The EASY COURSE in HOME RADIO

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LESSON II.-RADIO SIMPLY EXPLAINED

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ONE OF THE FOLLOWING SET OF SEVEN LESSONS
1. A GUIDE FOR LISTENERS IN. 2. RADIO SIMPLY EXPLAINED. 3. TUNING AND WHAT IT MEANS. 4. THE ALADDIN'S LAMP OF RADIO. 5. BRINGING THE MUSIC TO THE EAR. 6. HOW TO MAKE YOUR OWN PARTS. 7. INSTALLING THE HOME SET.

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LESSON TWO

Radio Simply Explained

By Waldemar Kaempffert

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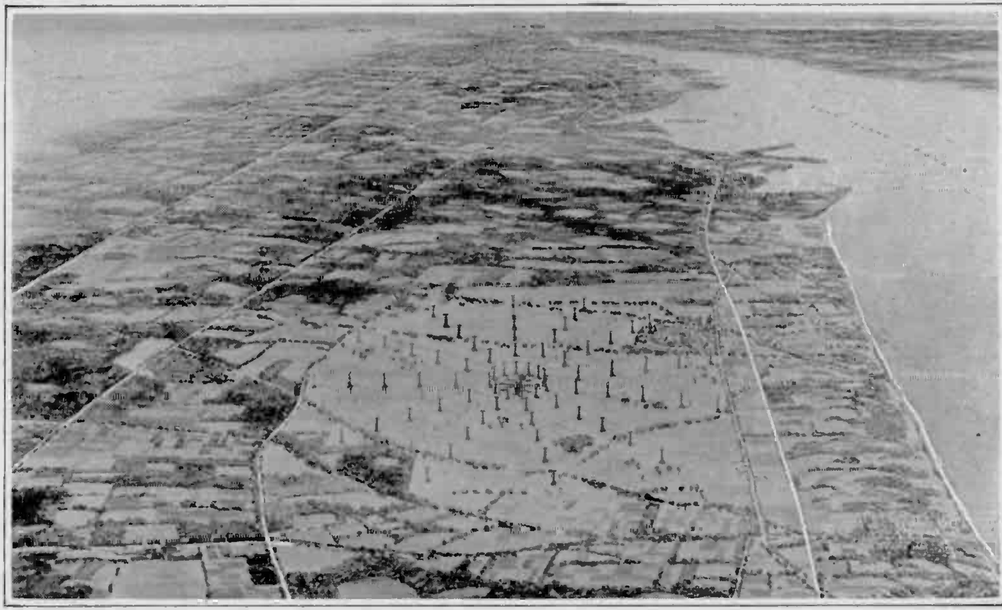


When the great transatlantic station at Port Jefferson, L. I., is completed, it will appear to a man in an airplane as in this picture. From a central power house radiate twelve lines of towers, like the spokes of a wheel. The towers carry the antenna. Each antenna line will be used for communication with a particular region of the earth—the region toward which the line points.

LESSON TWO

Why Do We See?

FROM the horn of the loud-speaker or from the telephone head-set clamped to your ears come the strains of "Celeste Aida" sung by a tenor in a distant broadcasting station. You hear his voice and so do perhaps a hundred thousand others at precisely the same time. A whole county, even a whole state, becomes a huge auditorium.

How does the tenor's voice reach you? Newspaper and magazine articles on radio give the impression that the music comes out of the air. But your common sense tells you that the air plays no part in the transmission of the song. If it did you would be able to hear it on the street without any telephone receiver at all.

No, it cannot be the air that conveys the notes of "Celeste Aida" to you. If it is not the air, what is it? You are confronted with the same question that puzzled scientists generations ago. Why does light travel through transparent glass? There is no air in the glass. Why do we see the earth and the stars? Interstellar space is airless. Why does light travel through a glass vessel from which all the air has been pumped out?

To answer these questions and to explain why we see at all science had to make a colossal assumption. It had to assume that there is some transmitting medium infinitely finer, infinitely more subtle than air, a medium that pervades everything. All things are composed of atoms, the air included. Between the atoms is this medium, this subtle, unfelt, unseen, unheard ether. Hence everything is plunged in ether, even the atoms of the air.

But how does ether act to transmit light? It must be displaced, pushed, shaken in some way to produce waves. Although the ether is an assumption it is not an assumption but a proved fact that light does travel in waves. Atoms vibrate in the sun, send out waves in the ether. Rock a boat and you generate waves in water. When an atom rocks fast enough it sets up waves in the ether, and when the waves strike our eyes we say that we see.

Waves in the Air and Waves in the Ether

Sound is a wave motion in air, and the wave motion is caused by a puff or a push. A stone dropped into water exerts a push and thus sets up a wave, and this wave, because it is itself a push, sets up a second, until we have wave after wave radiating from a center of disturbance. When I shout "Hello" my lips push air, and thus set up waves in the air, which beat against your ear-drums. As each air-wave reaches you (and there may be hundreds of waves a second) your ear-drum is pushed in more or less, only to spring out again ready for another push after the wave has passed. The ear-drum moves in and out as fast as the waves beat against it. We call this process "hearing." Sound waves thus travel in air at a speed of 1,087 feet a second at freezing temperature—about 741 miles an hour. If you could shout loud enough to be heard from New York to Chicago, a distance of 981 miles, it would take your voice only about one hour and twenty minutes to reach its destination.

Light waves travel in ether not at the rate of 1,087 feet a second, but at the rate of 186,000 miles a second. This is not the place to describe how the speed of light is determined. There are at least four ways of measuring it, and the results of all four agree so closely that there can be no doubt that light waves do travel at the rate of 186,000 miles a second.

In radio we deal also with waves in the ether—waves which must therefore resemble light waves, even though we cannot see them. The voice that comes to you from the broadcasting station is a voice which has first been transformed into ethereal waves, and then back into a voice by means of the telephone receiver.

One great difference between the ether waves that we call light and the ether waves that we use in radio is this: *Light can be seen; radio waves cannot be seen.*

Curiously enough, much was known about radio waves long before they were discovered. James Clerk Maxwell, a brilliant English physicist and mathematician, proved that light waves are electromagnetic waves in the ether and then went a step further and showed on paper that there are other electromagnetic waves which had not been discovered because they did not affect our senses. And one set of these waves proved to be those that are practically applied in radio communication.

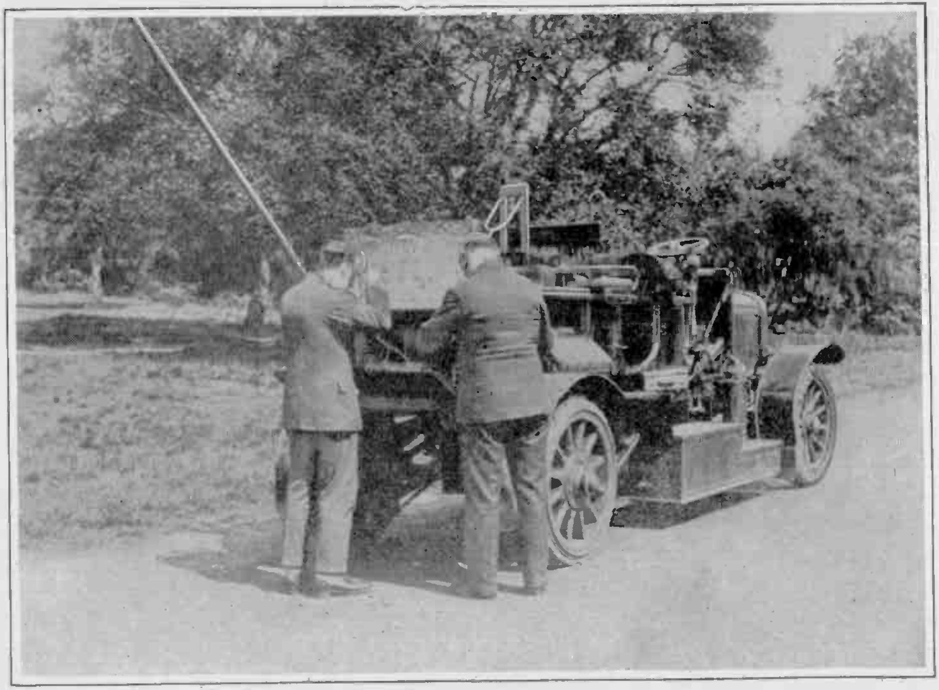
After Maxwell had proved that invisible electromagnetic waves could exist in the ether Professor Heinrich Hertz made an apparatus for detecting them—a kind of artificial "eye." For that reason they are often called

"Hertzian waves." They proved to have the very properties Maxwell predicted they would have. For example, like light waves, the Hertzian waves flash through space with a speed of 186,000 miles a second. The whole art of radio communication reduced itself to inventing apparatus which would violently upheave the ether into such waves and devices which would detect them.

What "Wave Length" Means in Radio

When you look at the sea restlessly undulating with great breakers tumbling in a mass of white foam over a sand bar or on a beach, it is hard to believe that the sea is not actually moving bodily along in a straight line instead of simply rising and falling. If the sea did actually move from place to place the land would soon be inundated. Wave motion in any medium is simply a rhythmic rising and falling. Watch a cork in the heaving sea. The cork simply rises on the crest of each wave and falls back into the trough. For hours it remains practically in the same place, simply bobbing up and down. It is the wind and currents of the sea that cause the cork to travel at all and not the waves.

As the sea plainly enough teaches us there are big waves and little waves. *The distance from one crest to the next crest* immediately preceding or following is called the "wave length." What distinguishes big waves from little waves is this distance from crest to crest—the wave length. "Amplitude," as it is called, is another distinguishing characteristic, and by amplitude is meant the elevation of the crest measured not from the trough of the wave



That country firemen can communicate with headquarters milos away was recently demonstrated in England. It was shown that additional apparatus, ambulances, and doctors could be summoned.

but from an imaginary horizontal line of rest midway between crest and trough. The *height* of a wave is the distance from the bottom of the trough to the crest.

Wave lengths are so important in radio that we must clearly understand what they are in order to construct apparatus which can be "tuned in" to receive music that comes to us from the broadcasting station.

The waves of visible light are so short that in order to be seen they must number from 30,000 to 60,000 to the inch. The waves used in radio may vary in length from about a hundred meters to thirty thousand meters. Ocean waves may have a length of three hundred meters —984 feet. But think of the great invisible, all-pervading ocean of ether heaving with waves that measure thirty thousand meters from crest to crest—about eighteen miles! Such is the wave length occasionally employed by the great stations that send radio messages across the Atlantic to Europe and across the Pacific Ocean to Australia.

Note that in radio we always measure wave lengths not in yards or in feet but in meters. Radio was developed by scientists, and in science the metric system is that which is employed in preference to all others.

The bigger the wave the greater is the amount of energy passed along. It takes a big stone to produce a big splash in water and big waves that travel far. Long waves travel farthest whether they be waves in water or waves in the ether.

"Wave Frequency" and What it Means

Watch the waves of the sea very narrowly. Count the waves. You discover that the heaving is very regular

—clock-like in its regularity. The little cork that bobs up and down rises more slowly on the big waves than on little waves. The number of times a minute that a wave rises or falls, or the number of waves that break upon a beach in a given time, is called the "wave frequency"—another term that means much in radio.

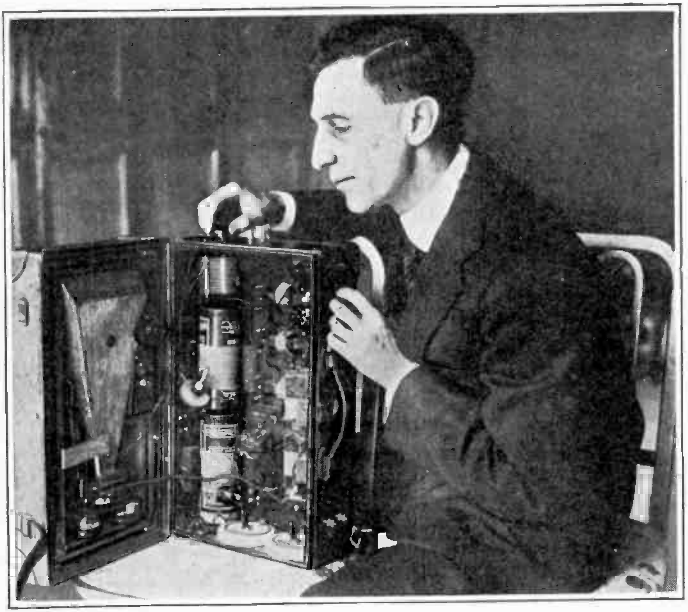
The frequency or the number of light waves that enter the eye each second is not millions but millions of millions. It ranges from 400 to 750 billions, and by a billion we mean here a million times a million.

