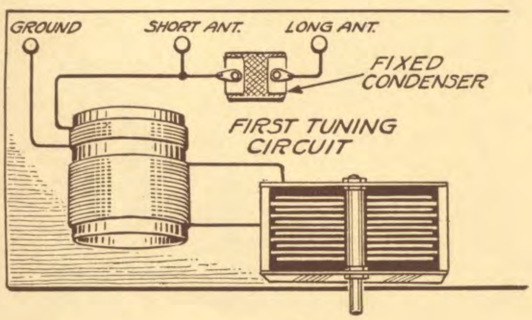

Fig. 13.

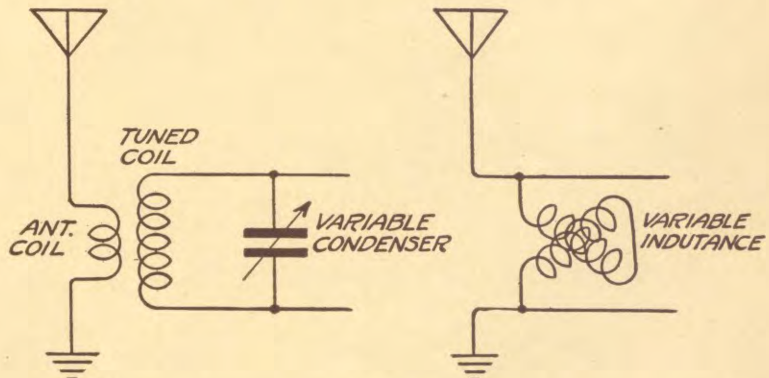

Fig. 14.

Connecting a long antenna to the "short antenna" terminal will make the receiver more sensitive but it may so change the tuning of one circuit that all the tuned circuits won't work properly together. In addition, this connection will make the set less selective. Connecting a short antenna to the "long antenna" terminal will make the set less sensitive, but it will become more selective at the same time.

Most antenna circuits are like the one at the left hand side of Fig. 14. The inductance or coil in the antenna circuit is not tuned. Of course, this coil is coupled to another one which is tuned and this gives somewhat the same effect as tuning the antenna coil--but this is only a comparatively weak tuning effect at best.

Other antenna circuits are designed like the one at the right hand side of Fig. 14. Here we have a variable inductance connected to the aerial and ground. The aerial and ground are the plates of a condenser and this condenser has a capacity which cannot be changed. But the variable inductance may be changed so that the antenna circuit is tuned to resonance at any frequency we wish to receive. This variable inductance consists of two coils arranged so that the coupling between them may be changed. Later on I will tell you all about this device, which is generally called a "variometer."

Tuning the antenna circuit to resonance balances out the reactances so that nothing but the high frequency resistance is left to oppose the flow of current. This plan increases the antenna current greatly, consequently increases the sensitivity of the set.

TUBE LIFE.

The sensitivity of a receiver will be greatest when the tubes are new because then there is the greatest emission of electrons from the filament or cathode and the vacuum within the bulb is at its best. As the tube is used, the filament gradually wastes away and the materials which produce the emission are lost. The output of the tube is thus reduced as it grows older until finally this effect makes a noticeable difference in the receiver's performance.

Tubes are supposed to last for at least 1,000 hours of use. Nearly any first class tube will last longer than this and still give good results. Poor tubes will last only a few hundred hours at most.

The life of a tube will be long when the voltage applied to the filament or to the heater is no higher than that for which the tube is designed. Voltages more than five per cent above the rated value will shorten the life of any tube. Voltages slightly below the rated value will allow the tube to have a longer life, but its performance will not be quite up to the mark.

As a tube comes toward the end of its useful life the sensitivity of the receiver will fall off. In addition to this effect, the tone quality will commence to get decidedly bad. When a tube is completely worn out the signals from the loud speaker will be badly distorted, will sound "thin," rasping and harsh. To keep a set at its best the tubes really should be replaced with new ones every thousand hours of operation or about every year of average use.

GAIN IN TUNED CIRCUITS.

When we were studying resonance it appeared that circuits like those in Fig. 15 had induced in them currents which were quite large and which flowed back and forth between coil and condenser or which circulated entirely within the tuned circuit. We found that the application of a rather small voltage to one of these circuits would cause a large current to flow within the circuit, and that this large current produced a great drop of voltage across the ends of the coil as the current flowed through the reactance of the coil. The ratio between the original small voltage and the voltage which appears across the coil is called the "gain" of the circuit. Oftentimes you will hear about circuits having a "high gain" or about "low gain circuits."

