RADIO FOR AMATEURS

How to Use, Make and Install Wireless Telephone and Telegraph Instruments

BY

A. HYATT VERRILL

AUTHOR OF "THE BOYS' OUTDOOR VACATION BOOK,"
"THE BOYS' BOOK OF CARPENTRY," ETC.

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PREFACE

RADIO is probably the most important, the most wonderful and the most interesting of all modern inventions and unlike many other modern wonders it is within the reach of all. That this has been appreciated is proved by the fact that there are already over 700,000 receiving stations or sets in use in the United States, that over 15,000 sending or transmission stations have been given licenses by the United States Government, and that, within the past three months, over 200,000 receiving sets have been installed. Between the time these words are written and the date this book is published as many more will have been added to the tremendous total, for radio has come to us by leaps and bounds, and it has come to stay. It is no passing fad or fancy and nothing has ever been received with the universal enthusiasm and world-wide interest as this almost magical invention which is destined to play a tremendous part in the future of the world. Why, many ask, has radio so suddenly become popular? Wireless telegraphy has been known for years and yet, aside from a few amateurs and boys, it was little used except by professionals. Why, then, has radio become well-nigh universal overnight, so to speak? The answer is: radio telephony, broadcasting stations and the war.

Indeed, possibly the war should be placed first, for the perfection of wireless telephony, the establishment of broadcasting stations and the manufacture of radio equipment at prices which bring it within the reach of all are direct results of the war. War necessitated the perfection of the science until it reached a practical stage and brought about the invention of instruments which made this possible, and manufacturers, who had been making instruments and equipment for the war, turned their marvelous resources and knowledge to producing instruments for use of the public, while, in order to popularize the instruments and create a demand for them, huge stations were established to send broadcast music, songs, weather reports and news which any one with a receiving set is welcome to hear. To-day, the air is literally full of music, of voices, of songs and of countless other sounds. We are surrounded, penetrated, enveloped by invisible, inaudible vibrations which may be caught and heard by means of the cheap and simple receiving sets. Pick up the phones or receivers of such a set and what do you hear? As the instrument is tuned you catch the chatter of some amateur operating on a short, weak wave length,—for the government limits amateur sending stations to wave lengths of 200 meters. Tune to a longer wave and at the 360 meter length you hear the band concerts, the grand opera songs, a theatrical performance, a phonograph record or a weather forecast from the broadcasting station. If the set has a wider range of tuning and you can pick up the long wave lengths of the high powered stations you will hear the crash and roar of dot and dash messages flashed instantaneously from the great stations at Berlin, from the British station in Wales, from the station at Arlington, from that at Cristobal, or at Rocky Point, L. I., or perchance some station in South America, in California or even in Manila or the Orient. No wonder then that those who possess wireless sets and can listen to the voices, the signals, and the music from far distant points grow enthusiastic and that radio telephony has such a hold upon the public. And there is ever the chance of adventure, of thrill or of romance about it as well. From time to time, freak messages are borne for countless thousands of miles beyond their normal distance. A boy in Keyport, N. J., talking to a nearby friend's station was heard in Aberdeen, Scotland, by a ship 2000 miles at sea and by a station in Honduras. He was using a cheap small set supposed to be incapable of sending a message over 100 miles and yet, by some magic, by some wizardry of the ether, his voice was carried for thousands of miles. There is ever the chance for such happenings; there is ever the likelihood of hearing some distress signals from a ship, of picking up some news item of world-wide importance hours before it appears in the daily papers; it is like starting into an unknown country or embarking on an uncharted sea and never knowing what may or may not occur. And there is the romance also that appeals. You glance from your window and see the clear blue sky, bright with sunlight if it is day, illuminated by the silvery moon and twinkling stars if at night, and you know that there, unseen, indistinguishable,—traveling with the speed of light—are strains of music from far off orchestras and bands, the voices of famed opera stars, the news of deaths of kings or the fate of nations; the frenzied calls for help from some sinking ship; messages from the antipodes; signals from over trackless oceans and, like a wizard or a fairy of childhood's tales, you possess the magic wand which will grasp these in their mad flight, will bring them to earth and that will enable you to hear these ether-borne messages and sounds. The magic wand is the receiving set; perhaps contained in a little case scarcely larger than a cigar box; perhaps consisting of a few simple instruments connected by bits of wire upon your table, —an apparatus any intelligent school boy can construct and yet possessing powers beyond the wildest dreams of the ancient alchemists.

And if you have gone further and have become a confirmed radio "bug" and have a transmitting station or sending set, you can have the added pleasure and thrill of talking to some distant fellow enthusiast. You can add your own invisible, inaudible words to the countless myriads that fill the air and will know that hundreds, perhaps thousands, of other listeners are hearing what you say. But have a care that the ever watchfully listening radio inspector's attention is not attracted unpleasantly to the message you are sending. Be sure you are not exceeding the "speed limit" so to speak, that in your enthusiasm you are not sending your words or messages on waves longer than your license permits. He is ever "on the job," the traffic officer of the air, and if he finds you beyond your limit look for trouble,—a revocation of your license and the end of your sending.

But don't expect too much from radio. People have gone mad over it in a way. They imagine that with a set costing a few dollars they can hear messages and music from far and near; that by investing fifteen or twenty dollars all the sounds carried on wireless waves will be brought to their ears and that friends and family, seated in the room with the instruments, can enjoy the concerts, the operas and the stories sent from the great broadcasting stations. Like everything else radio has its limits and the instruments have theirs. A cheap set will not give the results of an expensive set and the distance at which you can listen-in depends upon the set you own. If you wish to be sure of hearing a station farther than twenty-five miles distant you must have a set capable of doing so; if you are over fifty miles away you must have a still better set and if you wish to catch the sounds and make them audible throughout the room you must have a set designed to do this. And don't forget that if you send or transmit there is no privacy in the air. Whatever you say, any one within range can hear; you are not talking over wires to some friend and to that friend alone, but are talking to the world at large. Radio is not a medium suited to telling secrets or to gossiping and for that and other reasons wireless telephony will never take the place of the ordinary phone with its wires and switchboards.

To many people radio only appeals as it is brought to them ready-made as one might say. They have no interest in the whys and wherefores, they have no desire to learn how it operates, how the instruments are made or the functions of the various appliances. As long as it works they are content, but they miss half the fun of radio communication. Just as the fellow who knows the mechanics and the principles of a motor car gets far more enjoyment out of his machine by looking after it himself, by tinkering with it, by adding new devices and improvements and by learning its every whim, its every part and how to keep it in the pink of condition, than does the chap who is helpless if his car stalls and who never looks under the hood but calls the garage if anything goes wrong, so the radio enthusiast who knows the principles and the operation and the construction of his set gets the greatest pleasure from it.

And fortunately the bulk of amateur radio fans are of this type. One can scarcely become interested in the subject without becoming an enthusiast and it is almost impossible to refrain from experimenting. This is a mighty fortunate thing, for there are many matters about radio which are little understood, many objections and faults to be overcome, innumerable improvements to be made, many things to be discovered. Many of the most notable inventions and discoveries of the past have been made by accident. Beyond doubt many will be made by accident in the future, and the amateur or the boy who experiments with radio, who is anxious to learn all about it and who is of a constructive or inventive turn of mind is liable to stumble upon some device or arrangement which will revolutionize radio. It is for the benefit of radio enthusiasts who wish to learn "why the wheels go round," who want to master the principles and fundamentals of wireless and who are anxious to make or install their own instruments that this book has been written. The author, who has been in close touch with the subject since the earliest days of wireless, believes that few amateurs, and especially boys, care about technicalities and one of the great advantages of radio is that technicalities are not necessary in order to master the subject. Therefore, all technical terms, mathematical tables, academic discussions, involved descriptions and scientific theories have been omitted from the pages of this book as far as possible and where it has been impossible to avoid using some technical phrase or term an explanation of it has been given. The book is not intended as an advanced treatise on the subject nor as a text book. Neither does it pretend to enter into the underlying theories and principles of electricity. Instead, it is written merely as a handbook and guide to amateur radio operators, to help them in an understanding of radio telegraphy and telephony, to teach them the functions of the various parts of radio apparatus, to show them how the various instruments are constructed and to supply them with information which will enable them to install and make their own outfits.