Color is a matter of wave length and wave frequency. "That is deep red" you say as you point to an autumnally tinted leaf. You mean that your eye is responding to 400 billion vibrations a second. So, as you run up the color-scale from deep red to violet, your eye is called upon to respond to higher and higher vibrations. The color we call violet is a sensation produced by vibrations numbering 750 billion a second. There are vibrations even higher, but we cannot see them. In a word color as such exists is not in the world around us, but in our eyes alone. All that exists outside of us is something that sends us vibrations. Our eyes are transformers of vibrations: they change vibrations into color. Radiated heat waves have frequencies ranging from five billion to two hundred billion a second. The Hertzian waves of radio have a frequency varying from 10,000 to 3,000,000 a second—hence too slow to be seen with human eyes.

All these waves—visible light waves of different colors, radiated heat waves, radio waves—are electromagnetic waves in the ether. Although the ether is a purely hypothetical medium it has been explored about as thoroughly as the deepest part of the ocean. It is a-tremble with waves. Proceeding from the higher pitches in the scale to the lower we have first the X-rays. Far beyond the visible violet are two octaves of invisible ultra-violet waves. Lower down comes one octave of what we call light—visible light ranging from violet to deep red. This visible light is followed by seven deeper octaves of "dark-heat" waves, so called because they are not associated with visible light. Below these lie five octaves of waves that no one has yet discovered but that surely exist. Next come the wide band of Hertzian waves applied in radio, ranging in length from a fraction of an inch to eighteen miles and more. In a sense the Hertzian waves therefore correspond with the base notes of a piano and the X-rays with the treble. Only, the ether has a great many more octaves than a piano.

How We "Tune In"

Wave length in radio corresponds with pitch in sound and with color in light. Sounds are transmitted through the air by bodies that move back and forth or vibrate and thus create a train of waves. If the waves come through the air regularly, we hear a musical note which may be shrill or high-pitched or deep or low-pitched. The pitch depends on how many waves reach our ears in a second, and this in turn depends on how many times the sounding body vibrates the air. When we tighten or loosen the string of a violin we raise or lower its pitch. We call this "tuning." In radio we also speak of "tuning," and when we do we mean simply that we are adjusting the radio pitch of the receiver to the pitch of the transmitting station. Pitch is a matter of wave length.



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Dr. Dunmere of the Bureau of Standards has constructed a portable receiving set which is contained in an ordinary dress-suit case of the smallest size. Small as the equipment is, it includes batteries, condensers, vacuum tubes, and other essentials.

The smaller the waves and the smaller their length, the more of them strike the receiver, whether it be an eye, an ear or a radio detector. Hence when we "tune in" on a wave length of three hundred meters in radio we simply adjust the receiving instrument to receive waves of that length, just as a violinist tunes his instrument to agree in pitch with the piano that his accompanist plays.

Wave length can also be explained in terms of light. When we say that one color is "red" and another "blue" we mean that the pitch of the color we call red is lower than the pitch of the color we call blue. In other words, red has a greater wave length than blue. When we look at the world through a piece of red glass our eyes see with light of one wave length. When we look through a piece of blue glass, we see the world with light of another wave length. Hence we "tune in" on definite wave lengths of light when we wear red, yellow or blue spectacles. A radio broadcasting station which makes the ether ripple with Verdi's "Celeste Aida" on a wave length of three hundred and sixty meters is like a lighthouse or beacon which sends forth beams of red light only. A normal eye can detect all the colors in the rainbow; a color-blind eye cannot. Hence, a tuned receiver is color-blind, in a radio sense. The human eye is a far better "tuner" than any we have yet devised for radio reception.

A tuning instrument is wanted which will be as marvelously sensitive as the eye. Between deep red (400 billion vibrations a second) and red-orange (437 billion vibrations a second) is a difference of wave length far less than between 360 and 361 meters in radio; yet our receiving devices are still so made that we cannot "tune in" more closely than seven meters. A highly trained eye can distinguish about one thousand different tints in the visible spectrum. Far more extensive is the invisible radio spectrum, and radio is still so young that we cannot yet make use of all its tints or wave lengths.

"Damped" and "Continuous" Waves and How They Are Generated

We have seen that if radio waves are to be set up in the ether something must vibrate or rock back and forth with a rapidity of 10,000 to 3,000,000 times a second. An electric spark, such as that which ignites the explosive mixture in an automobile engine, strikes the ether sudden blows and sets up electromagnetic waves. A blow must be struck to set up a wave in any medium. If, for instance, you move your hand back and forth as rapidly as you possibly can, you cannot strike blows on the air, and hence your hand cannot produce a sound. But a tuning fork strikes the air several hundred blows a second, and for that reason it produces sound waves. The snap of the electric spark is exactly what is needed to set up a radio wave in the ether.

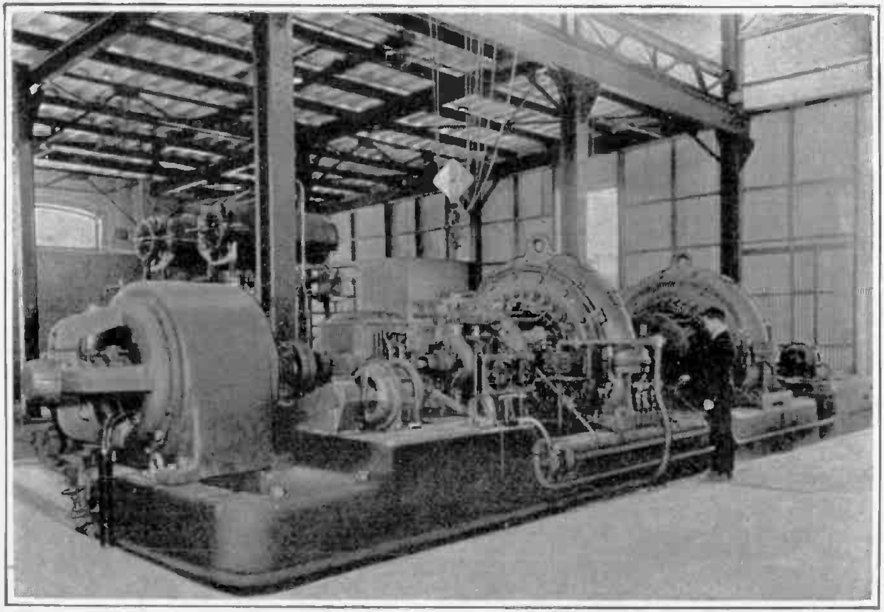
Such a spark seems to create a kind of splash in the other, or rather a series of splashes, since the spark leaps back and forth thousands of times a second between the terminals. In the spark we have electricity oscillating and therefore producing alternating current. The eye cannot follow the oscillations of the electric spark. Delicate photographic apparatus reveals the fact that, like a plucked corset-steel held in a vise, the oscillations grow and die in the fraction of a second, and because they die they create "damped waves" or the kind produced when a stone is thrown into water. It takes far longer to describe what an oscillatory spark is than for the spark to live and die. There may be as many as thirty oscillations of an electric spark in a period of time that may be as long as one ten-thousandth of a second or as short as one one-hundred thousandth of a second.

Pluck the string of a violin and you send out damped waves that die out; you know that they die out because the note itself dies out. "Undamped" or "continuous" waves, on the other hand, do not die out. Draw a bow across a violin string and you have "undamped" or "continuous" waves; you know they are continuous because the sound continues so long as the bow is in action.

Generating Continuous Waves

If the spark could be made to pass steadily it would cease to be a spark. It would be an arc. Many arcs glow in our streets. They ought to be good transmitters of waves. Unfortunately the current that leaps back and forth with such apparent steadiness and produces a dazzling blue light is too slow. The oscillations occur only twenty-five to five hundred times a second and we want at least 10,000 alternations a second.

Duddell, an Englishman, and Poulsen, a Dane, made discoveries which enabled radio engineers to generate continuous waves with arcs. They hit upon ways of producing alternations so rapid that an arc could be used instead of a spark for radiating waves. With their inventions the radio telephone, in a sense, was born. For



An ordinary alternating current dynamo generates current of what is called 60 cycles frequency. This means that in each second the current oscillates back and forth in the wire 120 times, one oscillation back and forth being called a cycle. In radio from 5,000 to a million and more cycles are needed to set up waves in the ether. Special alternators are therefore required. Here is the alternator built according to the design of Dr. E. W. Alexanderson for the great transatlantic radio station at Port Jefferson, L. I. It is probable that in the future the alternator will give way to the vacuum tube as a generator of waves.

arcs radiate into space fully eighty per cent. of the energy used in radio communication, if we leave amateur stations out of consideration.

What Poulsen did can best be explained by considering an ordinary pendulum. Start the bob swinging and eventually it dies down. In a clock, the pendulum is kept swinging by the energy of a coiled spring; each beat is equal in amplitude to any other beat. These beats are continuous or undamped oscillations. Poulsen invented a way of producing electrical oscillations in an arc—oscillations which would not die down. After each oscillation a fresh electrical push was given.

Alternating currents can radiate waves in the ether from the wires through which they flow. But we must have thousands of alternations a second, as we have seen. Ordinary alternating current dynamos or generators cannot turn fast enough to produce any such number of alternations. Special dynamos have been invented by R. Goldschmidt in Germany, and by Dr. E. Alexanderson in the United States, which meet the requirements. Although some stations are equipped with such dynamos, so that they look for all the world like ordinary power-houses, it is likely that in the future Hertzian waves will be generated by what is variously called the "vacuum tube," "electron tube" or "therminoic valve"—an invention which has had such an extraordinary effect on radio, particularly on broadcasting, that a whole volume in this "Easy Course in Home Radio" has been devoted to it. To understand just how the marvellous vacuum tube operates we must delve into the heart of electricity and matter. Indeed, we must be able to answer the question, "What is electricity?"—at least in a general way—before we can realize the tremendous importance of the vacuum tube. Although something will be said further on in this volume on the vacuum tube, it seems best to refer the reader to Professor Morecroft's book in this series, where a simple description of the vacuum tube may be found.

Changing the Voice into Electricity and Back Again

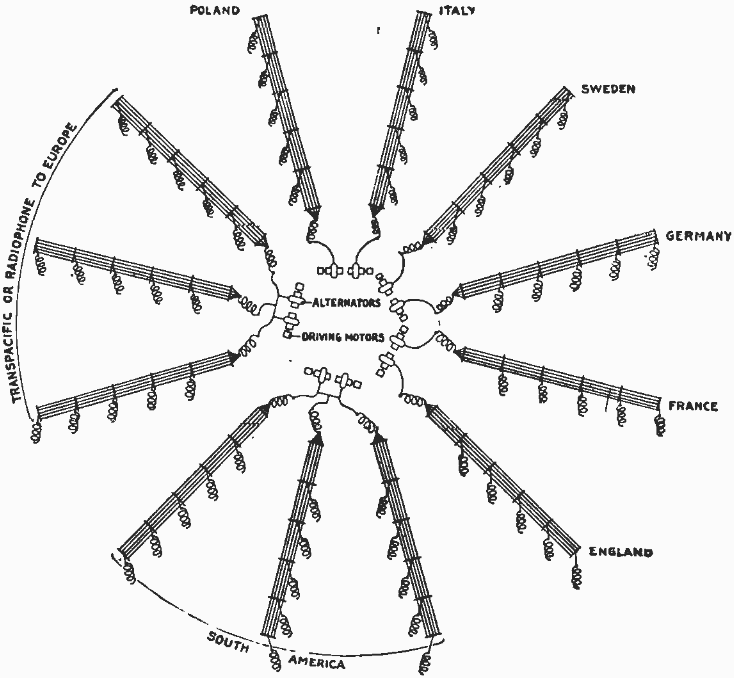
With the invention of methods of generating continuous waves, radio telephony became not only a possibility but a reality. When you telephone from one part of the city to another you know that your voice is not literally carried over the wire. A current passes through the wire, and in talking the current is varied as the voice rises and falls. When you say the single word, "Hello" you modify the current in perhaps a thousand different ways; you mold the electric waves that pass through the wire into an electrical "Hello" pattern. This is called "modulation." In radio telephoning the same process occurs. The waves that are constantly radiated into space are molded or modulated by the voice. The molded or modulated waves strike the receiver. The telephone translates the modulated waves into modulated sound waves, exactly like those of the singer or speaker's voice in the broadcasting station. We think we hear the actual voice, just as we think we hear the actual voice of Caruso as it comes out of the horn of a talking machine. The electromagnetic waves in the ether correspond in a sense with the grooves in the phonograph record.