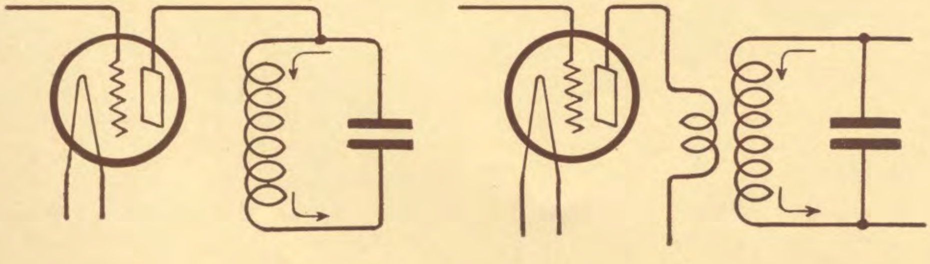

Fig. 15.

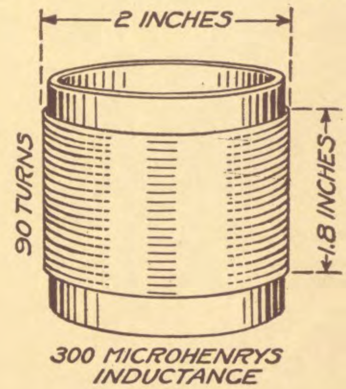

Fig. 16.

When an oscillatory circuit containing a coil and a condenser is tuned to resonance, the reactance disappears and only the high frequency resistance remains. The current which circulates in the circuit is then equal to the applied voltage divided by the high frequency resistance in ohms. (We went over all this in the lesson on resonance --if you don't recall it, you should go back and study that lesson over again.)

To take a practical example, we will work with the coil shown in Fig. 16. We have 90 turns of number 26 double silk covered wire on a tube giving a diameter of two inches. The inductance of this coil is almost exactly 300 microhenries. Measuring the high frequency resistance of this coil we find it to be as follows at several of the common frequencies:

550 kilocycles	4.5 ohms
750 kilocycles	6.0 ohms
1000 kilocycles	8.0 ohms
1250 kilocycles	10.5 ohms
1500 kilocycles	17.5 ohms

If we assume that a potential of 10 volts is applied to an oscillatory circuit containing this coil it appears that the current in the circuit at 1000 kilocycles will be 10 (volts) divided by 8 (high frequency ohms), giving as a result $1\frac{1}{4}$ or 1.25 ampere.

The reactance of a 300-microhenry coil at 1000 kilocycles is about 1884 ohms. Sending a current of 1.25 ampere through a reactance of 1884 ohms produces a voltage drop of 2355 volts. This is true because the voltage drop is equal to the current in amperes multiplied by the number of ohms in a circuit or part of a circuit. Now we have an original voltage of 10 producing a voltage of 2355. Dividing 2355 by 10 gives us 235.5, which is the "gain" of this circuit at 1000 kilocycles frequency.

In place of going through all this figuring, we can use a formula to tell us the gain:

$$\text{Gain} = \frac{\text{Kilocycles x Microhenrys in Coil}}{\text{159 x Ohms of High Frequency Resistance}} \qquad (1)$$

Using this formula it appears that the gain of a circuit using the coil of Fig. 16 at various frequencies is as follows:

At 550 kilocycles	230
At 750 kilocycles	236
At 1000 kilocycles	236
At 1250 kilocycles	224
At 1500 kilocycles	161

From a frequency of 550 kilocycles up to well above 1000 kilocycles the gain remains almost unchanged. But then, at higher frequencies, the rapidly increasing resistance which I showed you in the first table commences to get the best of the argument and the gain falls off quite rapidly.

This tuned circuit gain is really a measure of the coil's efficiency at various frequencies. The greater the inductance and the less the high frequency resistance, the better gain we will get all the way across the frequency band.

STATIC.

A person naturally would think that it is necessary only to increase a receiver's sensitivity to a high enough value and to then reproduce the signals from any transmitter, no matter how far away that transmitter might be. But we quite quickly would come to a point beyond which extra sensitivity does us no good at all.

A receiver takes in and amplifies all the radio waves which come to its antenna. Some of these waves are produced by broadcasters and other transmitting stations which we wish to hear, others are produced by interference of the kinds we studied in one of the earlier lessons, while still other waves are caused by atmospheric disturbances which come from lightning and other electrical discharges in the air.

Electric waves which are caused by natural things are called "static." They also may be called "strays" or "atmospherics."

There is a certain amount of static in the air at all times. Sometimes there is only a little static, then again there may be a great deal. The field strength of the static waves is called the "static level." During an electrical storm the static level is very high. When the weather is changing from hot to cool or the other way around, or when the weather is quite warm, and during the period around sunset the static level is rather high.