The author has endeavored to make his descriptions and explanations simple, concise and easily understood; he has taken types rather than definite makes and designs of the various instruments as subjects for discussion, and he has tried to make the diagrams so simple and plain that any boy can understand them and work from them.

Radio is one of the simplest things in the world, once it is understood, and while a large or expensive receiving or sending set may appear very complicated and a mere hodge-podge of wires, knobs, connections and instruments to the uninitiated, yet in reality it is only necessary to understand nine instruments to understand every radio sending and receiving set ever made or designed. Indeed, perfectly satisfactory receiving sets can be made with only three instruments and a little wire and no profound knowledge of electricity is required in order to make or use radio apparatus.

Radio has already made gigantic strides within the past few years and yet it is still in its infancy. There is as much or even more to be done than has already been accomplished. Thousands of experts and many more thousands of amateurs are constantly working and experimenting with it. When you are tinkering with radio instruments you are ever working on the verge of the unknown, the mysterious, the mightiest and most remarkable of forces. At any instant you may make an astounding discovery; a seemingly simple experiment may result in incalculable benefit to the world; luck or chance may solve a problem which has baffled the greatest authorities for years and now and then you may obtain a glimpse of something more astounding, more mysterious and more inexplicable than man, in his wildest fancy, ever conceived.

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CHAPTER I

A BRIEF HISTORY OF WIRELESS

It was only a few years ago that the world was startled by the announcement that messages or telegrams could be sent from one place to another without connecting wires. It seemed a marvelous, an incredible thing, a magical performance, and many intelligent and scientific persons openly scoffed at the claims of the inventors. But despite this, wireless telegraphy became an accomplished fact. To be sure, the early results were very crude and unsatisfactory; the distance to which messages could be sent was limited and few believed that wireless communication would ever be a commercial success or would compete with telegraphy over wires or cables. There were tremendous difficulties to be overcome, special instruments to be devised, countless experiments to be made. But gradually and surely wireless was improved until radio telegraphy was an everyday affair and people took it as a matter of course, and the day arrived when wireless messages were successfully flashed across the Atlantic. In those earlier days of wireless, very little was known as to the action, the principles or the control of wireless or electromagnetic waves and even to-day there is much mystery, much that is unknown in regard to them. From time to time came reports of messages received from far-distant stations,—from half way around the globe—and while these were "freak" messages yet, as the knowledge of radio increased, as it became a recognized science and as better and better instruments were devised, the range of wireless communication was rapidly increased, until practically all the world was within touch by radio. The wireless operator, listening at his receivers, heard many strange sounds and signals,—odd, unintelligible things and at rare intervals the sounds of voices or of music. Already the idea of wireless telephony had been broached and many men were earnestly engaged in experimenting with the possibility of transmitting vocal and other sounds by means of radio. Whenever a wireless operator reported having heard such sounds over his instruments, those who believed that radio telephony would one day be successful were encouraged, for often the sounds thus accidentally transmitted could be traced to their source and were found to have been produced where a wireless transmitting apparatus was being used. But in every case, the sounds thus heard were broken, interrupted and fragmentary. By a process of reasoning and elimination, the key to the mystery was at last discovered and soon thereafter various experimenters succeeded in successfully sending and receiving vocal and instrumental sounds by radio over considerable distances. Oddly enough, however, the first really successful long distance radio telephone message was accomplished by boys, the Bancroft Foote Boys' Club of New Haven, Conn., holding the world's distance record up to 1913. Then came the Great War and along with airplanes, submarines, poison gases, high explosives and other things, radio was developed and perfected by leaps and bounds. The outside world knew or heard very little of the marvelous strides being made by the radio experts during the war and what they did hear from time to time was so eclipsed by war news of more vital interest that little heed was given to it. Now and then some short article in a magazine or newspaper would mention wireless telephones, would speak of airplanes equipped with wireless, would call attention to pocket, or at least, very compact wireless apparatus, or would describe some new invention by which boats or even ships had been controlled by radio. But the public gave little heed. There were too many big things going on, —the world was too much upset and torn by the war, there were too many other interests to give much heed to wireless, while many people who did read took the statements with a grain of salt, so to speak, and thought them exaggerated or overdrawn. Then came peace and suddenly the world discovered that radio telephony was an accomplished fact, a perfected science, a commercial thing. People forgot that it had been developing for years; that it had been brought to perfection through countless experiments, the expenditure of vast sums and the untiring efforts of master minds, and so, to the public, it came as an entirely new thing, as something which had appeared overnight, figuratively speaking. And not only had radio telephony been given to the world in a highly perfected state, but it had come within the reach of all and had been simplified until the veriest amateur or any schoolboy could use it and could even build his own apparatus. And yet radio, and especially radio telephony, is still in its infancy. Its possibilities have scarcely been scratched; its future cannot be conceived or foreseen. Even now, receiving sets have been built—many of them by boys—which can be placed in an ordinary safety-match box, while pocket sets have been designed and are used by police, firemen, motorists, aviators and others. Explorers in the far-off, frozen north, people in mid-ocean, travelers in unknown wilds, farmers on isolated ranches, lonely forest rangers, prospectors and miners far from civilization all listen daily to the music, songs, weather forecasts, baseball returns, important news and even operas and theatrical performances, brought to them on invisible waves through hundreds of miles of air. Daily, almost hourly, improvements are being made; new and better instruments are being devised and better and better results are being accomplished. Not only are the future possibilities of radio communication almost unlimited, but in addition, there is the vast field of power transmission by radio and of sending pictures by wireless. Both of these seeming miracles have been accomplished and while neither is yet a practical or commercial success, only time and experimenting are needed to bring wireless power and wireless picture reproduction to the present perfection of radio telegraphy and telephony. Indeed, the main obstacle to be overcome in wireless power transmission is a system of control by which the right power will be received by the right receiving station. In other words, the question of tuning, for it would be a most unfortunate and perilous thing to send power through the air by radio unless under absolute control. You can easily imagine what the results might be if some one using a few horsepower,—as, for example, a motorcycle or a small car or a sewing machine,—should accidentally receive several thousand horsepower intended for some big factory or if a great mill or traction line, requiring thousands of horsepower, should receive only the low power required by some farmer's pump and churn. But think of the possibilities, of the future of the world's work when radio power transmission is perfected, for perfected it will be and within a very short time at that. Then there will be no further need of fuel, of coal, gas, oil, gasolene, wood or steam. From the great cataracts of the world, power in unlimited quantities will be sent to every part of the earth and the rivers of Africa, of Asia and of South America will operate the mills, the spindles of looms, and the traffic of our cities. Our motor cars, elevators, electric lights and even our household machinery will be run by the waterfalls of far-distant lands, for there is more than enough power going to waste in mighty Kaietuerk in British Guiana, in Iguassu on the southern boundary of Brazil, in the Zambesi and Nyanza falls in Africa and in countless other cataracts to turn every mill wheel, operate every loom, run every motor car and do all the work of the entire world.

Almost more wonderful is the transmission of pictures by wireless. This has been done in a way already and sending pictures or photographs by ordinary telegraphy has been successfully carried out by numerous magazines and newspapers. Within a few years, a photograph of some event taken in Europe will be reproduced by radio and will appear in New York papers hours before the event actually happened on the other side of the Atlantic. Wireless is instantaneous and with the difference of five or six hours between our country and Europe we will be able to pick up a morning paper and read accounts of a marriage, a coronation, a murder or a great celebration and to look at photographs taken on the spot and which, we will read, do not occur until noon of the same day. Then, indeed, will the uttermost ends of the earth be brought together and our present day methods will then seem as antiquated and out-of-date as the ancient stage coach and pony express seem to us now.