Why We Use Antennae

We have seen that energy is transmitted in waves whenever anything "vibrates," "oscillates" or "alternates," and that a big alternating or vibrating object will set up bigger waves than a small object. A little rocking boat produces smaller waves than a big rocking boat.

It was Marconi who first realized that this applied to radio as well as to boats in water. His tiny spark formed part of a circuit. As the spark oscillated there was also an oscillation in the wire of that circuit. He discovered that if the wire were stretched between poles or masts it would come in contact with more of the ether and thus shake more of it into waves. The longer the wire the better, for there would be a better chance for the oscillating or alternating current to produce big waves. He found, too, that the higher the wires, strung between poles or masts, the more effective was the sending and the receiving. This is due to the fact that fewer obstructions are encountered by the waves at a height than at the ground. Although the electromagnetic waves pass through brick walls and mountains as easily as light passes through glass they meet some resistance. For that matter even the most transparent glass does not transmit all the light that strikes it.

After a while it became the general practice to hang the conductors from tall masts or towers and to call them "antennae." The term was borrowed from entomolgy. It is applied to the long feelers of insects. And the tall antenna of a great radio station with wires stretched between look for all the world as if they were reaching out



This diagram indicates the arrangement of the antennae of the great transoceanic radio station at Port Jefferson, L. I. When completed this station will be able to reach any part of the earth. Each antenna is intended to communicate with a particular country.

and trying to feel something in space. They do feel electric waves.

Since amateur stations or broadcasting stations are not intended to send signals over distances measured by thousands of miles (although the amateurs have actually been heard in Scotland) their antennae are not so long or tall as those of the great stations that telegraph to Europe or Japan and have towers several hundred feet high. It is easy to see why the big stations must have such high antennae. They must shake a great deal of the ether in order to form tremendous billows measuring ten and twenty miles from crest to crest. They are responsible for ether-quakes felt even in Japan. A large tuning fork will be heard farther than a small tuning fork and similarly, high power sent through a large antenna will send waves farther than a small one.

For the same reason the receiving antenna must be large if the detection is to be good. The bigger the waves that beat against a distant receiving antenna, the more powerful are the oscillations set up in the antenna circuit, and the more easily will they be detected.

How the Waves Are Received by Antennae

What happens in the receiving antenna circuit? The waves ripple out from the transmitting station in alternations of pressure. They strike the receiving antenna. They set up vibrations—electric vibrations—in the antenna. The result is an alternating current which surges back and forth in the antenna circuit as long as the waves beat against it. Hold a vibrating tuning fork near the

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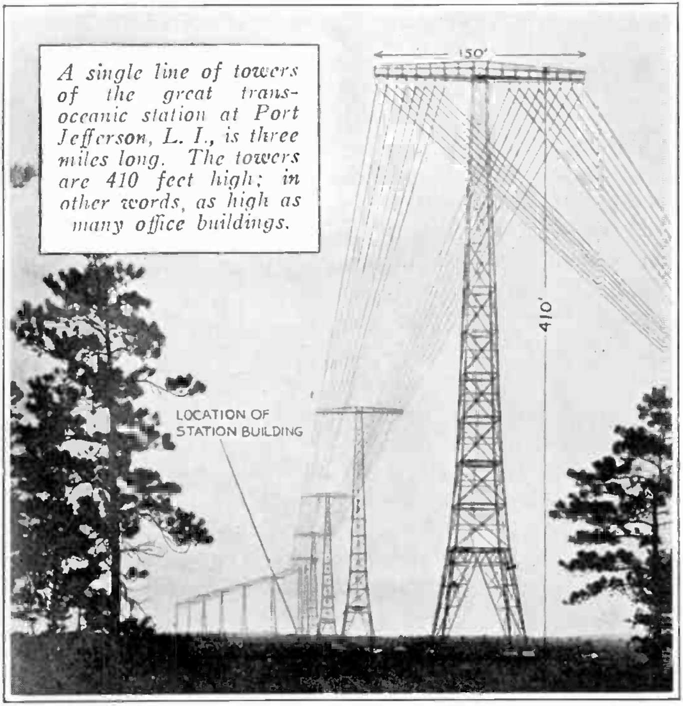
The umbrella is his antenna, and the receiving set is so small that it can be worn on the finger as a ring. Such diminutive sets have but little practical value. They are curiosities at best. Still, they serve to indicate what the future has in store.

piano. A sympathetic note will be heard from that string of the piano which corresponds with the note of the tuning fork. The ether is capable of setting up sympathetic electrical vibrations in a receiving antenna circuit, as the air is capable of making a piano string vibrate and sound.

The wires of the great trans-Atlantic stations are always so hung between the towers that they extend in the direction in which the waves are traveling. Suppose the wire of the antennae were strung at right angles to the direction of motion. Clearly the waves would quickly break over them and pass on. But if the wires reach out in the direction from which the message is to be received, it is evident that waves strike every part of them and produce a much more marked effect.

The erection of tall towers and masts is expensive and troublesome. It occurred to engineers that they might be dispensed with, at least for receiving, if there were only a way of exposing enough wire in the proper shape. The result is what is called the "loop" antenna. The loop consists simply of wire wrapped around a simple frame mounted on a pivot. Such a loop antenna can be swung on its pivot in any direction, and swung it must be in order that it may receive with the maximum intensity. When the loop is end-on to the transmitting station the signal or the voice is heard with greatest distinctness. Turn the loop at right angles to the direction in which the waves are coming and nothing is heard. Such a loop, mounted in a room or even in a cabinet, can receive music and speech from a broadcasting station.

For receiving broadcasted concerts a loop can be made by winding copper wire eight times around a frame four



A single line of towers of the great trans-oceanic station at Port Jefferson, L. I., is three miles long. The towers are 410 feet high; in other words, as high as many office buildings.

feet square. Such a loop can be hung by a string from a hook in the ceiling; thus mounted it is out of the way, and yet it can easily be turned.

It is with loops that ships determine their position at sea by listening to the signals sent from shore by what are called "radio compass" stations. Indeed, the loop is called a "radio compass" on shipboard, and sometimes a "direction finder."

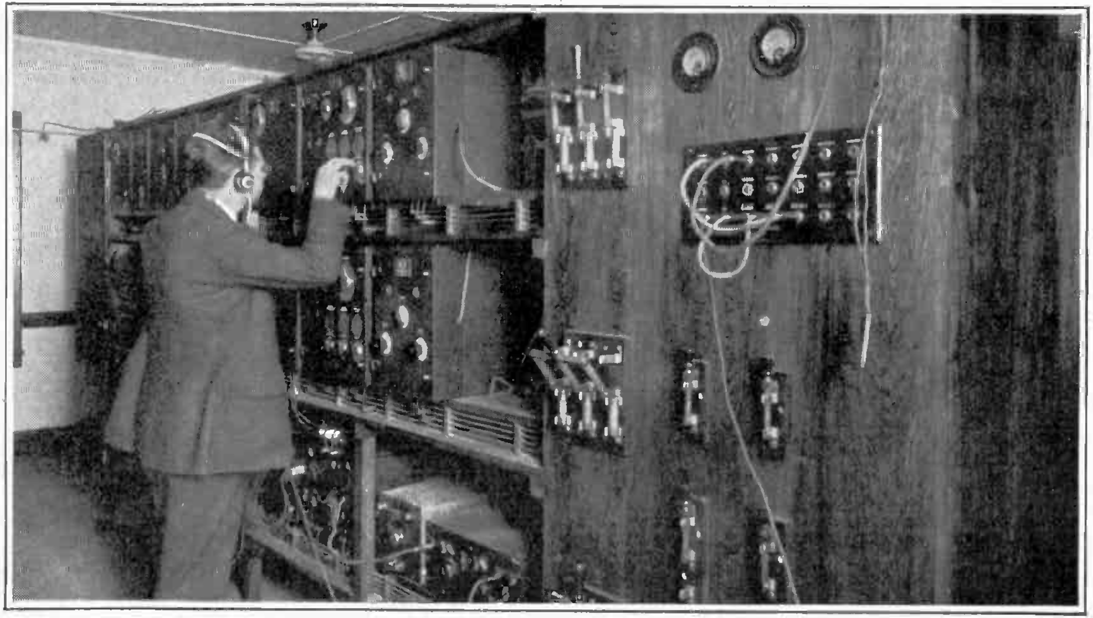
The radio compass stations did wonderful work during the war. Eccles, the great English radio engineer, thus tells how they enabled the British navy to follow the movements of the German fleet before the great battle of Jutland:

"The German vessel, which on May 30 sent instructions to the German fleet by wireless, was heard at several stations on the British coast, and her bearings from each were accurately determined. Some hours later, this same vessel wirelessed another batch of instructions, and our watching stations again determined her bearings. It was found on comparing the results that she had moved about seven miles down the river. This was recognized by Sir H. B. Jackson, the First Sea Lord, as sufficient justification for ordering out the Grand Fleet and clearing the North Sea."

So with the aid of the loop the British began to pursue the Germans before they were even at sea.

Detecting the Waves

In radio communication the transmitting antenna sets the ether in vibration so that waves are sent out in all



Fifteen miles from the great transmitting station at Port Jefferson, L. I., is the Riverhead station which receives radio messages from Europe and from ships at sea. This is the interior of the Riverhead station.

directions. If we are to receive the vibrations we must set a receiving antenna in electric vibration. This the waves do in striking the antenna. But the frequency is so high that no sense-organ of ours can tell whether or not the receiving antenna is electrically vibrating. The ear can hear sound directly; the eye can see light directly; but neither ear nor eye can perceive the Hertzian waves directly.

Many forms of detectors were invented soon after Marconi demonstrated that it is possible to telegraph through space with the Hertzian waves. We need not describe them all here; for most of them are obsolete. For broadcasting receiving sets either the crystal detector or the vacuum tube is employed.

General H. H. C. Dunwoody discovered that certain crystals possess the curious property of conducting electricity better along one axis than along another. Now the alternation currents set up in a receiving antenna are of very high frequency—so high that they cannot be heard in an ordinary telephone receiver. Suppose that half of them could be extinguished altogether. They would become audible. The crystal makes it possible to separate one alternation from the other and thus to produce spurts of electricity in one direction.

Many crystals possess this curious property of being able to suppress one of the impulses of alternating current. Examples are carborundum (carbide of silicon) anastase, molybdenite and hessite. Moreover, there are pairs of crystals, which, when placed in contact, are better conductors in one direction than in the opposite direction. Among them are graphite and galena, zincite and chalcopyrite. Because crystal detectors are cheap they are widely used in amateur receiving sets of small range. They cannot be used with a loud speaker without a suitable amplifier.

The Vacuum Tube and Its Operative Principle

The most wonderful of all radio detecting devices is the vacuum or electron tube which is also used for transmitting waves and for amplifying received energy. It has sometimes been called the Aladdin's lamp of radio. Certainly the lamp that Aladdin rubbed produced effects no more miraculous, no more startling.

Examine a radio vacuum tube closely, and you will see that it is much like an incandescent lamp. But the filament is surrounded by a metallic net or screen called the "grid" and the grid in turn is surrounded by a metal cylinder called the "plate." When the lamp glows something streams over from the filament to the cylinder through the grid, and the streaming is strangely controlled by the electric current that happens to be flowing through the grid in a local circuit.

To explain the action of the vacuum tube is to delve into the mysteries of matter and electricity. And the explanation came only after X-rays were discovered.