The static waves cover the whole frequency band. No kind of tuned circuit and no number of cascaded tuned stages in an amplifier will tune out the static. The most selective receiver ever made will receive and amplify the static, no matter what frequency the amplifier may be set to handle. The carrier wave from a transmitter is nice and regular as at the left hand side of Fig. 17 but the static impulses are of all kinds, about as indicated at the right hand side of Fig. 17.

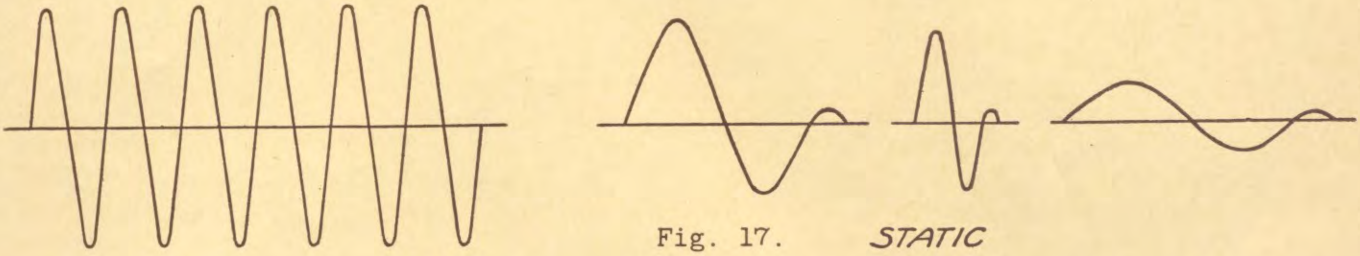

Fig. 17. STATIC

In Fig. 18 I have represented two carrier waves, "A" and "B," with their field strengths indicated by the distance of the lines above the base. Say the strength of station "A" is 15 microvolts per meter and that of station "B" is only 5 microvolts per meter. If the receiver amplifies all these waves equally the sounds from the loud speaker will be in proportion to the three field strengths.

The sounds from station "A" will be half again louder than the static and this station can be heard fairly well. But the sounds from station "B" will be only half as loud as the static noise and station "B" can hardly be heard at all. No matter how great the receiver's amplification, no matter how great its sensitivity, all three things will be multiplied together and the louder we try to make station "B" the louder we make the static at the same time. You can never bring station "B" above the static level as long as its field strength is below the static level to begin with.

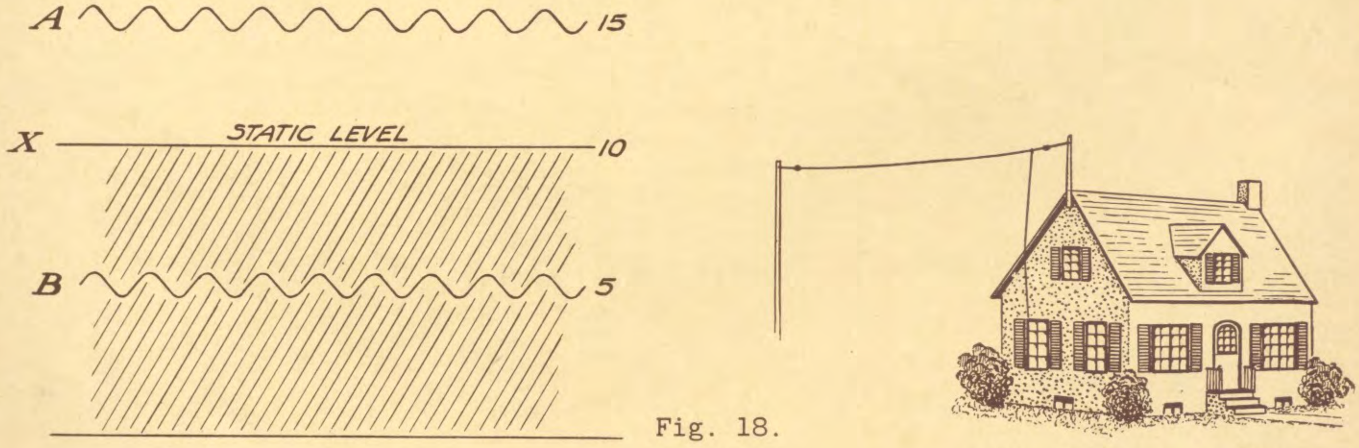

Fig. 18.

It is this static level which limits the useful sensitivity and amplification of a receiver. When a set is good enough to reach down to the static level, that's all there is to it. If the static level is high enough so that all transmitters more than 1,000 miles away produce a field strength below that of the static, then no amount of sensitivity will bring in stations more than 1,000 miles away because they always will be weaker than the static.

The only way to overcome this difficulty is to have transmitters of greater power. If a certain station having a power of 5,000 watts is just beyond the range of a set because its field strength is below the static level, raising that station's power to 10,000 watts or more will let you receive it satisfactorily. The higher the power used by transmitters, the easier our radio reception will become.