And beyond a doubt many of the improvements, many of the discoveries and many of the inventions that will bring such things to pass will be the work of amateurs and boys.

And now, having so briefly sketched the history and the past and future of radio, let us study its hows and wherefores, let us learn why the wheels go round, so to speak, and when we have mastered the principles and essential reasons for radio communication, learn how to build and install the instruments and how to use them.

CHAPTER II

PRINCIPLES OF SOUND AND ELECTRICAL WAVES

WE usually speak of wireless messages as traveling through the *air*, but in reality the medium through which the invisible waves are sent is the colorless, odorless and almost weightless substance known as *ether* or *luminiferous ether*, which occurs everywhere—in the air, in space, in all solids and in fact throughout the entire universe. Heat and light, sounds and energy are all transmitted by means of vibrations or waves through this ether and while the sound, light and heat waves have long been known, electromagnetic waves, as we know them, are a comparatively new discovery. It was the discovery of these waves or vibrations and of the laws governing them that made radio communication possible. Many people seem to think that these wireless waves are really sounds or sound waves which only have to be "caught" and tamed, so to speak, in order to be audible, but in reality, the two classes of waves are totally distinct. In order to understand just how these waves act we may compare them to the ripples of water in a pool when a stone or some other object is cast into it. Just as these ripples travel in all directions from the splash, so the wireless or electric waves radiate and travel away from the apparatus in the sending station. And just as the water ripples become lower and weaker and more indistinct as they move farther and farther from the splash, so the wireless waves become weaker and more indistinct the farther they travel from the sending instruments which start them on their journey. And in the same way that the ripples will move and toss a bit of wood upon the surface of the water, or will sway a sedge or reed, so the electric or wireless waves will produce a vibration or waves in the proper instruments erected for receiving them. If, when the waves are produced in the pool, we watch floating objects upon the water or stems of reeds, we will see that while such objects rise and fall and vibrate in unison to the waves, yet they do not prevent the waves from continuing on to the shore and neither do they travel along with the waves. Thus we may compare the floating objects or the reeds to sounds on wireless waves and while it might be a difficult matter to accomplish, still it would be possible to communicate by means of these water waves if splashes were made at regular intervals or in a certain notation. But in one way the waves of the pool are very different from the wireless waves in the ether. In the former, the waves are visible and are in a solid and are created and set going by mechanical energy represented by the muscular force of your arm used in throwing the stone. The wireless waves, on the other hand, are invisible waves and are in the ether and are created and set going by electrical energy represented by the spark, arc or oscillating devices of the wireless sending instruments. Originally, all wireless waves were set in motion by means of an electrical spark and while, to the human eye, each spark that flashes and crackles from the sending instruments as a message is sent appears to be a single spark, yet in reality each is made up of a vast number of small sparks following one another with inconceivable rapidity. These sparks discharge electricity or energy by the rush of current in one direction and then a similar rush of current in the opposite direction and for this reason they are known as *alternating currents.* Every time these sparks are discharged they start ripples or waves through the ether, and by making the sparks by means of a mechanical device known as a key, the sparks and the waves they create may be produced in any desired sequence or of longer or shorter duration. As these waves or oscillations in the ether will set up or induce sympathetic vibrations in any conductor they meet,—just as the ripples in the water vibrated the bit of floating wood—or the reeds—they may be "caught" or picked up by properly designed instruments known as *receivers.*

Thus, it is not at all difficult to understand how a series of sparks, produced in long and short lengths to represent dots and dashes of the telegraph code, will produce a corresponding series of oscillations and which by means of the proper appliances will be recorded as short and long vibrations or buzzes on a receiving instrument. But it is a far more difficult matter to thoroughly understand how the sounds of music, of the human voice and of similar things can be sent instantaneously for hundreds or thousands of miles through the ether by means of these electromagnetic or wireless waves.

It is a far easier matter to grasp this if we study it by means of conventional diagrams or imaginary waves illustrated by lines on paper. Thus, in *Fig. 1* the interrupted line represents the vibrations or dots and dashes of a message sent by wireless telegraph or spark transmitter, while *Fig. 2* represents the variations or vibrations of a sound wave produced by a certain word when spoken. It will be easily seen, therefore, that if we attempted to transmit the word or sound wave (*Fig. 2*) by means of the ordinary wireless telegraph wave or vibration (*Fig. 1*) the words or sounds would be broken and fragmentary as shown in *Fig. 3* and would be meaningless when heard by the receiver, although certain sounds,—such as music or the ringing of bells,—might still be recognizable, even though thus broken. On the other hand, *Fig. 4* shows diagrammatically the steady back and forth flow of a *continuous wave* current such as is used in radio telephony. *Fig. 5* shows the sound wave of a word and *Fig. 6* shows how this sound wave or word wave would appear if carried on the continuous wave (Fig. 4) without being broken or interrupted. Hence the real secret of transmitting the sounds of the human voice, music, etc., by wireless, lies in the production of extremely high frequency continuous waves or oscillations. Indeed, the waves or vibrations used in wireless telephony are of such incredibly rapid oscillation that they appear as a continuous stream or flow, a frequency of several millions a second being possible. But here again is a problem which had to be solved in order to render radio telephony practicable. The human ear cannot hear or record, or in other words "detect," vibrations of over 10,000 per second and so means had to be found for cutting down the high frequency oscillations to such an extent that the sounds carried by them would come within the range of the human ear. This is done by means of various appliances which will be described later, the principal one being the "detector" of the receiving set.