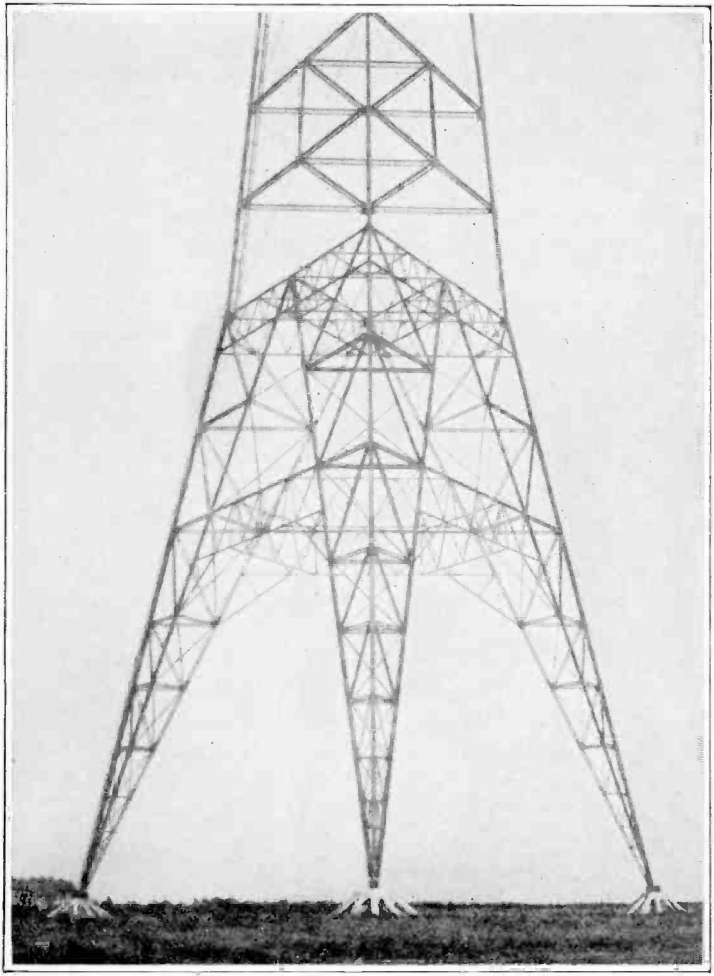
Most of us are familiar with X-ray tubes in these days when X-rays play such an important part in surgery, medicine and dentistry. The operator turns on the electric current. The tube glows with a purplish light. Many years ago, Sir William Crookes, the inventor of the tube, held a magnet outside of the glass. The purplish beam was bent aside by the magnet just as if it were a strip of steel. What could this mean? This could be no ordinary light, for never is a beam of light bent out of its course by a magnet. Crookes concluded that he was dealing not with ordinary light but with what he called "radiant matter." In other words, the purple glow was composed of particles infinitely small, particles that glowed as they shot through the tube, particles that could be bent from their course by a magnet.

What is Electricity?

A great question was raised, a question that could be answered only by fundamentally revising our notions about electricity and matter. It became necessary to assume that electricity must be composed of infinitely small particles, which cannot be divided. To these particles or bits of electricity the name *electrons* was given.

Experiments were made which proved that not only electricity but matter itself is composed of these electrons. The atoms, once supposed to be indivisible, are made up of electrons. A picture of the atom has been drawn, although no one has ever seen an atom, and although atoms are so small that several hundred thousands of them crowded together would be visible as a faintly discernible speck under the most powerful microscope.

An atom is conceived to consist of a nucleus around which electrons revolve. It is a miniature solar system. Iron differs from gold because the number of electrons grouped around the nucleus of the iron atom is not the same as the number of electrons grouped around the gold atom. The simplest of all atoms is that of hydrogen. It



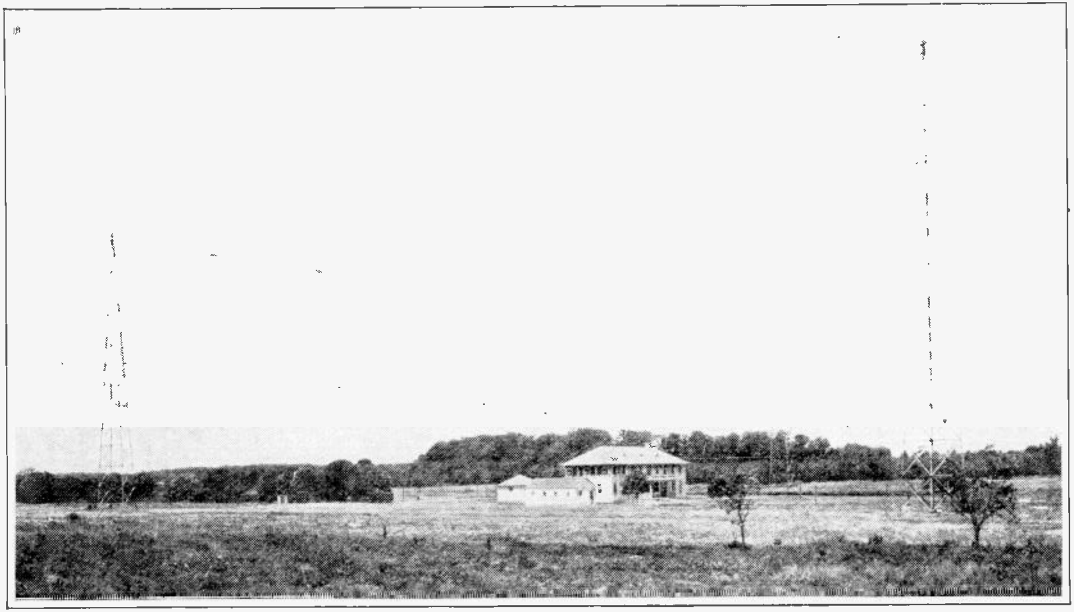
The base of one of the great towers of the Lafayette Station in France built during the war by the United States army.

has the usual central nucleus around which just one electron revolves. The most complicated of all atoms is that of uranium, which has ninety-two electrons revolving around the central nucleus. All we have to do in order to change iron into gold is to discover a way of rearranging electrons, of snatching superfluous electrons away, or adding them to systems. If this could be done as easily as it can be written about, iron would be converted into gold in factories and the world would be plunged into a most desperate financial plight.

Nature knows how to change one element into another by thus juggling electrons. For all we know, copper, iron —every element with which we are familiar is slowly changing from what it seems to be into something else. It is known that radium in the course of centuries actually does change in this way from an element which is constantly shooting off bits of itself, into lead and bismuth. It is probable that all the lead in the world was once radium that has rid itself of electrons and been reduced as a consequence to a baser metal.

This electron theory is not mere scientific moonshine. It has been experimentally proved. Although we cannot see electrons or atoms, we can see their effects. The electrons in many atoms have actually been counted.

So, it must be regarded as definitely proved that electricity and matter are both composed of electrons. Both are fundamentally the same. The chair on which you are sitting is composed of electrons, and so are you. An electric current flowing through a wire is nothing but a stream of electrons trying to find a resting place. Hence, you, the chair in which you are sitting, the money in your pocket, the sun, the stars, the green grass, the electric



This general view of the Deal Beach station in New Jersey shows how the four antennæ are supported in more or less vertical position by the suspension wires running from tower to tower. The station is arranged for what is called "four-channel" operation, the three outside antennæ being for telephone channels and the central antenna for telegraph transmission.

current that makes your lamp glow—all are brothers because all are composed of electrons exactly alike but arranged differently in different substances.

What is an Electric Current?

Each atom of matter—copper, rubber, water—has just so many electrons and no more. As long as it has its proper number no one would know that it had any whatever, so far as any electrical effects are concerned. That is why a chair or a book seems so unelectrical. But all substances may be deprived of electrons or may receive more than their proper share and when that occurs the substances are electrified. If a body has fewer electrons than its proper number we say that it is positively charged and give it a plus sign (+); if it has more we say that it is negatively charged and give it a minus sign (—).

Now the ordinary state of any body is to have exactly its own number of electrons. Batteries and dynamos have peculiar properties. They can push electrons out from the negative terminal and pull them in at the positive terminal. What we call an electric current is nothing but a steady flow of electrons in a conductor. When an electric spark flashes across the terminals of a gap, electrons surge back and forth, trying to distribute themselves so that there shall be no more on one side of the gap than on the other. So long as one side has too many and the other too few the excess electrons leap across. Because they have momentum and cannot stop dead, many more leap across than are necessary to establish equilibrium. The surging back and forth continues for an imperceptible fraction of a second. When both sides have exactly the same number of electrons the spark ceases to pass.

Why have we thus briefly sketched the modern electron theory? Unless we conceive electricity as an aggregation of restless, free electrons, unless we think of electrons as having mass, however minute it may be, we cannot hope to grasp the significance of the marvelous vacuum tube in radio communication or understand how it works. This might be inferred from the fact that the vacuum tube is often called the "electron tube," a name that indicates clearly enough that electrons must play some part in the operation.

In the tube, the electron stream from the glowing filament passes through the grid to the plate. The electrons are always negative. If the grid is charged negatively, ever so slightly, the electrons are repelled; if it is positively charged, the electrons are pulled over. The feeblest imaginable current in the grid produces a marked effect. Now the amount of energy received by an antenna is at best exceedingly small, but small as it is, it can be transferred to the grid, where it may either help the electrons to fly across to the plate or to check them. In either case the current flowing locally through the plate circuit is so markedly affected that the changes are easily noted. Thus are the nimble electrons practically applied in radio, and thus, by the electron theory, is the action of the vacuum tube explained.

This is but the roughest sketch of the vacuum tube's action as a detector. How one tube can be used to amplify the effects produced in another and how the tube can be made to generate the continuous waves used in broadcasting Professor Morecroft describes in Lesson Four.

The Future of Radio

The most profound scientist may be curiously short sighted and unimaginative. Neither Maxwell or Hertz or Branly or Lodge, all of whom had so much to do with laying the foundations of what we know as radio, ever dreamed that the electromagnetic waves could be used to take the place of telegraph and telephone wires. Curiously enough, a scientist who played no part whatever in developing radio first saw the astonishing, the revolutionary possibilities of the work that Maxwell and Hertz had done. He was Sir William Crookes, the man who invented what we call the X-Ray tube, although he was not the discoverer of the X-Ray. In a memorable article published in the *Fortnightly Review* in 1892 on "Some Possibilities of Electricity" he wrote:

"Here is unfolded to us a new and astonishing world—one which it is hard to conceive should have no possibilities of transmitting and receiving intelligence. Rays of light will not pierce through a wall, nor, as we know only too well, through a London fog. But the electrical vibrations of a yard or more—will easily pierce such mediums, which to them will be transparent. Here, then, is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present costly appliances. . . . What, therefore, remains to be discovered is—firstly, a simpler and more certain means of generating electrical rays of any desired wave length, from the shortest of a few feet in length, which will easily pass through buildings and fogs, to those long waves whose lengths are measured by tens, hundreds and thousands of miles; secondly, more delicate receivers which will respond to wave lengths be-

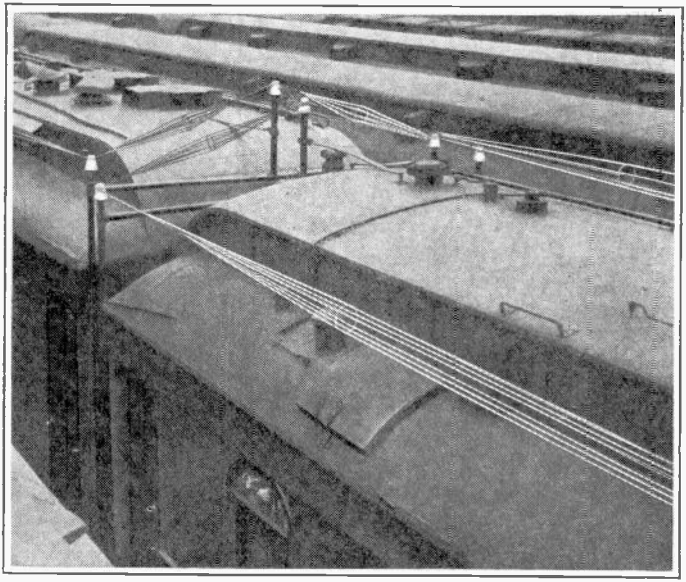


Photo by International

How the aerial was strung on the roof of a car on the Lackawanna railway to receive radio music and speech while the train was rushing along at the rate of sixty miles an hour and to enable those on board to communicate with their friends who were within range and who had receiving sets.

tween certain defined limits and be silent to all others; thirdly, means of darting a sheaf of rays in any desired direction, whether by lenses or reflectors, by the help of which the sensitiveness of the receiver . . . would not need to be so delicate as when the rays to be picked up are simply radiating into space in all directions and fading away. Any two friends living within the radius of sensibility of their receiving instruments, having first decided on their special wave length and attuned their respective receiving instruments to mutual receptivity, could thus communicate as long and as often as they pleased by timing the impulses to produce long and short intervals on the ordinary Morse Code."