Static produces noises which may be classed as crashes, snapping, rattling and continual crackling. Sounds which are almost exactly similar are produced by loose connections and dirty joints in the set, so before you assume that static is causing the trouble you had better investigate the condition of things inside the receiver.

Many schemes have been devised for the reduction of static while holding onto the signal. Most of them work on the principle of taking the static into two circuits and balancing the energy of one circuit against that of the other so that the static disappears. All of these devices have been complicated, adding a great deal of cost to the receiving apparatus. They have not proved very satisfactory and as a result none of them has come into common use.

When receiving a program with the static rather strong, the farther you get from the loud speaker the less static and more signal you will hear. Therefore, placing the loud speaker in an adjoining room will appear to reduce the static. Slightly detuning the set will often help matters. Detuning means to turn the dial a little ways off the setting for exact resonance.

While static is bad the volume control should be turned down as far as possible while still leaving fairly good program reception. Many receivers control the volume by means of a variable resistor connected between antenna and ground. This method, which is shown in Fig. 19, is of considerable help in reducing the noise. You can attach such a variable resistance to any set. The maximum value should be about 5,000 to 10,000 ohms. The volume will be greatest when the resistor is turned to give the greatest resistance. As the resistance is lessened, more and more of the signal current passes to ground through it and less of the signal goes into the set.

FADING OF SIGNALS.

Have you ever listened to a distant station, heard it come in very loud for a minute or two, then gradually fade away until the signal could hardly be heard no matter what you did with the volume control? That effect is caused by "fading" and now I will tell you how it comes about.

Somewhere about one hundred or two hundred miles above the surface is a layer of air which has been "ionized." Ionization means that electrons have collided with atoms of a gas and have caused other electrons to become separated from the atoms. The electrons which do the colliding come from the sun's rays.

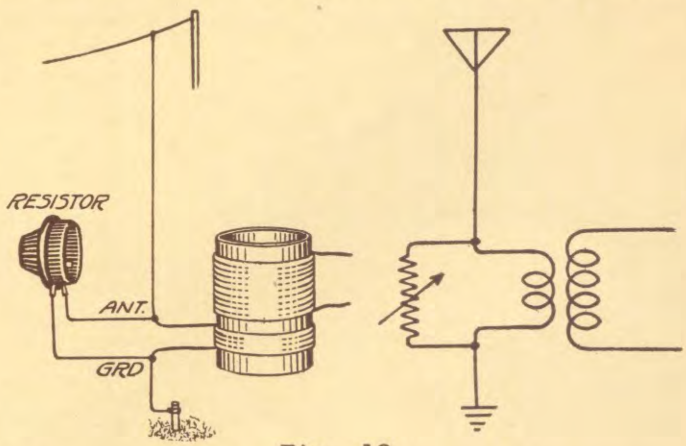

Fig. 19.

The ionized air is a fair electrical conductor. Ordinary air down around us here is not ionized, is not a conductor, and is a very good insulator. From the layer of conducting air the radio waves are reflected very much as light is reflected from a mirror. The ionized air is called the Kennelly-Heaviside layer, after the two men who worked out the idea of its existance.

After the radio waves get quite a ways from the transmitter we find that they have spread through all the space between the earth and the ionized layer. Waves travelling near the surface of the earth are called the "ground wave." The other part goes up into the sky until it strikes the Kennelly-Heaviside layer. That part is called the "sky wave" or the "reflected wave."

Now look at Fig. 20. I have represented the two waves, ground wave and reflected wave, passing from a transmitter to a receiver. The reflected wave goes up until it hits the ionized layer and is then reflected back downward. The reflected wave has to travel a greater distance than the ground wave between transmitter and receiver. If wave "a" and wave "b" leave the transmitter together, wave "a" will get to the receiver a little later than "b" because "a" has to go up to the ionized layer and back again. Then these two waves will arrive at the receiver in the relative positions shown by "c" and "d".