But to return to the subject of wireless and sound waves. As such high frequency continuous waves are not essential where messages are transmitted by dots and dashes only, a wireless telegraph sender can produce waves which answer every purpose by means of a spark-gap. But for radio telephone messages this would be impossible and so other devices are used to produce the required high frequency waves. Formerly, an arc-light was utilized, but nowadays an exceedingly delicate device known as a *vacuum tube* or *audion bulb* is employed. By means of this, which will be described farther on, extremely high frequency continuous waves are produced and it was really the discovery or invention of this device which brought radio telephony to its present status. But while wireless telephony cannot be carried on by means of the ordinary spark which serves for wireless telegraphy, yet wireless telegraphy messages *can* be sent by means of the high frequency continuous waves of the vacuum tube, so that with one and the same instrument both wireless telephone and wireless telegraph messages may be sent through the ether merely by making certain adjustments and adding a few instruments to the equipment. And without any alteration whatever a wireless telephone receiver will pick up both wireless telegraph and wireless telephone messages. In fact, one great complaint on the part of amateurs using small or inexpensive receiving sets is that while the dots and dashes of radio telegraph messages can be plainly heard, no music, singing or similar sounds are audible, while very often, the wireless telegraph messages so interrupt or interfere with the music and voices as to be exceedingly annoying. In order to eliminate or cut out all the sounds and signals, with the exception of those desired, devices have been made for the purpose of "tuning," as it is called. As the various sending stations create electrical waves of different lengths (expressed usually in meters) it is necessary to adjust the receiving instruments to receive or record sounds or vibrations of certain definite wave lengths. Many people think that the distance at which they can hear by their radio telephone sets is dependent upon the wave lengths of the sending stations, but this is not the case, for the distance at which messages can be heard depends entirely upon the sensitiveness of the receiving instruments, whereas the wave lengths which can be heard or detected depend upon the tuning of the instruments. Most receiving sets are rather limited in the variation of wave lengths which they can receive and the enormously powerful currents sent out by the big naval and government stations with wave lengths of thousands of meters do not affect them and might be nonexistent as far as hearing them is concerned, although the same instruments will "pick up" and detect vibrations of wave lengths of from 200 to several hundred meters without trouble. Neither does the distance to which the waves travel depend upon their length, for even the smallest of electrical waves probably travel completely around the earth; but such a wave, at a great distance from its origin, would be so weak that no present day instrument could record it. In order to create waves which are recordable at great distances, a high power must be used, just as throwing a large stone into the water would create larger and more powerful waves than a small stone. It must be borne in mind, however, that for transmission over great distances long wave lengths, or, in other words, lower frequency currents, penetrate the ether far better than the shorter and higher frequency currents, but until the invention of the Audion bulb or vacuum tube these waves of extreme length could not be picked up by any instruments. With the invention of the tube it became possible to send messages of extreme wave length which could be recorded and thus messages may now be sent almost around the earth. And just as tuning devices are required to tune or adjust your receiving instruments to certain wave lengths, so similar devices must be provided for sending sets in order to send out or start waves of the desired length. Moreover, by properly tuning the transmitting instruments, the waves may be sent in harmony or resonance. To make this simpler, we may compare it to striking a weight or pendulum suspended from the end of a cord. If this weight is struck at the point shown at *A, Fig. 7*, it will swing away and if, on its return swing, it is struck again at the same point or before the full swing is accomplished, a large amount of the force of the blow is wasted in overcoming the momentum of the moving weight, as at *B, Fig. 8*. But if we wait until the pendulum swings back to its limit before we strike it, as shown at *C, Fig. 9*, a very slight blow will serve to drive it back, as there is no momentum to be overcome. Thus, by adjusting the length of the cord and the space between blows so that each blow strikes the weight just as the latter comes to the end of its swing, a continual motion may be maintained with the exertion of very little force. Any one who has ever pushed a person in a swing knows of this and has found how much easier it is to drive the swing higher and higher by exerting the push as the swing reaches the limit of its backward motion. In almost the same way, but substituting electrical for mechanical energy, it is possible, by lengthening or shortening the period of an electrical circuit, to reach a point of adjustment where each succeeding wave or vibration will occur at just the right time to aid the one preceding it and thus the waves are sent far greater distances with the same energy than would be possible if a wave died down before it was boosted along by the one following,—a condition which is known as being "damped." With the old type spark-gap as the wave producer, really continuous waves were not however, possible, for each spark, as it leaps the gap, sets up a separate wave, whereas with the arc-light or vacuum-tube transmitter, the stream of waves is continuous. The difference between the two is better understood by the diagram *Fig. 10,* in which *A* shows the train of waves from the spark-gap while *B* represents the continuous wave from a tube transmitter. It will be seen by this that the spark-gap's waves are really intermittent and that they vary in strength or "amplitude" as it is called, or, in other words, gradually become smaller. This decrease is known as *"decrement"* and in the continuous wave of the tube or arc transmitter this "decrement" is so slight as to be negligible. So you will see that not only has the discovery of the vacuum tube and its continuous waves made radio telephony possible, but it has also vastly improved wireless telegraphy, and save for experimental work or where code messages only are sent by amateurs, the old type of spark-gap transmission has been practically abandoned. However, as the principles of wireless transmission are the same in each case and as the spark-gap is the simplest form it will be easier to master the operation of the various parts of a sending set by first studying the older and very simple form of sending apparatus. Even if you never use or see one of these transmitters, still a knowledge of its principles is very important and will be a very great help to you in mastering the principles and operation of more up-to-date outfits. Wireless apparatus may seem very complicated and confusing at first sight, yet one of radio's greatest advantages is its extreme simplicity. Indeed, there are few electrical devices so simple as those used in radio communication, and moreover, no deep study or profound knowledge of electricity is required to enable a person to construct and operate radio apparatus. Fundamentally there are but nine distinct instruments used in wireless and, if we confine ourselves to the modern tube sets, there are even less. The nine mentioned are:

Induction-coils. Tuning-coils. Condensers. Spark-gaps. Crystal-detectors. Vacuum tubes. Rheostats. Phones. Ammeters.

In addition, there are, of course, accessories, such as wires, batteries, switches, terminals, binding-posts, keys, etc. But if you once learn the principles and operation, the functions, construction and need of the nine instruments named, you can understand any radio set, for either sending or receiving, no matter how complicated or involved it may appear, for every instrument and device used in radio telegraphy and telephony is a variation, modification or combination of these. When you once understand this and bear it in mind, you will no longer be confused and frightened at the interminable lists of instruments and devices sent out by dealers and manufacturers, or mentioned in articles and descriptions. You will recognize an induction-coil as an induction-coil,—no matter what it may be called. You will know that a tuning-coil operates on the same principles, regardless as to whether it is called a "loose-coupler," a "vario-coupler" and so on, and you will find that condensers, despite variations in construction and design, are all alike in principle and operation. Indeed, radio communication may be successfully carried on with very few and simple instruments and a receiving set may be made using but three of them:—*a tuning-coil, detector* and *phones.* But as it is much easier to learn and understand the principles of the various instruments by studying them in connection with one another than if taken separately, we will begin by studying a simple spark-gap wireless telegraph sender.

Fig 1

Fig. 2

Fig 3

Fig. 4

Fig. 5

Fig 6

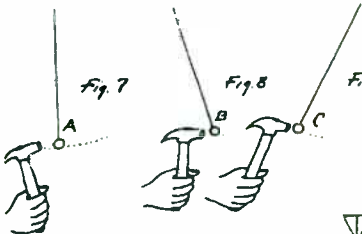


Fig. 7 Fig. 8 Fig. 9

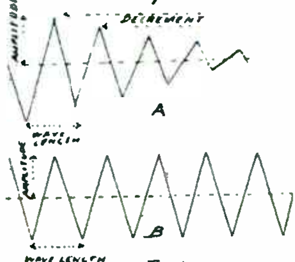


Fig 10

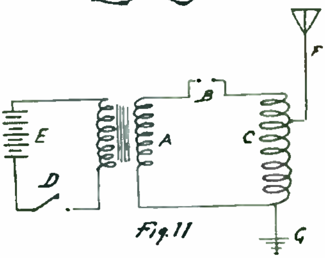


Fig. 11

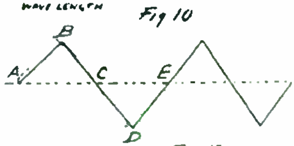


Fig. 12

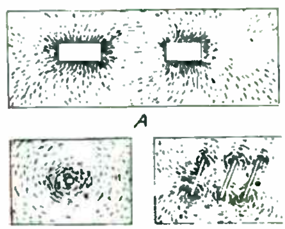


Fig. 13

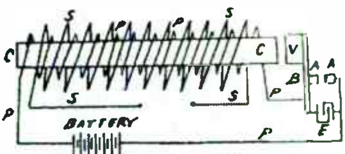


Fig. 14

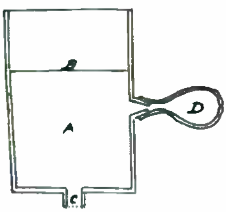


Fig 14 F.

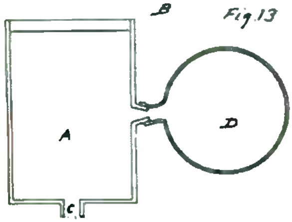


Fig. 14 G.