That dream has come true, even more wonderfully than Crookes had predicted that it would. In 1896, four years later, Marconi made the first experiments in transmitting Morse signals through the ether. At first he managed to communicate telegraphically over a few hundred feet and then over a few miles.

In 1897 Marconi was asked:

" — and how far do you think a dispatch could thus be sent?"

"Twenty miles," was his answer.

"Why do you limit it to twenty miles?"

"I am speaking within practical limits. . . . The distance depends simply upon the amount of exciting energy, and the dimensions of the conductors from which the waves proceed."

And now we are telegraphing to Europe and Japan. Radio telephone conversations have been conducted between New York, Paris and Honolulu. Music, sermons, opera, lectures are heard by thousands.

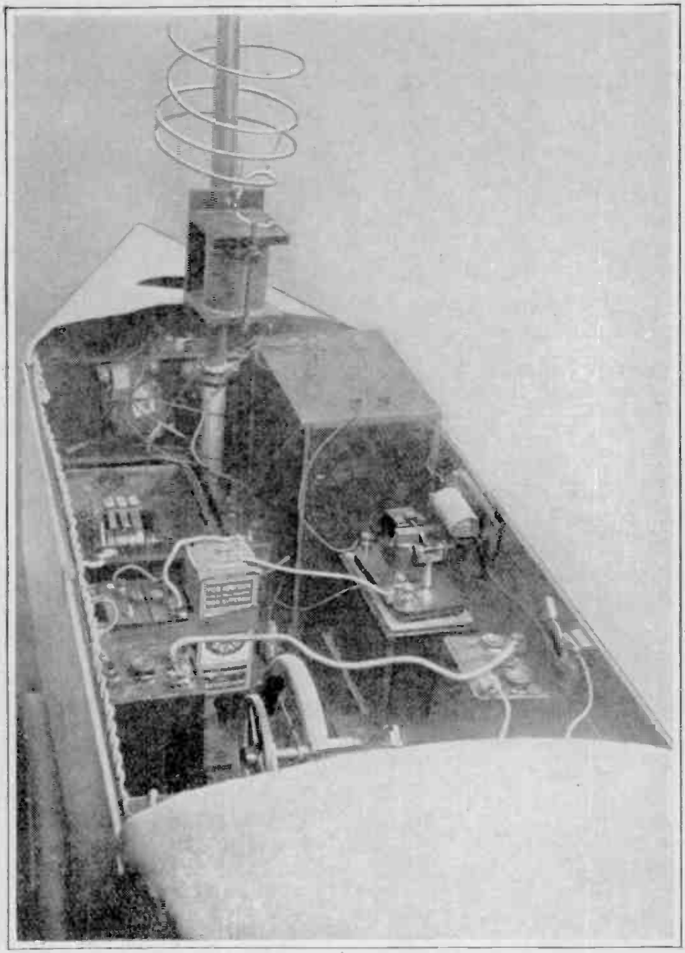
In 1896 Tesla patented a crewless submarine controlled from a station by radio. Others followed him with devices to fire off guns by radio, start and stop motors, ring bells, and do a hundred different things. The latest of these inventors is E. R. Glavin, who devised a wagon that can be made to start or turn or stop in any direction by radio. Some day armies will have crewless "tanks" thus directed from a safe distance.

No one dreamed of broadcasting's possibilities, even ten years ago. It was regarded as a serious limitation that radio communication was not secret and that there was no more privacy about a message than there is about a corner political meeting. What was once a drawback is now a technical virtue. Broadcasting, a new way of reaching thousands and even millions at the same time, is the outcome.

Some day we will look back with amusement at our present instruments and our delight with them. Good as our stations are, they will be as obsolete in a few years as quill pens, crinolines, and high wheel bicycles. Pocket-receiving sets will be developed which will be marvelously efficient. Some day you will see a man stop in the middle of the street, clap a telephone receiver to his head, and listen to that which he wants to hear—the news about trouble that the Afghans are giving the British, about the murder that has shocked the town, about the election.

No backwoodsman or camper will be utterly cut off from the outer world. He too will have his portable set, and even though he is in the heart of the Canadian wilderness, he will listen to the jokes and the songs of some Broadway musical comedy. Every train will have its radio telephone. Is the train late? You call up then and there and inform your wife that dinner must be served without you.

Broadcasting may some day bear the same relation to the ear that the motion picture bears to the eye. We have silent plays written for the camera. Shall we also have unseen plays for the ear? Will a new art be developed—the art of the ear-play, the purely aural drama that will depict human emotions and human destinies in spoken



© Keystone

This is the interior of the radio-controlled automobile shown page 39. The cover has been removed to reveal the internal, operative mechanism.

words alone? The "movies" took the talk out of the drama. Who knows but radio broadcasting will put the talk back and take away vision. The blind drama looms up as a possibility.

For aught we know the stock and news ticker may be doomed. Baseball scores, stock quotations, storm warnings—everything of general interest will be tossed into the ether and heard by him who has the proper electromagnetic ear. Every well-appointed apartment house and hotel will be a radio receiving station, and every tenant will "listen in" to broadcasted opera, to a lecture, to a speech by a great orator. Candidates will no longer travel around the country tediously in order to address a few thousands every night, but will speak to millions through some broadcasting station—speak at the same time to the ranchman in Utah and the business man in New York. Is there any stirring event? It will be heard at once in every home. Does the President address Congress? His remarks will be heard not only by the Senators and Representatives before him but perhaps by one-tenth of the population of the United States. Is Congress wrangling about a tariff bill? Every one of us can "tune in" and listen to our representative and promptly "sign off" when he wearies us.

And then there is the coordination of our land telephone lines with radio into a system which will enable us to communicate with London from Chicago. It is the vacuum tube which has made possible the feat of telephoning from New York to San Francisco over land wires, and it is the vacuum valve which enables us to combine wire telephoning with radio telephoning. The day is not far distant when a business man will pick up his regu-

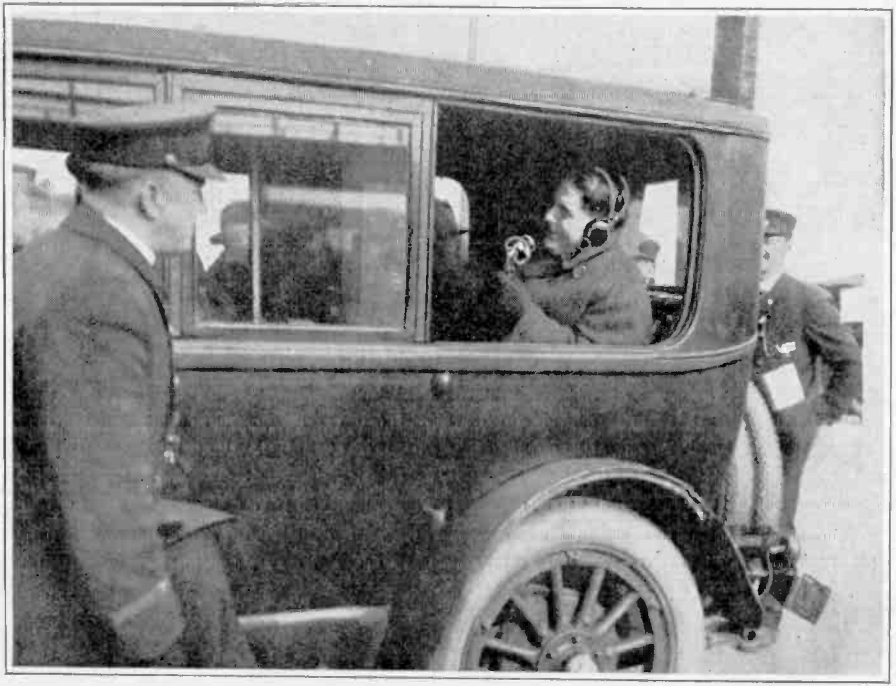


Photo by International

Even automobiles have been equipped with radio receiving sets. The Chicago police was the first to use radio in the interest of public safety. The automobile shown is one of those belonging to the Chicago police force.

lar desk telephone receiver and say in response to Central's "Hello":

"Give me radio long distance."

And when the radio-long-distance operator asks him for the number that he wants, he says:

"Piccadilly 2167. Ask for Sir James Arkwright."

He hangs up his receiver. In half an hour his bell rings.

"All ready for London. Piccadilly 2167, Sir James Arkwright on the wire."

And that business man in Chicago will *talk* to Sir James Arkwright in London, just easily as he talks to anyone in the United States—talk first over the land wires to a radio station on the shores of the Atlantic, then through the ether, then over wires leading from an English radio station to London. Lest this may be dismissed by a skeptic as a romantic Jules Verne dream, it may be mentioned that anyone in the United States can now telephone to Catalina Island off the coast of California by exactly the same process. Within the next few years all the great passenger liners and the fastest trains will be equipped with radio telephones. "Give me the Aquitania" or the "Twentieth Century Limited" you will say to Central, and you will telephone to a friend or a business associate on board from your home or your office.

At present broadcasting stations are too eclectic. Any one of them radiates news, lectures, music, sermons and market reports. In the future we may expect to have stations which will broadcast only news; stations which will entertain us only with opera or with plays or musical comedies; stations which will croon cradle songs and tell stories to ten million children at once. Your receiving set will have a tuning knob which plays over a dial bear-ing such legends as "News," "Stock Market," "Opera," "Dance Music," etc. On Sunday you will twirl the knob so that the pointer rests at "Sermons" and from some broadcasting station, situated perhaps in Chicago, a great minister or priest will preach to half the population of the United States.

Who knows but there may be stations that will entertain not merely a whole state or whole country, but half the world? Why should not the Carusos and the Galli-Curcis of the future sing not for a paltry five thousand in the Metropolitan Opera House but for all North America and Europe? At once visions of a super-opera loom up.

The deadening monotony of farm life will disappear. Opera? The farmer will have it, though he live a thousand miles away from the stage. Education? We shall have a radio university in which the foremost professors will expound their views to us with as much personal directness as if we were sitting in their presence. Sailors on lonely seas will listen too. We used to call the telegraph and the telephone "space annihilators." Space annihilation, indeed! We never knew what the term meant until radio broadcasting came. Eskimos and Patagonians, Chinese and Mexicans, Finns and Americans become next-door neighbors so far as radio is concerned and might all be in some huge auditorium. Somehow the world, for all its diameter of eight thousand miles, seems to shrivel into a little ball which can be held in the hand.

GLOSSARY OF RADIO TERMS

Compiled by Lester Maxwell

Aerial.—A system of elevated wires insulated from the ground and from surrounding objects, and intended to impart the radio energy generated by a transmitter into the ether of surrounding space. The aerial may comprise one wire or many wires, and it may be arranged in many different ways, such as a straight wire or a number of parallel wires; a number of vertical wires separated at the top but coming down to a common point, fan-like; a single pole or mast with the wires coming down and radiating away from the pole like the ribs of an umbrella, and so on. When used for receiving purposes, the aerial should be called an antenna, although these terms, erroneously, are often used interchangeably.

Alternating Current.—(Abbreviated A. C.) An electrical current whose direction of flow is constantly changing during a given period of time. The number of changes in a second is called the frequency. A sixty-cycle current, therefore, is one that completely reverses its direction of flow sixty times per second. In radio work alternating current plays a leading rôle. Alternating currents of commercial frequencies, such as 33 cycles, 60 cycles, and 120 cycles are referred to as low-frequency currents, while the radio currents running up into the tens of thousands and hundreds of thousands of cycles are referred to as high-frequency currents.