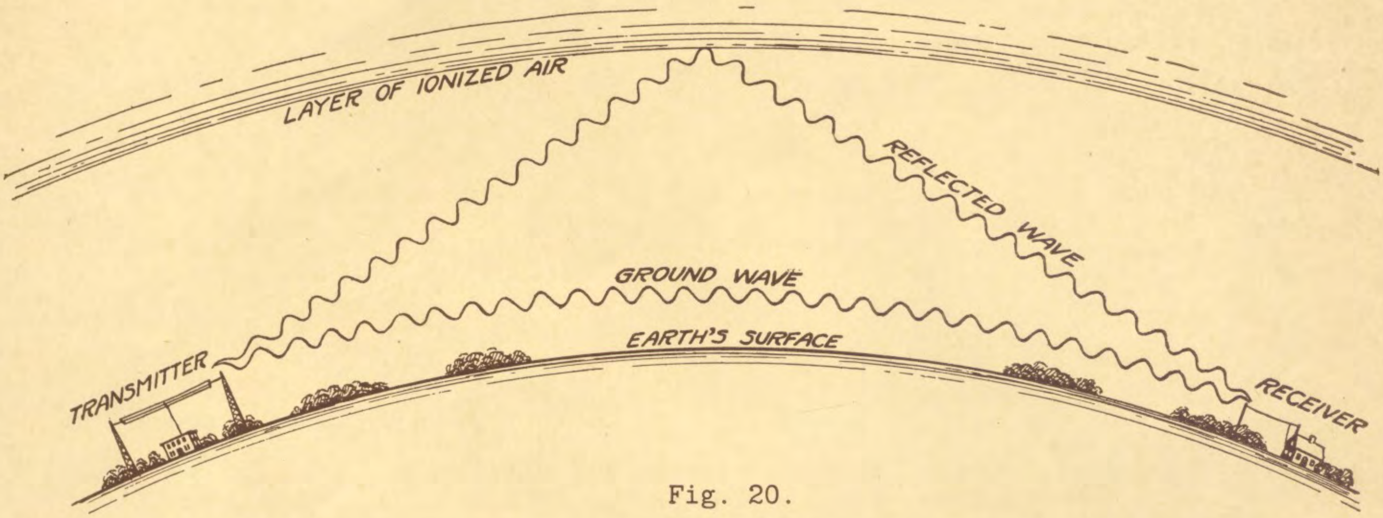

Fig. 20.

In Fig. 21 I have shown how the two parts of the signal wave might come to the receiver's antenna. Notice that the sky wave's voltage is positive just when the ground wave's voltage is negative. If the two voltages are of equal strength, they will balance each other and no current will be produced in the antenna. Consequently we would hear no signal.

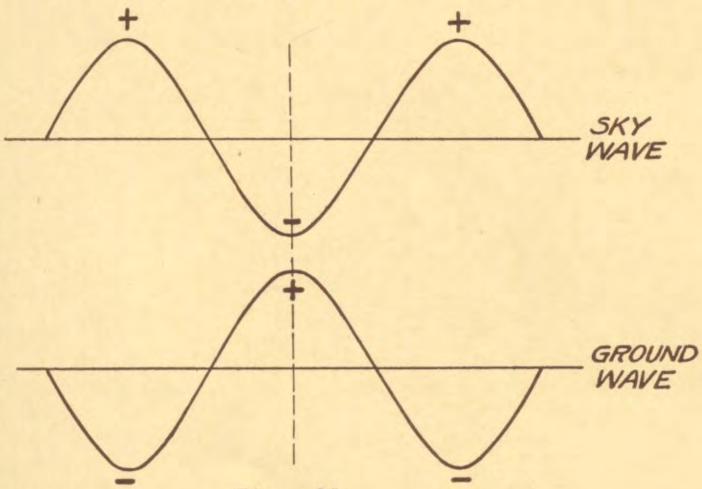

Fig. 21.

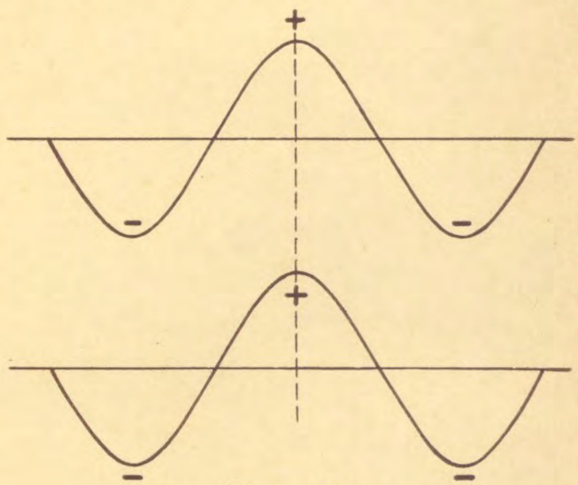

Fig. 22.

But now supposing that the sky wave gets to the antenna either a little sooner or a little later. Then the two waves might come in as shown in Fig. 22. Now their voltages come together, both positive and both negative at one time. The voltages add together and a strong current is produced in the antenna. This would make the signal very loud.

The ionized layer does not remain smooth and regular as shown in Fig. 20 but actually tosses and heaves like the waves on the ocean. The effect is somewhat like that shown by Fig. 23. Waves in the direction of arrow "A" will never reach the receiver. Waves following arrow "B" will strike the receiver's aerial. Wave "C" will pass beyond the receiver without doing any good.