CHAPTER III

SIMPLE WIRELESS TELEGRAPH INSTRUMENTS FOR SENDING BY SPARK

It is possible to send radio telegraph messages by exceedingly simple instruments and once you thoroughly master the principles and operation of these you will find it very easy to understand the most elaborate and complicated sending instruments, for there is every gradation from one to the other and the principles involved are the same in all. For the simplest form of wireless sending stations only four instruments are required (*Fig. 11*). These are the *spark coil* or *inductance coil*, A, the *spark-gap*, B, *the helix* or *tuning device*, C, and the *key*, D. But in addition to these there must be certain wires and batteries (E) for producing the electricity. The wires lead from the *Aerial* or *Antennæ*, F, to the instruments and also from the instruments to a *ground*, G, as shown in the diagram. In order to send a message it is only necessary to open and close the *key*, D, causing sparks to leap across the *gap*, B, and thus send forth the oscillations of waves from the aerial *F*. But before describing how to use a sending set let us take each of the various instruments of which it is composed and learn what they are for, how they are made and the principles upon which they operate. Probably the most important and perhaps the least understood of these is the *induction coil* or *transformer A*, and whether the true induction coil or a transformer is used depends upon the current or form of electrical energy the set uses. Although an induction coil may be operated either by *alternating* or *direct* current,—the former being a current that flows back and forth, whereas the latter flows in one direction only,—a transformer can only be used on an *alternating* current and when the *induction coil* is used on an *alternating* current it serves really as a *transformer*. But just another word as to *alternating* and *direct* currents. Just as we found it easier and simpler to understand how wireless waves carry sounds by studying diagrams, so we will find it easier to grasp the difference between the two kinds of currents by means of diagrams. In *Fig. 12* the curved line represents an alternating current which starts at *A*, increased until it reaches its greatest force at *B*, and then dies down until it reaches *C*, when it swings in the opposite direction to *D*, and increases again to *E*. This flow back and forth, or oscillation, is repeated over and over again a certain definite number of times each second and each time that the current swings from its lowest point to its highest and returns to its lowest point it is said to have covered a "*cycle.*" In the diagram, for example, the point from *A* to *E* is a *cycle* while from *A* to *C* is known as an *alternation* so that a current that is said to have 70 cycles a second will have 140 alternations a second or 9000 alternations a minute. On the other hand, a direct current flows in a straight line and in order to cause such a current to swing back and forth or alternate some instrument must be used to break it up and at the same time increase its voltage as well as to produce what is known as an *electrostatic field* in the ether, and this is where the induction coils or transformers come in. In order to thoroughly understand how the induction coil works we must first understand something of its principles. The first principle is that known as *induction* or, in other words, a form of electricity known as *induced electricity* or electricity produced by magnetism. If a fine ~~wire is~~ coiled on a cylinder or tube and a magnet is slipped inside, a current of induced electricity will be formed in the coil of wire. Oddly enough, this current is of but momentary duration, for it exists only while the magnet is being moved and just as soon as the magnet remains motionless the induced current ceases. Although it seems almost magical to produce electricity in this way, the real source of the energy is in the mechanical force or muscular exertion used in moving the magnet, for you must remember that all electricity or electrical energy is produced by the transformation of some other force into electrical energy. But despite this, when we induce a current of electricity in the coil by moving the magnet back and forth, we are also bringing into play one of the most remarkable phenomena in nature and which is known as the *magnetic field* and regarding which very little is really known. But like a great many things in nature, and especially in electricity, the magnetic field is easily demonstrated and seen, even if we cannot explain it. If you take a sheet of thin glass or paper and place a common horseshoe magnet below it and scatter fine iron filings on the upper surface you will see the filings rush about until they assume a regular form or pattern as shown in *Fig. 13 A*. This is what is known as a *magnetic phantom* and the lines of filings show the lines of force which form the *magnetic field* of the horseshoe magnet. You will also find, if you are fond of experimenting and are of an inquisitive mind, that if a wire is passed through a sheet of paper or a card and an electrical current turned through the wire that the filings scattered on the card will rush into a very different pattern and will form regular, concentric circles about the wire, as shown in *Fig. 13 B*, while a coiled wire through a card will produce a still different *magnetic phantom, Fig. 13 C*. By trying magnets and electrically charged wires of varying forms you will find that the lines of force of the *magnetic field* as shown by the iron filings vary with each different shape, but that the coil gives the largest and strongest phantom. This principle of the magnetic field is one of the important factors in the functions of an induction coil. In the simplest type of such a coil there is a coil of wire known as the *primary, Fig. 14 P*, wound around a core or center of soft iron, *Fig. 14 C*, the whole surrounded by another coil of much finer wire known as the *secondary, Fig. 14 S*. If a current of electricity is allowed to flow through the primary wire, a magnetic field is produced which induces a far more powerful current in the secondary coil, the increase in voltage or power being in ratio to the number of times the turns in the secondary exceed those in the primary. Roughly, therefore, a coil with 100 turns in the primary coil and with five thousand turns in the secondary will give an induced current fifty times as great as the original current flowing through the primary. But as the induced currents are produced only when the *magnetic field* is changing, a mechanical device is employed to turn the primary current off and on. This is known as a *vibrator* or *interrupter* and every one who has ever used a gasolene motor knows how this vibrator buzzes on the end of the spark-coil. It is a very simple little device and consists of a spring pressing against a point which may be adjusted by a screw and which is connected with one wire from the battery. *Fig. 14 A A.* As the heat generated where the two touch is intense the contacts are usually of platinum or iridium. The spring, *Fig. 14 B,* is placed directly over the internal iron core of the coil and is connected to one of the wires of the primary coil. When a current passes through the primary winding the iron core is transformed into an *electro-*

magnet which draws the spring *V* from its contact, and thus shuts off the current from the battery. The instant this happens the core loses its magnetism, releasing the spring and permitting it to again make a contact and let the current once more flow through the primary of the coil. In this way the magnetic field is constantly changed and thus a powerful induced alternating current is produced in the secondary coil.

In addition to all these parts I have described, coils of this type are also provided with a device known as *condenser, Fig. 14 E,* which is made of pieces of tin foil separated by waxed paper or mica,—a most simple little affair which any child could make, but which, nevertheless, possesses really remarkable properties. The *condenser* is connected between the battery wire and the terminal of the primary wire, as shown in the cut, and its function is to prevent sparks taking place at the contact-breaker's points and in addition to add to the intensity of the induced current in the secondary. Condensers are so little understood by most people that it may be well to try to explain what they do. In a way they are misnamed, for they are really accumulators rather than condensers, or perhaps it would be better to say reservoirs. Their main function is to increase capacity and they can best be explained by comparing them to an elastic bulb of rubber attached to a receptacle holding liquid, *Fig. 14 F.* If we assume that the rubber would expand or stretch when the pressure of the liquid in *A* reached the point *B* we can understand that any additional liquid poured into the receptacle *A* would cause the bulb to stretch more and more until it had reached its limit and nearly twice as much liquid had been placed in *A* than would have been possible without the bulb, *Fig. 14 G.* Then, if the liquid is drawn off through the opening *C* and the pressure is thus released, the bulb would begin to contract and force the liquid it contained into the receptacle *A*. Thus the bulb increases the capacity of the receptacle to which it is attached. The condenser in an electrical circuit acts in the same way and increases the capacity of the circuit and at the same time, by giving out the electricity it has stored, produces a steady flow of current.

But to return to the coil. When one of these is in operation, the secondary current will jump or leap across a break or opening in the secondary wire and this spark, jumping across the gap of a device known as a *spark-gap,* is what starts the wireless or radio waves of the wireless telegraph instrument on their journey. There are many forms of these spark-gaps, some consisting of adjustable rods on standards, as shown in *Fig. 15 A;* others, known as *quenched-gaps*, *Fig. 15 B*, consist of brass or metal plates between sheets of mica, while still others are known as *rotary-gaps* and consist of electrodes mounted on a disk or wheel and which revolves between two larger, adjustable electrodes. But as spark-gaps and spark-coils are not used in wireless telephony and are far inferior to the vacuum bulb for sending any form of radio message, there is no reason to go into further details regarding them. Very closely related to spark-coils or induction coils, are *transformers,* which are used only in transforming an alternating to a direct current. There are two principal forms or types, known as the *open-circuit* and *closed-core* forms, the former being very similar to an ordinary induction coil without the vibrator or contact-breaker, *Fig. 16 A*, whereas the closed-core form consists of a rectangular or square core made up of sheets of soft-iron and with the primary and secondary wires wound on opposite sides of the core as shown in *Fig. 16 B*.