Alternator.—An electric machine capable of generating alternating current. The usual alternator has the general appearance of a generator or dynamo.

Ammeter.—An instrument for measuring the flow of current in amperes through a given circuit. The ammeter is connected in series with the circuit, while the voltmeter, which measures volts, is connected across or in parallel with the circuit. If the meter mechanism cannot handle the entire current flow, which is often the case with heavy currents, the greater part of the current flows through a special conductor of known conductivity, and the ammeter is connected across this special conductor so as to receive a small portion of the current, in a known ratio to the full current. The ammeter can be calibrated accordingly. This special conductor is known as the "shunt."

Ampere.—The standard electrical unit of current flow.

Amplifier.—A device that builds up or amplifies either the radio energy intercepted by a receiving set, or the sound-producing current. There are two kinds of amplifiers, namely, the *radio frequency* amplifier and the *audio frequency* amplifier. The former builds up the intercepted wave energy before passing it on to the detector, there to be rectified into audible or sound-producing current. The latter builds up the sound-producing energy; in other words, it does not increase the sensitiveness of the receiving set, as does the radio frequency, but it builds up the strength of the signals so that better results are obtained. The radio frequency amplifier goes ahead of the detector and makes for sensitiveness; the audio frequency amplifier follows the detector, and makes for loudness.

Amplitude.—The crest or peak of a wave or oscillation measured from an imaginary horizontal, median line of rest. In radio the amplitude means the highest point attained by each wave—the crest. A wave may have a large or small amplitude, according to the energy which produced it. Amplitude should not be confused with height of wave, which is measured from trough to crest.

Announcer.—In the radio-phone broadcasting studios an announcer introduces the singers and speakers, gives out the bulletins and other features of the program, and gives the call letters, name of owners, and location of the station. In the large radio-phone broadcasting stations the announcer is not a radio operator.

Antenna.—The name given to an aerial used for receiving purposes only. (See Aerial.)

Arc.—An electrical discharge steadily maintained between two electrodes or current-carrying members, such as carbon rods, copper cylinders or plates, silver plates, and so on. The arc is used for generating high-frequency oscillations or waves in transmitting. In the early days of the radio-phone it was used almost exclusively as the generator of the continuous waves for radio telephone work.

Armstrong Circuit.—(See Regenerative Circuit and Feed-back).

Atmospherics.—This is another name for "static." Sometimes these disturbances are called "strays" or "X's." They have been referred to as the "noises of space," by radio men with a poetic turn of mind. Atmospherics are the noises caused in a radio receiving set by atmospheric electrical disturbances. They are at their worst during the summer months, and almost totally absent in winter. Atmospherics are largely caused by miniature lightning storms which take place in the clouds themselves.

Audio Frequency.—Frequency that is well within the range of audibility of the human ear. All frequencies below 10,000 cycles per second are termed audio frequencies, while those above are called radio frequencies. (See Amplifiers.)

B Battery.—A relatively high-voltage battery, say of 22½ or 45 volts, employed for the plate circuit of a vacuum tube. B batteries are made in the dry battery form, and as storage batteries which may be recharged. Also, the B batteries come in the fixed voltage model, and in the variable voltage model. For detector work, the variable voltage model should be employed for best results.

Bakelite.—An insulating material moulded in all kinds of forms, such as panels, handles, knobs, dials and binding posts, and largely employed in receiving and transmitting equipment.

Broadcasting.—The simultaneous transmission of music or speech by radio telephone, or the simultaneous transmission of news or special bulletins to a great number of receiving stations. Broadcasting differs from the usual radio communication in that it is public and intended for anyone who cares to receive it, while other radio communication is private and intended for some specific receiving station.

Buzzer.—A device capable of interrupting an electric current so as to produce weak oscillations that may be employed for testing a crystal detector. The detector is tested by running one wire from one of the interrupter points of the buzzer to the ground-lead of the receiving set, and then, while the buzzer is operated, the crystal is adjusted until the buzzer interruptions are heard loudly and clearly, indicating that the crystal detector is at its best. A buzzer is also employed in transmitting work for the interruption of continuous waves so as to make them audible with an ordinary receiving set. This is known as buzzer-modulated C. W.

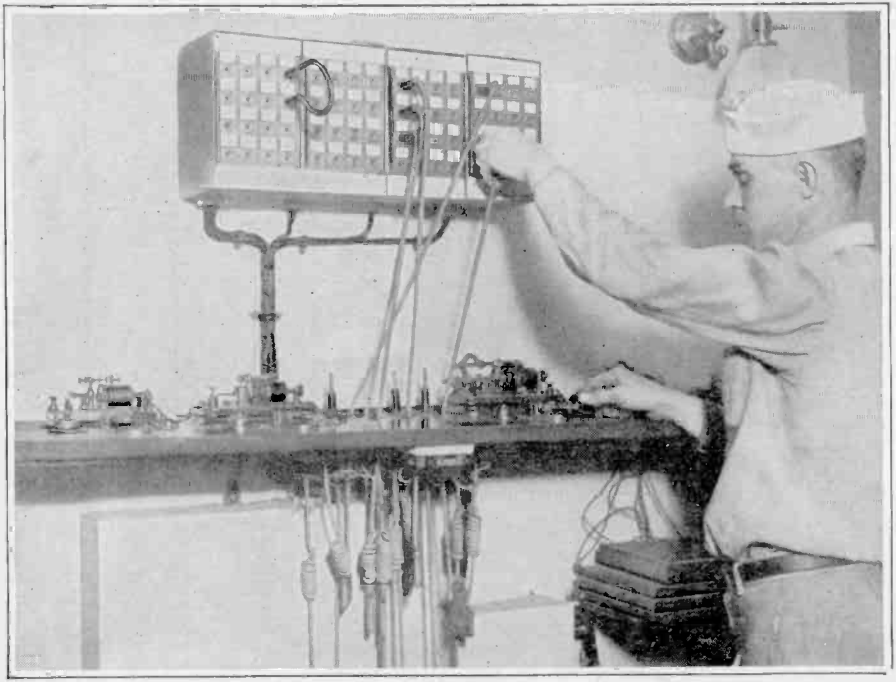
Capacity (abbreviated C).—This is one of the factors in all radio work. Capacity is the property of circuits or things to accumulate a charge of electricity. The unit of electrical capacity is the farad; but since the farad is too large for practical radio work, the micro-farad (abbreviated mfd., equal to one millionth of a farad), is employed. The capacity of a condenser, which is an instrument that represents a given electric storage facility, is always given in microfarads or mfds.

Cascade Amplification.—In all high amplification work the amplifiers are arranged in steps, so that one feeds its output into the next stage of amplification, while the second stage feeds its output to the third stage, and so on. This is known as the cascade arrangement.

Choke Coil.—A device that possesses a marked choking or damming effect when placed in an alternating current circuit. Such choking action is called "impedance" when used in radio work. Choke coils are employed in transmitting work, to prevent the high frequency current from flowing back through the generating members and either using themselves up without doing real work, or even doing damage to the electrical equipment.

Circuit.—The path followed by an electric current is known as the circuit. A circuit, so far as radio is concerned, may be open or closed, primary or secondary, or oscillating.

Coupling.—In certain radio transmitting and receiv-



Everyone who owns a receiving set has heard the announcer in the broadcasting station say "Stand by for the time signals from Arlington." This picture shows the process that occurs at Arlington. The relay is connected up to send out the time signals from the Naval Observatory in Washington. In other words, the Observatory clock does the sending, using the Arlington station as a relay. The signals are sent automatically from 11.55 A.M. to 12 M. and from 9.55 P.M. to 10 P.M.

ing arrangements it is necessary to transfer energy from one circuit to another. This is generally done by having a few turns of wire in each circuit, which may be brought nearer together or drawn farther apart. When the coils are brought close together, we have what is known as a *close coupling;* when they are drawn farther apart, we have *loose coupling.* The primary of a coupler, which gives the coupling effect, is the one that has the source of power, while the secondary is the coil that receives the power transferred by the primary.

Condenser.—A device consisting of two or more metallic surfaces separated by a non-conductor or dielectric, capable of receiving and holding a charge of electricity, and discharging it when called upon to do so. The condenser plays an important rôle in tuning operations, both in receiving and in sending. It is also employed in the generation of radio waves.

Counterpoise.—One or more elevated wires insulated from and placed but a short distance above the ground, as compared with the usual antenna or aerial which is placed high above the ground. The counterpoise serves as the ground in place of the usual ground connection. Where it is impossible to obtain a good ground connection, the counterpoise is employed. Again, in aircraft-radio the counterpoise arrangement must be employed, and in this case all the metal fittings and guy wires of the aircraft are employed as the counterpoise, while one or two trailing wires serve for the aerial. The counterpoise is used in continuous wave transmission for the reason that it may give greater stability than the usual ground connection.

Continuous Wave (abbreviated CW).—This is a form of radio wave which is maintained at a constant amplitude, as distinguished from the damped wave which is produced in trains or groups each consisting of a number of oscillations which rapidly die down in amplitude until zero is reached. Continuous wave transmitters are more efficient than damped or discontinuous waves in radio telegraphy and are absolutely necessary in radio telephone work.

Crystal Detector.—A radio-wave detector device consisting of one or two crystals possessing certain rectifying properties that cause them to rectify or convert radio energy into audible currents, so as to affect the telephones. In some designs a single crystal is used, with a fine wire (known as the "cat whisker") or metal point in contact. In other designs two crystals are used in contact.

Decrement.—The rapidity with which damped wave trains die down or are damped from the maximum amplitude to zero. The radio laws have something to say regarding the decrement of a transmitter, for the decrement has much to do with the sharpness of tuning.

Detector.—A device that rectifies or transforms the intercepted radio waves into visible or audible indications. The two general classes of detectors in present-day use are the crystal detector and the vacuum tube.

Direct Current (abbreviated DC).—An electric current that flows continuously in one direction, as distinguished from alternating current which changes its direction of flow. A direct current always flows from the positive source to the negative return.

Duo-Lateral Coils.—Compact inductance coils with a unique winding that makes for great wave length value with a rather small amount of wire.

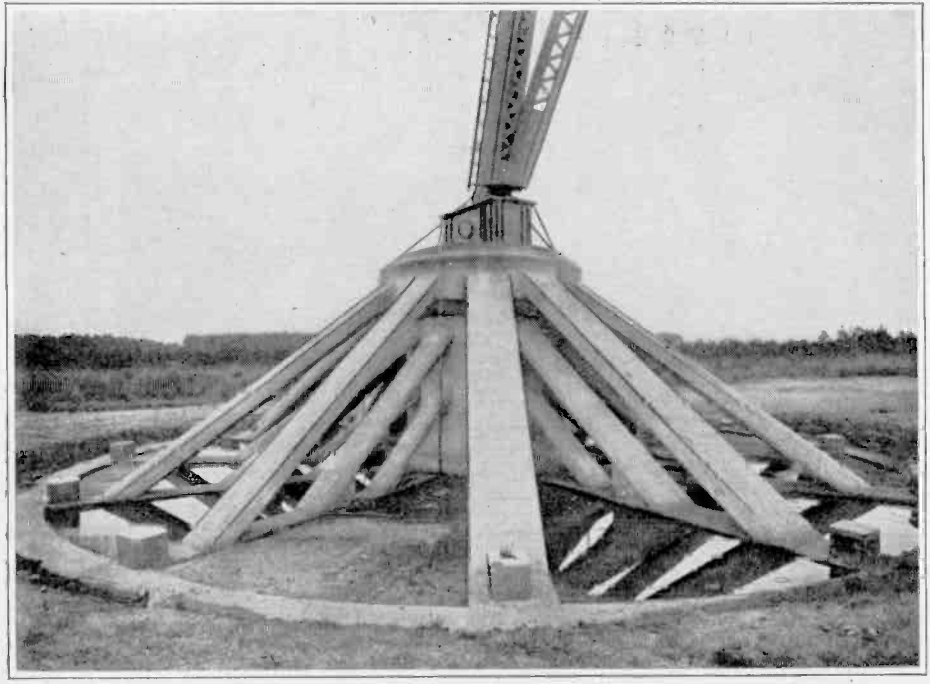
Electrolyte.—The liquid used in a storage battery, composed of water and sulphuric acid. The electrolyte changes its density or specific gravity according to the relative charge of the battery, and it is this changed density or specific gravity that serves to indicate the condition of a storage battery at all times. (See Hydrometer.)