Movement of the ionized layer produces all kinds of queer effects in radio reception from distant stations. If you are very near a transmitter your signals come mostly from the ground wave and are steady and regular. If you get a long ways from the transmitter, the ground wave is very, very weak and nearly all the signal comes from the reflected wave. It is when the signal is delivered by the reflected wave that movement of the ionized layer of air plays many tricks. The volume or the field strength will rise and fall. There will be anywhere from one to ten minutes between times of great signal strength and of very little strength.

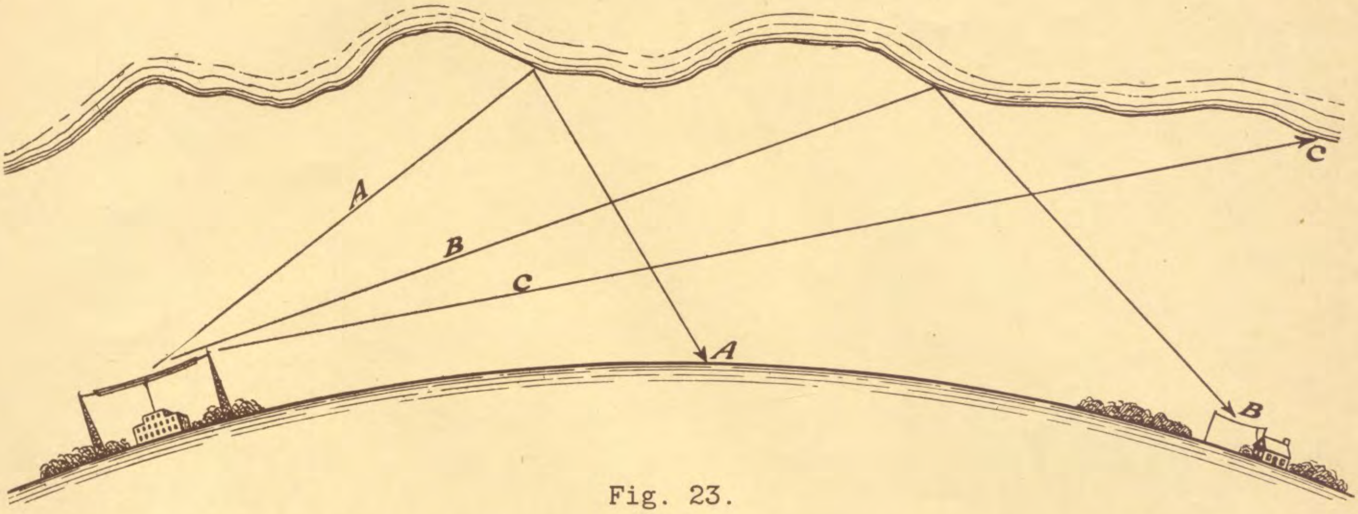

Fig. 23.

Fading is always worse at night than in the daytime. Radio waves lose their strength after traveling only a short distance in the daytime. But after dark the waves travel out to great distances. Then you can receive stations which are far away but you are quite likely to be bothered with fading.

Inasmuch as radio waves do not travel on through the Kennelly-Heaviside layer but are reflected back from it toward the earth, all the ideas about sending radio signals to other planets, such as Mars, seem to have little chance of being successful. The ionized air makes a casing around our earth through which no radio waves have ever been proved to penetrate.

The carrier frequency has quite a little to do with the distance over which radio signals may be received satisfactorily. In the broadcast band of frequencies we get the best distance with the lowest frequencies and the least distance with the highest frequencies. A 550-kilocycle signal goes about sixty per cent farther than a 1500-kilocycle signal.

As the frequency is increased above 1500 kilocycles the distance range commences to increase and it increases very rapidly until it is greatest between frequencies of 7500 kilocycles (40 meters wavelength) and 10,000 kilocycles (30 meters).

From all I have told you in this lesson you can see that reception from great distances depends on many things outside of the receiver itself. Very fine performance may be due to exceptional conditions, to the receiver's having a good location, to absence of static, to good weather conditions and to favorable land and water formations between transmitter and receiver. Poor performance may not mean that there is anything at all wrong with the set--it may mean that all the conditions are exceptionally bad and that no receiver could do good work.

At the end of this lesson I am giving you a data sheet on the air line distances between many of the more important cities. This table will let you check up on the performance you get by telling just how many miles away is the transmitter from which you are getting signals.

In the next lesson we will find out how the different kinds of batteries do their work. Batteries are still the source of power for hundreds of thousands of receivers in districts where no central station current can be had and also in the hands of owners who are still satisfied with the work being done by their old battery-operated sets. Then we will be ready to go back onto the subject of tubes and will make detailed studies of all the types now being used.

DATA SHEET.