In both forms there are no contact breakers, for as these devices are used only with an *alternating current* which is constantly changing its magnetic field, no vibrators are required to produce an induced current in the secondary. I have already spoken of the simple little *condenser* in connection with induction coils and have hinted that it possessed remarkable properties and now let us see what these are and why they are so useful, for condensers are one of the most useful and important parts of wireless instruments. If you should take a condenser apart you would find it was made of alternate sheets of tin foil and waxed paper or mica and that there was no connection between the sheets of tin foil. *Fig. 17.* Although this is all there is to it, yet it stores up electrical energy and releases it automatically as the current is made and broken and by using condensers of the variable type, which may be adjusted, fine tuning in radio telephone sets is greatly aided. The next part of the simple transmission set which we are now studying is the *helix* or *tuning-coil, Fig. 18.* This is also a form of induction coil and in its simplest form is merely a coil of wire around a framework or core as shown in *Fig. 18 A,* while another form in which there are secondary and primary windings is shown in *Fig. 18 B*. In both cases, however, the purpose is the same, which is to develop the highest possible high-frequency waves, or in other words, to "*tune*" the waves to the point where, as before explained, they will travel the farthest with the least loss of energy. When a simple *helix*, as *Fig. 18 A*, is used, tuning is accomplished by snapping the wires off and on the coil by means of metal clips, whereas in the other type, known as a *loose-coupled helix*, the tuning is done by raising or lowering the secondary or upper coil. It is well to bear in mind all these devices used in the earlier types of simple sending sets, for many of them, or at least variations of them under other names, are used in the latest and most up-to-date radiophone sets and the principles of these are exactly the same as those described. Thus you will find inductance coils of various forms and helices or tuning coils of numerous types and under many names. You may be confused if you read about radio in some magazine or paper and hear of "loose-couplers," "vario-couplers," "variometers," "choke-coils," "amplifying transformers," "modulators" and many other things, but once you know the principle of an induction coil all the types of inductances are easily understood while the principles and functions of loose-coupled coils, vario-couplers, variometers, and other tuning devices are identical with that of the older and more easily understood helix.

CHAPTER IV

CRYSTAL DETECTOR RECEIVERS AND HOW THEY WORK

Simple as is the apparatus required for sending wireless telegraph messages by the old type spark-gap, the instruments and equipment for receiving are even simpler. In its very simplest form, a receiving set consists of but three instruments, known as the "*detector,*" the "*tuning coil*" and the "*receivers*" or "*phones.*" And, aside from the phones, any school boy can make such a set with odds and ends in a few hours. In *Fig. 19* these various units of such a set are shown, but far better results will be obtained by adding a condenser as shown at *Fig. 19 VC.* Receiving sets of this type are those ordinarily sold for $15 to $25 and any one can readily construct such a set at home at a cost of less than $7 which will receive messages, music, voices, etc., exactly as well as ready-made set costing several times as much. But before describing how this set is made and how it operates, it will be well to study each of the various instruments it contains and to learn its purpose and how each is made. The most complicated of all the phones or receivers, and as these are used on all receiving sets and cannot be made at home and as their operation and principles will be very fully described later on there is no need of going into the matter here.

The most important part of the set and really the simplest is the *detector* or *mineral detector*. This little device is extremely simple and cheap; any person can make one in a few minutes which, even if it does not look quite as well, will answer every purpose of the ready-made detector. The detector consists of a metal cup or holder, *Fig. 20 A*, containing a bit of crystal,—usually of the lead ore known as galena,—*Fig. 20 B*, and an adjustable wire or point, *Fig. 20 C*. Like many another simple thing, however, the detector is extremely important and is a most remarkable affair. It serves as a gate or valve to shut out a part of the high frequency, alternating waves and thus reduces their vibrations to the point where the vibrations they set up in the telephone receivers are audible to the human ear. This may not be very clear to you and so, before going ahead with our study of the receiving set and the detector, let us thoroughly understand these vibrations and how they carry sounds and how they are recorded or received. As I have said in a previous chapter (Chapter II), the human ear cannot hear sounds or vibrations of more than 10,000 vibrations per second. So, as the continuous waves or high frequency waves used in radio vibrate at many times this speed, they would produce sounds in the receivers of the phones which our ears could not possibly detect unless some means were provided for reducing them to what is known as "audible frequency," or in other words, to less than 10,000 vibrations a second. This is exactly what the mineral detector does, for galena and some other crystals possess the marvelous property of letting electrical currents pass through in one direction and not in the other. As a result, if we assume that an alternating current is represented by *Fig. 21 A*, then, after it has passed through the detector it will appear as in *Fig. 21 B*, or in other words, it has been cut in half. Perhaps you wonder why, if this is done, the sounds carried by the waves are not also cut in half and thus made unintelligible, exactly as they would be if sent by the interrupted dot and dash current from an ordinary wireless sender. But we must bear in mind that, in the first place, even if the waves or oscillations are reduced, they are still flowing smoothly and evenly or continuously and are not coming by jerks and jumps as from a telegraph sender. Moreover, although we ordinarily speak of sounds or sound waves being "carried" by the electric waves or oscillations, yet, in reality, the sound waves are not actually carried by them at all, and vibrate or travel very slowly as compared with electrical waves. What really happens is that the sound waves, where they are produced in the sending station, are impressed or superimposed upon the high frequency waves. It is a good deal like the record of a phonograph. If we consider the grooves or spirals which are followed by the needle of the reproducer as the high frequency, electrical waves, we may compare the almost invisible serrations upon them, and which produce the sounds, as the sound wave impressions upon the electrical waves. In a way, this might be illustrated by the diagram, *Fig. 22,* in which *A* is the high frequency wave while the indentations *B* are the variations in them made by the sound waves of a word or of music. But even with the waves cut in half by the detector mineral, we would still be unable to hear the sounds or vibrations made by the waves without other mechanical means, for the electric waves or oscillations are no more audible to human beings than are light waves. But by using a telephone receiver to catch the reduced waves flowing through the detector, the vibrations or waves in the ether are transformed to sound waves which we can hear. To refer to the phonograph simile again; the sound from the receiving station is sent into a telephone transmitter which transforms the sounds to vibrations of a metal diaphragm which in turn joggle or cut into the electrical waves, just as the person making a phonograph record talks into a horn provided with a diaphragm which vibrates and causes a needle to cut little depressions in the lines of the record. Then, when the electrical wave, with its smooth-flowing oscillations waved and undulated by the vibrations of the sounds, enters the receivers, every irregularity produces a corresponding vibration upon the metal diaphragm, thus reproducing the original sounds, exactly as the impressions on the wax phonograph record cause the needle of the reproducer to vibrate its diaphragm and duplicate the sounds which produced the impressions in the wax.

And now it may be a good plan to see how the telephone receiver is arranged so as to transform electrical vibrations to sound waves. Although there are many forms of receivers, yet all are the same in principle and the simple everyday telephone receiver is as good an example as any and when we study this we will find that the basic principle which governs it is our old friend the *magnetic field* which was such an important item in the induction coil. The receiver, *Fig. 23*, consists of an iron disc or diaphragm, *A*, placed close to, but not quite touching, the end of a bar magnet, *B*, which is wound with fine insulated wire, *C*. This coil of wire is connected with the wires from the detector and aërial so that the electrical waves gathered by the aërial and passed through the detector traverse the coil. We have already learned that by passing a coil of wire around a bar of iron and then turning a current of electricity through the wire we will produce an electromagnet, and thus you can readily see how the varying current passing through the coil, *C*, constantly alters the magnetism of the bar, *B*, thus causing the diaphragm, *A*, to move back and forth or to vibrate and so produce the sounds we can hear. In a somewhat similar manner, the microphone or phone transmitter on the sending instrument of a radio telephone operates to transform the sounds of our voices, etc., to varying electrical currents. The interior of a phone transmitter, *Fig. 24*, consists of a receptacle, *A*, filled with minute granules of carbon, B, held in place by a flexible strip, *C*, while the electrical connections are made with the diaphragm, *D*, on one side and the carbon on the other. As long as the bits of carbon remain loose they resist the current and prevent it from passing through, but as soon as they are pressed together they allow the electricity to rush from the diaphragm to the other connection. When sound waves, as from a voice, cause the diaphragm, *D*, to vibrate, the motion of the latter acts upon the flexible strip, *C*, thus moving the particles of carbon and allowing the current to pass through as they are forced together and shutting it off as they are released; the amount of current passing through varying in quantity in exact proportion to the amount the granules are forced together and in perfect unison to the vibrations of the diaphragm. Therefore, you can readily see that the microphone or transmitter turns mechanical vibrations, caused by sound waves striking a metal disc, into electrical waves, while electrical waves, altering the magnetism of an iron bar, become converted into vibrations we can hear through the mechanical medium of another disc.