Electron.—This stands for the ultimate particle of matter, which is a charge of negative electricity. Electrons are emitted by the incandescent filament of the vacuum tube and attracted by the cold plate. The grid, which is placed between the filament and the plate, serves to absorb more or less of these electrons and thus controls the number that reach the plate. It is this action that controls the plate current, and since a very small charge on the grid can control a far greater volume of current in the plate circuit, we have the basis for the vacuum tube detector, amplifier, modulator, and so on.

E. M. F.—Abbreviation for electro-motive-force, meaning the electrical pressure or potential, the unit of which is the volt.

Ether.—Since radio communication is said to be a wave motion set up by a transmitter, it is necessary to conceive of some medium for this wave motion. This medium is called the ether. It is a hypothetical medium of great elasticity and extreme tenuity, and is said to pervade all space as well as the interstices of solid bodies. It is also the medium which transmits light waves, heat waves, and electric waves. While it is true that the Einstein theories have shattered the former concept of the ether, it is still employed by radio men in explaining the action of radio.

Fading.—Due to certain atmospheric conditions



The base of each tower of the great Lafayette Station in France has three legs. This is one of the legs.

which are not altogether understood but whose existence is well authenticated, radio signals often die down or fade away when received at a distant point. This is especially noticeable when receiving radio-phone programs from some long-range radio-phone station. The speech or music, loud one moment, gradually dies down, only to come up again some time later.

Feed-Back.—In the Armstrong regenerative circuit a certain portion of the energy in the plate circuit is thrown back into the grid circuit so as to raise the grid potential. The increased grid potential, in turn, gives a greater plate effect, which, once more, feeds back a certain part of its energy to the grid circuit, and so on. This action results in considerable self-amplification. The feed-back action is also employed in the generation of oscillations for transmitting purposes.

Frequency.—In radio work and in alternating current practice, the rapid reversal of the current in a circuit. Frequency is applied only to alternating currents. High frequency currents mean currents above the usual commercial frequencies, which are 33-cycle, 60-cycle, and 120-cycle. Audio frequency currents mean currents up to 10,000 cycles. Radio frequency currents are those above 10,000 cycles.

Grid.—That member of the vacuum tube which is placed between the filament and the plate, and which serves to absorb a greater or less number of electrons. The grid is generally made in the form of a spiral or zigzag or again like a tiny ladder.

Grid Leak.—This is a very high, non-inductive resistance connected across the grid condenser or between the grid and the filament of a vacuum tube to permit excessive electrical charges to leak off to an external point, thus furnishing stable control under all operating conditions. The grid leak may be a pencil line drawn on a piece of paper and clamped between heavy copper washers. The pencil line may be heavier or lighter according to the resistance required.

Ground.—The antenna or aerial is one side of the wave distributing or wave receiving system, while the ground is the other. The ground consists of a suitable connection with the ground, such as a water pipe, steam pipe, gas pipe, large metal plate buried in moist soil, bare wires laid in deep trenches and then covered over, and so on. The British call the ground connection the "earth."

Harmonics.—In receiving radio-phone programs, one is often surprised to hear a given radio telephone on an altogether different wave length. This lower or higher adjustment of the tuner brings in the radio telephone much weaker than the real adjustment, but nevertheless sufficiently loud sometimes to interfere with other receiving operations. In radio work, such interference is due to harmonics, and is most noticeable in undamped or continuous wave operation. These harmonics differ in wave length and frequency from the original and true operative wave. The first harmonic is three times the true frequency, or one-third the wave length of the aerial; the second harmonic is five times the true frequency or one-fifth the wave length; the third harmonic is seven times the true frequency or one-seventh the wave length. High-power stations are sometimes heard at very short wave lengths.

Henry.—The unit of inductance.

Hertzian Waves.—Radio waves named after Prof.

Heinrich Hertz of Germany, who discovered them in 1887.

Honeycomb Coil.—A compact inductance coil with a unique winding that makes for great wave length with a rather small amount of wire.

Hook-Up.—A diagram giving the wiring or connections for radio apparatus. Hook-ups are diagrams which make use of the various radio symbols to represent the different pieces of equipment.

Hot-Wire Meter.—The usual electrical measuring instruments cannot be employed in measuring high-frequency radio currents. It therefore becomes necessary to use special instruments which have a fine platinum wire whose expansion and contraction, brought about by the radio current of fluctuating strength, operates an indicator over a calibrated scale.

Hydrometer.—An instrument for taking the specific gravity of the storage battery electrolyte. The hydrometer gives a specific gravity reading, which in turn indicates the relative charge of the storage battery. In this manner the radio operator knows just when to place his storage battery on charge, and when to stop charging.

Impedance.—The term applied to the resistance offered by a coil of wire to an alternating current flowing through it due to the counter-electromotive pressure, irrespective of the actual resistance of the conductor in ohms. Counter-electromotive pressure is developed in all forms of inductance, and this counteracts the flow of current to a greater or less degree. Impedance may be said to be the result of reactance.

Inductance.—The property of a material system by virtue of which it is capable of storing energy electro-

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Quartermaster-Sergeant D. M. Dusenberry of the U. S. Signal Corps designed this "parlor loop." The loop is turned on its pedestal in the direction from which the sound waves come.

magnetically. The unit of inductance is the Henry. In radio work the mil-Henry and the micro-Henry are the units employed.

Insulator.—A non-conductive material through which current will not normally pass.

Jack.—The hole which receives the plug used in making rapid connections in radio receiving and transmitting apparatus.

Kick-Back.—The flow of current from high frequency generating equipment back through the current supply line where it does not belong and where it may do some damage. Certain forms of choke coil and graphite resistance rods connected to the ground are sometimes used with transmitting equipment so as to prevent kick-backs.

Kilowatt (abbreviated KW).—One thousand watts, a unit used in measuring large amounts of electricity. However, a kilowatt is considerably in excess of an electrical horsepower, which is 746 watts.

Lead-in.—The connection between the antenna or aerial and the receiving or transmitting apparatus.

Log.—The record kept in commercial radio stations of their radio business day by day.

Loop or Loop-Antenna.—A wooden frame with a number of turns of wire wound about it so as to form a square loop. Such a device is employed in place of the usual antenna and ground for receiving purposes. In certain rare instances, such as trench communication work in military operations, it has been employed for transmission. The loop is a directional device, working best when pointing edge on towards the transmitter. The use of the loop gives greater selectivity and also reduces materially the static disturbances that prove so troublesome in the summer. The loop is the basis of the radio compass, now so extensively used in navigation.

Loose-Coupler.—A device that serves to couple two circuits so that energy may be transferred from one to the other and their relation may be increased or decreased by making the coupling closer or looser, as demands may dictate. (See Coupling.)

Loud-Speaker.—A modification of the usual telephone receiver, made on a large scale so as to produce a large volume of sound which is distributed throughout a room by means of a horn. The loud-speaker does away with the necessity of head 'phones and puts the radio receiving set on a par with the phonograph, so far as convenience is concerned.

Megohm.—One million ohms.

Microfarad (abbreviated mfd.).—One millionth part of a farad. This is the practical unit of capacity, employed in radio.

Microphone.—An instrument for converting sounds into electrical fluctuations or modulations in a given circuit. The microphone takes the voice or music and converts it into variations of an electric circuit, and these variations, in turn, when passed through a distant receiver, are translated back into the original sounds. The usual microphone, such as is used for wire telephone and also with small radio telephone transmitters, consists of a mass of loosely-packed carbon granules held between two carbon blocks, and subjected to a varying pressure according to the sound waves falling on the diaphragm.

Milliamperes (abbreviated MA.).—The thousandth part of one ampere.

Modulation.—The act of varying an electric current in a given circuit by means of the voice or music. Thus the modulation of a given radio-phone broadcasting station may be said to be good, fair, or poor, according to how realistic the voice or music sounds at the receiving end.

Natural Frequency.—The natural or fundamental wave length of an aerial or antenna without inductances or capacities of any kind added to it. Every aerial or antenna has a natural frequency or wave length of its own.

Ohm.—The unit of electrical resistance.

Ohm's Law.—The fundamental law of electricity is known as Ohm's law. It states that the current in amperes flowing through a circuit is equal to the pressure in volts divided by the resistance in ohms. Thus with any two factors in an electrical problem known, it becomes possible to determine the third or unknown factor, so far as direct current practice is concerned. In alternating current practice there are other factors that must be taken into consideration and that complicate materially such calculations.

Oscillations.—Alternating currents of extremely high frequency are known as "radio oscillations." If the voltage or amplitude of a series of oscillations is constant, the oscillations give rise to continuous or undamped waves; on the other hand, if the voltage or amplitude is not constant but is rather of a damped or decaying nature, like the beats of a pendulum, which swings less and less until it comes to a dead stop, then we have damped waves. A series of waves is called a train.

Parallel.—In all electrical work various devices and

An airplane radio-telephone set of the type recently adopted by the Postal Department for the use of pilots. The range of this instrument is two hundred miles.

equipment, such as lamps and batteries, may be connected in series or in parallel. The series arrangement is such that the current must flow through one device after another until all the devices have been traversed, after which the current returns to the starting point. Parallel wiring means that all the devices are arranged across the two current-carrying members as the rungs of a ladder, and the current, therefore, flows through all the units or devices at the same time. In the series arrangement we build up or require greater voltage. Thus five 110-volt electric lamps, connected in series, would require 5 x 110 volts or 550 volts to light them to full candlepower. The same five lamps, arranged in parallel, require only 110 volts, but if each lamp draws ½ ampere, then the parallel arrangement calls for 2½ amperes, while the series arrangement, calling for greater voltage, requires only the same amperage as is called for by each lamp, or ½ ampere. Please note, therefore, that parallel hook-up calls for greater amperage, and series hook-up for greater voltage. In connecting batteries, the series arrangement builds up the voltage. Five dry batteries arranged in series will give 5 x 1.4 volts or 7 volts. The same batteries, connected in parallel, will give only 1.4 volts, but the amperage will be 5 x 25 amperes (the usual capacity of a dry battery on short circuit) or 125 amperes. In connecting dry batteries in series, the center post of one cell is connected to the outside of the next cell, and so on.

Plate.—One of the elements of the usual vacuum tube. The plate is the cold electrode which attracts the hot electrons from the filament.

Plate Circuit.—The circuit connected with the plate of the vacuum tube. This circuit contains the telephone

An experimental receiving set was installed in the club car of a train on the Chicago, Milwaukee and St. Paul Railroad. It proved feasible to receive music while the train was running at full speed.

receivers and the "B" battery or high-voltage battery, generally of 22½ volts rating. In some forms of regenerative receivers, a variometer is included in the plate circuit so as to tune this circuit for the purpose of feeding back some of the energy to the grid. In other instances, the plate circuit includes a few turns of wire known as the "tickler," which induces some of the plate current into the grid circuit.

Plate Battery.—Usually called the "B" battery. A 22½ volt dry battery or a storage battery intended to supply a steady current for the plate circuit of the usual vacuum tube. In amplifier work the "B" or plate battery may be as high as 45 volts, and for extreme amplifications as high as 90 to 100 volts.

Plug.—A device consisting of two contacts on a brass rod, which may be inserted in a hole known as the jack, the latter making contact with the two contact members of the brass rod. This method ensures a rapid method of making and breaking connections. It is the same arrangement as is found on the usual telephone switchboard. In radio the plug and jack are widely employed, especially for the telephones of the receiving set, and for the microphone of a transmitter. There are certain types of automatic jacks so constructed that when the plug is inserted, a separate circuit is closed, aside from the actual circuit in which the plug is to form part. Such an arrangement is used to light tube filaments when the plug is inserted, and to extinguish them when the plug is withdrawn.

Primary.—The first circuit of an electrical combination where two circuits, which transfer energy from one to the other, are employed. The primary contains the original current or source of power, while the secondary receives more or less of that power. Thus in transmitting practice, the primary would be the coil in the oscillating or local circuit, containing the generating equipment, while the secondary would be the coil in the aerial-ground circuit. The primary of a receiving set, on the other hand, is the coil in the antenna-ground circuit, while the secondary is the local or detector circuit.