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AIR LINE DISTANCES

In Miles

To– / From	Atlanta Ga.	Boston Mass.	Chicago Ill.	Cincinnati Ohio	Cleveland Ohio	Denver Colo.	Des Moines Iowa	Detroit Mich.	Fort Worth Texas	Kansas City Mo.	Los Angeles Cal.	Louisville Ky.
Atlanta, Ga.	....	935	590	375	550	1210	740	600	750	675	1940	320
Baltimore, Md.	580	350	600	420	310	1500	915	405	1240	965	2315	500
Boise, Idaho	1830	2270	1455	1665	1755	640	1160	1670	1265	1160	665	1625
Boston, Mass.	935	....	840	725	540	1765	1160	600	1575	1250	2595	825
Buffalo, N. Y.	700	400	450	390	175	1370	765	215	1220	865	2200	485
Chicago, Ill.	590	840	....	250	300	900	300	235	810	400	1725	270
Cincinnati, O.	375	725	250	....	220	1075	500	225	820	540	1875	90
Cleveland, O.	550	540	300	220	....	1205	605	90	1025	690	2015	305
Denver, Colo.	1210	1765	900	1075	1205	....	610	1140	645	555	830	1035
Des Moines, Ia.	740	1160	300	500	605	610	....	540	640	180	1435	480
Detroit, Mich.	600	600	235	225	90	1140	540	....	1005	645	1975	315
El Paso, Texas	1295	2065	1250	1335	1520	555	980	1475	545	835	700	1255
Fargo, N. D.	1110	1305	5700	820	840	640	395	745	975	550	1425	820
Fort Worth, Tex.	750	1575	810	820	1025	645	640	1005	....	460	1210	750
Galveston, Tex.	690	1580	945	890	1100	925	850	1100	285	675	1425	805
Hastings, Neb.	900	1405	560	735	860	355	255	795	545	225	1175	695
Hot Springs, Ark.	500	1280	575	550	765	750	490	745	275	325	1435	490
Jacksonville, Fla.	285	1015	860	630	770	1470	1025	830	945	950	2155	595
Kansas City, Mo.	675	1230	400	540	690	555	180	645	460	....	1350	480
Los Angeles, Cal.	1940	2595	1725	1875	2015	830	1435	1975	1210	1350	....	1825
Louisville, Ky.	320	85	270	90	305	1035	480	315	750	480	1825	....
Memphis, Tenn.	335	1125	475	410	625	880	485	615	450	370	1600	320
Miami, Fla.	610	1275	1175	950	1080	1730	1340	1150	1150	1245	2355	925
Minneapolis, Minn.	905	1110	355	600	625	700	235	540	870	415	1520	605
Nashville, Tenn.	220	940	395	240	455	1020	525	470	645	470	1775	155
New Orleans, La.	425	1335	825	700	915	1080	825	930	470	680	1675	625
New York, N. Y.	740	190	705	555	400	1600	1010	475	1375	1075	2425	650
Norfolk, Va.	505	465	695	475	430	1560	985	520	1225	1010	2350	530
Oklahoma, Okla.	755	1490	690	755	945	505	470	905	190	295	1180	675
Omaha, Neb.	815	1260	425	625	735	485	120	660	590	165	1310	580
Philadelphia, Pa.	660	265	655	495	355	1550	965	440	1310	1025	2360	570
Pittsburgh, Pa.	525	475	415	255	115	1300	705	210	1085	775	2115	345
Portland, Maine	1022	100	890	800	605	1805	1195	655	1640	1300	2360	890
Portland, Ore.	2170	2500	1725	1960	2030	985	1480	1935	1610	1395	825	1955
Richmond, Va.	470	470	620	400	355	1490	905	445	1170	935	2285	455
St. Louis, Mo.	470	1025	255	315	485	775	260	450	560	225	1570	250
Salt Lake, Utah	1580	2075	1250	1440	1550	370	950	1475	975	920	575	1400
S.Francisco,Cal.	2135	2640	1815	1995	2115	945	1545	2040	1455	1500	345	1985
Seattle, Wash.	2180	2460	1710	1950	2000	1020	1470	1920	1660	1505	955	1945
Washington, D. C.	535	385	590	400	300	1475	990	395	1190	925	2255	465

DATA SHEET.