And now, if we thoroughly understand these matters, we will return to our receiving set. As I have already explained, the detector detects the vibrating, high frequency currents and cuts them down before they enter the receiver and are there transformed to sounds; but in a way, the device is misnamed, for it is really a *modifier* rather than a detector.

As we know that countless wireless waves are constantly passing through the ether, or air as we say, you will wonder how the receiving set picks these up and renders them audible without bringing in a confused jumble of messages. This is exactly what would happen if we were to install a receiving set consisting of the detector and phone receivers alone, and to prevent this we must use a tuning device of some sort. The function of a tuner is to select or pick up messages of certain wave lengths and upon the delicacy and range of the tuning device depends the success of the set to very great extent. There are various forms of tuning devices used, but all are much alike in principle and operation and are mainly variations of inductance coils. A plain coil, *Fig.*

25, may be used as a tuner, for by having it tapped at various points the wires may be snapped on or off by means of switches or clips and thus the messages of certain wave lengths may be received. Still better is a tuning coil with a slider, *Fig. 26*. But the type of coils known as *loose coupled* or *vario-coupled* coils are far better, for these can be more finely adjusted. These consist of two coils, one within the other as shown in *Fig. 27*, the inner or secondary coil, *A*, being arranged so that it may be moved back and forth within the primary coil, *B*. In addition, a slider is arranged on the primary coil *C*, which by being moved back and forth on the rod *D* gives a still finer adjustment. When you wish to pick up a message and place the receivers at your ears and adjust the detector you will hear a jumble of noises, signals, fragments of words, music and various screeches, squeals and howls which sounds like a menagerie at feeding time more than anything else. This is caused by messages from various stations and of various wave lengths being detected and brought to you at the same time. But by moving the slider and the movable coil back and forth you can gradually tune out all but certain sounds, for by doing this you vary the wave lengths of your receiving instruments and the inductance of your coil. The single coil with slider operates in precisely the same way and on the same principles and so does the vario-coupler which is merely a rotary coil, revolving within a fixed coil; honeycomb coils which are merely various sized coils arranged so that they may be "plugged" or switched out and in the circuit and all the other types of tuning devices. And while speaking of tuning it may be well to explain just what tuning accomplishes and why it works. If you have a board perforated with holes of various sizes and roll a number of marbles of different sizes over this, you will find that while the small ones fall into the small, the medium and large sized holes and the medium sized ones into the large and medium-sized holes, the large ones pass over all but the large holes. But if you devised an arrangement by which, at will, you could regulate the size of the holes to catch only the small-sized marbles and let all others roll by, you would be doing very much the same sort of thing that you accomplish by tuning. Unless you have a very large aërial and a specially good set the longest waves will pass your instruments by without affecting them, just as the big marbles rolled over all the small and medium sized holes without falling through. There will still be the short and medium length waves which will be caught by your aërial and will be detected and made audible by your instruments. But when you tune, you so alter the receiving wave length of your instruments as to block out all but the waves of definite lengths, for by varying the slider on your coil and by moving the internal coil of your vario-coupler or loose-coupler you really alter the length and capacity of your aërial. Still, by such means, it is practically impossible to tune out waves of nearly the same lengths as those you wish to hear exactly as the small marbles *would* insist in dropping through the medium-sized holes with those of medium size. To render tuning still more selective and accurate, various other devices are employed in conjunction with the tuning coils. Among these are *variable condensers*. A variable condenser is exactly like an ordinary condenser already described with the difference that it is so arranged that the alternating metal sheets may be moved or varied. Sometimes the condenser is in the form of sliding plates, *Fig. 28*, while at other times it is of the rotary type, *Fig. 29*, and by attaching either one of these to your set between the ground connection and the wire from the tuning-coil to the receivers, as shown in *Fig. 19 VC*, the set may be tuned so accurately that practically all but the desired waves are eliminated. Although such crystal receiving sets do very well for receiving code telegraphic messages and for hearing music, songs, etc., for comparatively short distances, they cannot be depended upon to hear radio telephone messages more than 25 miles away. Moreover, they have the great disadvantage that they cannot be amplified or increased until the sounds received are audible without the use of phone receivers. They are useful for beginners, they are cheap, they are easily made and serve excellently for early experiments and as a means for learning the principles and construction of radio instruments, but if really good results are wanted, if you wish to hear messages from long distances or if you wish to amplify or increase the sounds so they may be heard all over a room or hall, you must make or buy a totally different sort of receiving set known as the vacuum tube set and which uses a very different type of detector and has many features not found in the crystal sets.

But before taking up the question of regenerative and tube sets as they are called, we had better learn something about the aërials, grounds and other parts of the sets without which radio is impossible.

CHAPTER V

AËRIALS, GROUNDS AND COUNTERPOISE

THE aërials or antennæ of radio apparatus are the most conspicuous part of all. We see them upon practically all ships, upon housetops, stretched between posts in the country and extending like a gigantic spider's web from one lofty tower to another at the big commercial stations. The function of the aërial is to send out, or rather distribute, the wireless waves from the sending station and to catch or absorb them at the receiving station.

There are countless forms of aërials, some simple and some complicated, but the principles and functions and basic construction of all are alike, and as they are among the most important of wireless communication apparatus and successful radio work could not be carried on without an aërial of some sort (at least with our present-day knowledge), great care should be used to see that they are properly made and installed. In some ways an aërial with its attendant "lead-in" wires and "ground" or "counterpoise" is the simplest part of the outfit, and yet, unless care is taken and the aërial, etc., is properly set up, the whole apparatus will be a dismal failure.

One of the great advantages of radio telephone receiving sets is that a single wire aërial will serve exactly as well, if not better, than a more elaborate and complicated affair. Indeed, it is perfectly possible and practical to use an indoor aërial consisting of a single wire run around a room, dropped down an airshaft, stretched in a garret or along a hall or even wound on a frame like a huge coil. In fact, an old iron bed spring or an iron bedstead will serve the purpose of an aërial and while such makeshifts will not give very good results, if any, with a crystal set, yet they will serve very well if you have a regenerative set which can be amplified. But to return to aërials out of doors. For sending, a many-stranded aërial is best and probably the best form is the *Cage Aërial* shown in *Fig. 30 A,* but any of the other forms shown in this figure will serve very well, while, as before mentioned, a single wire will do as well for receiving as many. The main thing is to get the aërial long enough and high enough to absorb or catch waves of sufficient strength to be audible in your receivers. Usually a single wire from 100 to 150 feet long and well up on a roof will serve every purpose for a receiving set and as the "lead-in" or wire which connects the aërial to the instruments also serves as part of the aërial itself, the farther above your instruments you can place the aërial the better. In erecting an aërial be sure that it is thoroughly insulated from all surrounding objects. Attach the ends of the aërial wire to porcelain insulators as shown in *Fig. 31 A* and if possible, place another insulator between the guy wire which holds the aërial and its support, as in *Fig. 31 B*. Attach the lead-in near one end, as close to the end as possible, and see that a perfect joint is made by scraping the wires clean and joining them as shown in *Fig. 31 C* and soldering them together, after which wrap the joint with adhesive tape or you may use the same wire for both aërial and lead-in by running it through an insulator, taking a twist about itself and then carrying it on to the set. (*Fig. 31 D.*)