Potential.—Another term for voltage, when used in the electrical or radio sense.

Potentiometer.—An instrument for regulating the voltage supplied to a device or circuit within very delicate limits, as compared to the rougher variations obtained with a rheostat. The potentiometer is a resistance which is connected directly across the source of current. It is provided with a sliding contact, which moves from one side to the other. The device or circuit to be fed this delicately varied current, is connected with one side of the resistance, and with the movable slider. Now, as the slider is moved from one side to the other, current is taken off the resistance in proportion to the distance between the slider and one end of the resistance. This method of regulating voltage is a very delicate one, and it applies a more steady load on the current source. Potentiometers are used in applying very critical voltages on plates in vacuum tubes, when the utmost efficiency is sought.

Radiogram.—A dispatch sent by radio telegraph. It is the word in radio communication that corresponds with telegram.

Radio-Phone.—A wireless telephone or radio telephone. This word is coming into very general use.

Radio.—This word has more or less supplanted wireless, in the United States, at least, although it dates back only a few years.

Radiation.—The propagation of radio energy through space. When applied in practical radio work, it means the amount of energy that is being delivered to the aerial circuit, and presumably propagated through space. Thus we speak of good radiation and poor radiation, depending on the proportion between what is put into the wireless or radio transmitter, and what actually flows into the aerial in the form of radio oscillations. Radiation is generally determined by means of a hot-wire milli-ammeter in the aerial circuit.

Radio Frequencies.—Frequencies corresponding to vibrations far above those to which the human ear will respond, are known as radio frequencies. All frequencies above 10,000 cycles per second are termed radio frequencies.

Radio Link.—The radio section that forms part of a regular telephone system. Thus in certain parts of the United States, where conditions militate against the installation and maintenance of a telephone line, a radio link can be established, so that radio telephony spans the gap. In California there is a radio link in regular use between Santa Catalina Island and the California main land. This radio link bridges the gap in the regular telephone system, so that persons talk to each other with regular telephone instruments and in their own homes, little aware that their voices are carried through 31½ miles of space in order to span a bit of the Pacific Ocean.

Reactance.—The reactance of a circuit is a function of the inductance, capacity, and the impressed frequency.

Rectifier.—An apparatus which converts alternating current into direct current. In radio, a rectifier is employed in charging storage batteries on alternating current circuits, and for operating vacuum tubes on alternating current circuits. Various types of rectifiers are in general use. Some of these are vibrating devices which serve to take each half of an alternating current cycle and place it on its proper side so that all the + will be on one side and all the — on the other, thus giving direct current. Others have a special form of vacuum tube which permits only half of the alternating current cycle to come through, thus giving direct current. Again, the usual crystal detector is a rectifier, since it converts the high frequency alternating currents of radio energy into pulsating direct current, for the telephone receivers.

Regenerative Circuit.—In a circuit containing a vacuum tube, it is possible to take a small part of the plate current and throw it back into the grid circuit, so as to build up a greater potential for the grid. In this manner a more pronounced effect is obtained for the plate circuit, and this, in turn, is again thrown back to the grid circuit, also with an increased effect on the plate, and so on, over and over again. This throwing back or feed-back of energy is known as the regenerative action, and is also known as the Armstrong circuit, named after its inventor. This feed-back of energy is obtained in two ways, as a matter of regular practice. The first is to place a variable inductance, such as a tuning coil or variometer, in the plate circuit so that this circuit can be tuned until it feeds back energy into the grid circuit. The second method is to connect a few turns of wire in the plate circuit, and to bring these few turns of wire into close quarters with the grid circuit, thus inducing a greater or less amount of plate energy. This arrangement is known as the tickler. The regenerative action results in a marked self-amplification for the usual vacuum tube, and gives excellent results for weak signals.

Relay.—A device employed when one circuit is to cause another circuit to perform some given task. Thus a weak current of one circuit can close the circuit for a much more powerful current. In radio work the vacuum tube is often used as a relay. Using a very weak current, such as the intercepted radio waves, it becomes possible by means of a vacuum tube to control a relatively powerful local current. The vacuum tube in this case can well be called an electronic relay, for such it is.

Resistance.—Opposition to the flow of an electric current through a conducting medium. There is no such thing as a perfect electrical conductor. Every metal has some resistance for electric current. Copper has very little resistance, and for that reason it is widely used. Silver has even less but it is too expensive. However, it is well to note that in certain radio instruments the conductors are silver plated, in order to afford the lowest possible resistance to the radio energy which flows on the surface of a conductor rather than through the core.

Resonance.—Resonance in a given circuit exists when the natural frequency of that circuit has the same value as the frequency of the alternating current introduced in it. It is an ideal condition when it does obtain. If a circuit is not in resonance with the applied alternating current, then the best results cannot be obtained because it is forced to function or respond to an abnormal condition. Two circuits are brought into resonance when

Playing jazz to be broadcasted to a hundred thousand listeners within a range of two hundred miles.

they are in absolute harmony. Tuning the receiving set to a given radio-phone is a matter of bringing the receiving set into resonance.

Rheostat.—A device which provides a variable resistance so that the voltage of a given power source may be regulated to meet requirements. The more resistance is introduced into a circuit by means of a rheostat, the lower the voltage that reaches the apparatus or circuit, and so on.

Selectivity.—In radio work, the ability to select any particular wave length to the exclusion of others. Thus good selectivity means the picking out of one broadcasting station while several transmitters are working in the general vicinity. Selectivity means sharp tuning.

Sharp Tuning.—Instances where a slight change in the tuning adjustments throw out a given transmitter. The sharper the tuning of a given receiving set, the greater its selectivity. In transmitting, sharp tuning means the generating of a very pure wave which will be received within narrow limits on all receiving sets.

Spider-Web Coil.—A novel means of producing compact inductance coils. A piece of fiber, composition sheeting, or other material is first cut down to a small disc, and radial slots are then cut in it so that they come within a reasonable distance from the center of the disc. Then wire is wound in these slots, with the wire first on one side, then on the other, back to the first side, and so on. In other words, each turn zigzags in and out of the disc leaves formed by the radial slots until the winding is completed. Such coils are quite flat yet are highly efficient.

Series.—(See Parallel).

Specific Gravity.—The relation which any liquid bears to the weight or density of water. In radio work specific gravity is encountered in the electrolyte of the storage battery, which must be constantly watched. The specific gravity of a storage-battery electrolyte, may be determined by using a hydrometer, which indicates the exact condition and tells when to stop charging and when to recharge. The hydrometer has a little float or "bob" which indicates the specific gravity.

Spaghetti Tubing.—Varnished cambric sleeving which is placed over delicate wires in order to insulate them electrically as well as protect them from mechanical injury.

Slider.—A device that moves along and makes contact with a coil of wire or a resistance material at any point.

Stand By.—An expression employed in radio when a transmitting station pauses, meaning that the listeners should keep their adjustments and wait for a given length of time until the transmitting station resumes.

Soft Tube.—Vacuum tubes are said to be "soft" or "hard" according to their content. Thus the "soft" tube is one containing some gas; in other words, it has not been exhausted to a high vacuum. The "hard" tube, on the other hand, has a nearly perfect vacuum. Soft tubes make excellent detectors, while hard tubes make good amplifiers.

Storage Battery.—A battery that may be recharged whenever it becomes exhausted. In radio work the storage battery is employed for the filament current supplied to the vacuum tubes.

Static.—(See Atmospherics).—Disturbances of an electrical nature which interfere materially with radio communication.

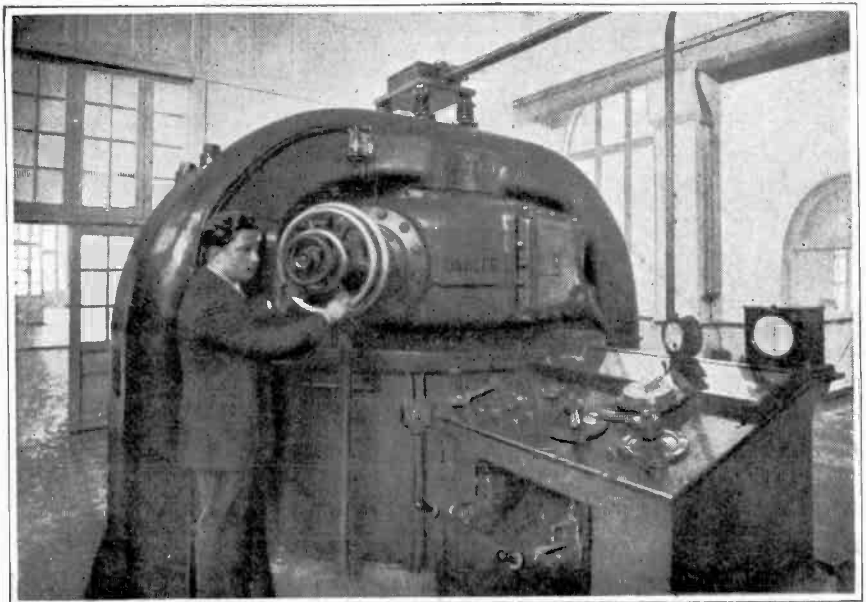
Tickler.—The coil employed in throwing back or feeding back some of the plate energy into the grid circuit.

Transformer.—A device employed in electrical and radio work for the transference of energy from one circuit to another. All transformers have a primary and a secondary. The primary has the original current, while the secondary has the transferred or induced current. The transference of energy can take place so that there is a change in the voltage and amperage, or no change at all, as may be desired.

Tuning. — Altering the capacity and inductance values of a receiving or transmitting circuit so as to vary the equipment for the reception or transmission of signals. Tuning enables the receiving operator to pick up a desired transmitter to the more or less complete exclusion of all others.

Undamped Waves.—A train of radio oscillations that maintain a constant amplitude or potential. Undamped oscillations or waves are known as continuous waves, CW for short.

Vacuum Tubes.—The devices used in modern radio for receiving and transmitting purposes. A vacuum tube resembles nothing so much as an electric lamp, containing as it does a filament as well as a grid and a plate. The glass tube of this device has had its content more or less exhausted. In action, the heated filament gives off electrons, or tiny particles of matter, which are attracted by the cold plate. Meanwhile the cold plate attracts these electrons. The grid, consisting of a fine wire interposed



Within this casing is an arc somewhat like the arc that glows on many a street. But this arc is very much larger and is kept in operation by much more complicated apparatus. This is the 1,000 Kilowatt arc of the Bordeaux station. Since the cost of such an arc converter and its accessory apparatus is about $1,000 per kilowatt, the cost of the transmitting is easily $1,000,000. The arc burns in an atmosphere of hydrogen. Powerful electromagnets blow the arc flame to one side of the gap.

between the filament and the plate, absorbs more or less of the electrons and therefore alters the size of the electronic bridge formed in the tube, over which the plate circuit current has been passing.

Variometer.—A device which serves to vary the inductance of any circuit in which it is connected. The variometer consists of two sets of coils, a fixed and a movable set, which may be so placed with relation to each other that they either help or boost the inductance in each other, or buck their inductances. Thus the wave length can be built up by means of a variometer, or it can be reduced, according to the position of the coils.

Velocity of Waves.—Radio, electricity and light waves travel through space at the astounding speed of 186,000 miles per second.

Volt (abbreviated V).—The unit of electrical pressure.

Voltmeter.—An instrument for measuring the electrical pressure or potential in volts.

Watt (abbreviated W).—The unit of electric power. To find power in watts, multiply the voltage by the amperage. 746 watts equal one horse-power. 1000 watts equal one kilowatt (KW).

Wave Length.—Radio waves in their passage through space or ether, travel in undulations simliar to the waves of the sea. When the wind is blowing hard and steady the distance between each sea-wave crest is comparatively long while if the wind is blowing mildly and in short spurts, the distance between wave crests is accordingly shorter and we have short waves. In radio, substitute the wind for the transmitter and we have the same action. Wave length is, therefore, closely related to frequency;

i. e. long wave lengths have low natural frequencies while short wave lengths have greater natural frequencies. In general, short wave lengths are used for short distance low-power work, while long wave lengths are employed for long-distance high-power work.