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AIR LINE DISTANCES

In Miles

From \ To–	Miami Fla.	Minneapolis Minn.	New Orleans La.	New York N.Y.	Omaha Neb.	Philadelphia Pa.	Pittsburgh Pa.	Portland Ore.	San Francisco Cal.	Seattle Wash.	St. Louis Mo.	Washington D.C.
Atlanta, Ga.	610	905	425	740	815	660	525	2170	2135	2180	470	535
Baltimore, Md.	960	950	1000	170	1025	90	195	2365	2450	2340	730	35
Boise, Idaho	2370	1140	1715	2155	1045	2115	1865	350	515	405	1390	2045
Boston, Mass.	1275	1110	1335	190	1260	265	475	2500	2640	2460	1025	385
Buffalo, N. Y.	1185	735	1085	295	885	285	180	2165	2300	2130	650	295
Chicago, Ill.	1175	355	825	705	425	655	415	1725	1815	1710	255	590
Cincinnati, O.	950	600	700	555	625	495	255	1960	1995	1950	315	400
Cleveland, O.	1080	625	915	400	735	355	115	2030	2115	2000	485	300
Denver, Colo.	1730	700	1080	1600	485	1550	1300	985	945	1020	775	1475
Des Moines, Ia.	1340	235	825	1010	120	965	705	1480	1545	1470	260	890
Detroit, Mich.	1150	540	930	475	660	440	210	1935	2040	1920	450	395
El Paso, Texas	1660	1155	985	1900	875	1835	1590	1285	995	1375	1035	1725
Fargo, N. D.	1720	220	1220	1215	390	1185	950	1250	1445	1205	660	1140
Fort Worth, Tex.	1150	870	470	1375	590	1310	1085	1610	1455	1660	560	1190
Galveston, Tex.	940	1085	290	1385	830	1315	1125	1885	1695	1940	690	1200
Hastings, Neb.	1470	400	870	1265	135	1210	960	1270	1295	1290	445	1120
Hot Springs, Ark.	985	720	360	1105	490	1030	820	1735	1650	1760	340	925
Jacksonville, Fla.	330	1190	510	840	1100	760	705	2440	2375	2450	755	645
Kansas City, Mo.	145	415	680	1075	165	1025	775	1395	1500	1505	225	925
Los Angeles, Cal.	2355	1520	1675	2425	1310	2360	2115	825	345	955	1570	2255
Louisville, Ky.	925	605	625	650	580	570	345	1955	1985	1945	250	465
Memphis, Tenn.	880	700	360	950	530	875	650	1850	1800	1865	240	750
Miami, Fla.	....	1515	680	1100	1400	1025	1015	2715	2605	2740	1075	925
Minneapolis, Minn.	1515	....	1050	1010	290	975	740	1435	1585	1405	460	925
Nashville, Tenn.	820	695	470	760	605	685	470	1970	1960	1975	255	565
New Orleans, La.	680	1050	....	1160	845	1075	910	2065	1925	2100	605	950
New York, N. Y.	1100	1010	1160	....	1135	80	305	2420	2515	2385	870	200
Norfolk, Va.	800	1045	930	295	1095	220	315	2460	2510	2440	770	145
Oklahoma, Neb.	1235	690	575	1325	405	1255	1015	1490	1385	1525	455	1150
Omaha, Neb.	530	290	845	1135	....	1080	835	1375	1425	1370	1350	1010
Philadelphia, Pa.	1025	975	1075	80	1080	....	250	2375	2465	2360	800	120
Pittsburgh, Pa.	1015	740	910	305	835	250	....	2150	2220	2145	1560	190
Portland, Maine	1355	1145	1445	275	1320	360	545	2565	2725	2515	1095	480
Portland, Ore.	2715	1435	2065	2420	1375	2375	2150	....	535	145	1745	2320
Richmond, Va.	830	970	900	285	1020	205	240	2380	2435	2360	700	95
St. Louis, Mo.	1075	460	605	870	350	800	560	1745	1715	1700	....	705
Salt Lake, Utah	2100	990	1435	1950	835	1900	1650	635	590	605	1150	1825
S.Francisco, Cal.	2605	1585	1925	2515	1425	2465	2220	535	....	680	1715	2390
Seattle, Wash.	2740	1405	2100	2385	1370	2360	2145	145	680	....	1700	2300
Washington, D.C.	925	925	950	200	1010	120	190	2320	2390	2300	705	....

EXAMINATION QUESTIONS -- #31.

1. Will a station of 10,000 watts power reach twice as far as one of 5000 watts power?

2. Which will produce the greater signal volume, a field strength of 10 microvolts per meter or a sterength of 30 microvolts per meter?

3. With an antenna having an effective height of 10 meters, how many microvolts potential will be produced on the antenna by a field strength of 10 microvolts per meter?

4. From the following list pick out the things which increase sensitivity.
   Small antenna wire. High Antenna. Small coils and large tuning condensers. Exceedingly loose coupling. High "mu" tubes. Tuning to high frequencies.

5. Is the high frequency resistance of antenna circuits large or small as a rule?

6. If you connect a long antenna to the receiver terminal marked "Short Antenna" will it make the set more or less sensitive?

7. Does tuning an antenna to resonance make a set more or less sensitive?

8. If you lessen the high frequency resistance of a coil, will the gain be greater or less?

9. Will a selective receiver tune out static noises?

10. Is fading worse in the daytime or at night?