It makes but little difference as to the wire you use, whether ordinary copper or phosphor bronze. Copper-covered steel No. 12 or 14 is the best. Phosphor bronze of No. 14 size and made up of several strands is the next best, but copper wire

No. 14 will do almost as well and it makes no difference whether the wire is bare or insulated, for the high frequency waves pass through every object. Take care to insulate the lead-in as thoroughly as the aërial itself, for even wood when damp is an excellent conductor of electricity. Ordinary porcelain cleat insulators will do for this and where the lead-in passes through the window or other opening to the instruments be sure and use rubber insulated wire. By cutting a small notch in the window-frame, or even by jamming the window down on the wire and pressing it into the wood, there will be no trouble about carrying the lead-in to your room, but it is better to run the wire through an insulating tube made for the purpose. Another item to be borne in mind is to see that the lead-in end of your aërial is TOWARDS the sending station you most often desire to hear or towards the most distant station you wish to pick up. Also if there are trolley wires, electric light, telephone or telegraph wires, steel structures or buildings, steel towers or even an iron smokepipe near by, be sure and run your aërial at RIGHT ANGLES TO such things. There are good reasons for both these cautions. In the first place, all wireless waves are more or less *directive,* that is, they travel farther and better in some directions than others, and in the same way a receiving aërial is directional and will pick up the waves more strongly if pointed towards a station than if at right angles or away from it. In the case of elevated tracks, buildings, bridges, etc., there are two reasons for placing your aërial far from them and at right angles to them. The first is induction, or the tendency of an induced current to be produced between your aërial and the other objects; the second is leakage and the tendency of a neighboring steel structure to absorb a large part of the electrical waves that should go to the aërial. Still another matter should be considered and that is to avoid placing an aërial between or near tall buildings. It may seem very strange and ridiculous to think that a building will cut off the waves when they penetrate everything and can be received on an indoor aërial, but nevertheless the fact remains and as long as it does you must raise your aërial as far as possible above neighboring buildings. In erecting the aërial you may attach its guy-wires to chimneys, walls or other objects that are convenient, as shown in *Fig. 32,* or you may rig up an arrangement similar to the one shown in *Fig.*

33, by which you will be able to place your antenna on a tin or slate roof without making holes for the supports. Very often, too, it is a great advantage to have several wires radiating fan-wise as shown in *Fig. 34 A*, with a lead-in where they join, or in umbrella form as in *Fig. 34 B*, and either with the lead-in from the common center or with various lead-ins that may be connected or disconnected by a multiple-point switch as shown in *Fig. 34 C*. Such an arrangement will often pick up stations far better than a single aërial running in one direction and if provided with a switch, so that all but the one pointing in the direction of the station to which you are listening can be cut out, a great deal of interference by other stations will be eliminated.

In placing your aërial, no matter what form you use, you should stretch the wire tightly, which can be accomplished very easily by means of an ordinary clothesline pulley and a piece of rope, as shown in *Fig. 35*. The next step is to provide a *ground* and a *lightning-switch* or *air-gap*. Many people imagine or believe that an aërial "draws" lightning and endangers property, but as a matter of fact, quite the contrary is the case. Metal or wires do not "draw" lightning but merely form an easy way or a good conductor for the lightning to reach the earth and it is for this reason that lightning rods are placed on buildings. Wire trellises, vines, electric wires and steel beams are all excellent as lightning rods and it is the presence of such things in the tall modern buildings that prevent such structures from being injured by lightning. Bridges, skyscrapers, railway trains and steamships are repeatedly struck without the least damage being done and even without the occupants realizing it, merely because such things are good conductors and permit the lightning to ground itself without offering resistance. Wood, masonry, etc., are, on the other hand, poor conductors, and, except when wet, are almost non-conductors, as are animals and human beings. As a result, when lightning strikes such objects it meets with great resistance and tears, splinters or burns them. It is exactly like trying to force a huge and powerful stream of water through a pipe. If the pipe is large enough, the water will flow through without trouble, even though the pipe may be weak and frail, whereas, if the pipe is too small, it will either burst or overflow. There is nothing to show that aërials add in the slightest to dangers by lightning and the records of the

New York Fire Department do not show a single case of a building being burned or injured by lightning through an aërial. That there is no risk on this score is proved by the fact that a properly installed aërial does not affect the rates of insurance, and if installed in compliance with the rules of your local fire department, or with proper care and common sense, there is no danger of lightning whatsoever. All that is necessary is to provide your aërial and ground with a *lightning-switch* or *air-gap.* The latter consists of two metal points with a space of a few hundredths of an inch between them as shown in *Fig. 36.* To the terminal *A* the aërial lead-in wire is attached as is the wire to the set, with a special ground wire at *B.* Then, when lightning runs down the aërial, it will leap the small gap and make its way to the ground. Be sure to have this ground wire large enough, at least No. 4, and well insulated from all other wires and attach it to some metal object or even to an iron stake in the earth. The lightning switch shown in *Fig. 37* is also a very simple affair. In this, the aërial lead-in is fastened at *A,* the wire to the instruments is attached at *B* and the special ground wire is run from *C.* During thunder storms or electrical storms or when not in use the handle *D* is thrown over from the receiver side to the ground, thus cutting out all connections between the aërial and your set. Both air-gap and lightning-switch should be placed on some convenient spot outside the building, as on a window sill. For receiving sets the air gap is all that is required. Also bear in mind that to install or set up a sending aërial means securing a license as a transmitting station, whereas when installing a receiving aërial no license is required. The object of the aërial, as I have said, is to bring the oscillating currents from the ether to your instruments, but there must be some means for allowing these currents to flow through your instruments and reach the earth for all electrical currents must eventually ground and otherwise the waves would pass by and never be detected by your set. To provide a ground for your instruments, it is merely necessary to attach the wire to a radiator, water or gas pipe, being careful to make a good connection by scraping a bright spot on the pipe or other object and soldering the ground wire to it. If this cannot be done, twist the wire tightly about the pipe and wind it with adhesive tape after first covering the joint with tin foil.

Very often excellent results are obtained by using the odd affair known as a *counterpoise.* This is an arrangement somewhat like an aerial and which serves in place of a ground. A counterpoise is a great advantage in sending, but is not so much value in receiving and, as a rule, where you are receiving only, the results obtained do not justify the trouble of building a counterpoise. However, they are interesting things to experiment with and do no harm. The best form for a counterpoise is a fan-shaped affair as shown in *Fig. 38* and the best position is about three feet above the earth. But as such a location endangers passers-by and as the counterpoise is likely to be injured by people and animals running against it and may be buried in snow during the winter, it is better to raise it about seven feet above the earth, attaching the various wires to stout stakes and having them as carefully insulated as the aërial itself. But neither the form nor position of the counterpoise is essential. Many stations have a counterpoise at right angles to the aërial or opposite it and on the same level, and if you can allow considerable space between the two you can place a counterpoise on the roof under the aërial if you wish. Remember, however, that while *no ground* connection is required for your instruments with a counterpoise, yet you *must have* a *lightning switch*, an *air-gap* and a *ground-wire* connected to your aërial when using a counterpoise and so arranged that both the counterpoise and aërial may be cut out of your instruments and connected with the ground during a thunder storm. This may be done by having an air-gap in each separately or by using an air-gap in one and a switch in the other, or by means of a switch so arranged that both may be cut out from your instruments and connected with the ground at the same time, as shown in *Fig. 39*.

Very little is really known about the counterpoise. They are used by airplanes, where of course grounds are impossible, and it is known that in a way they act something like condensers, with the difference that while the condenser radiates very little electricity the counterpoise radiates a great deal. They are excellent affairs to play with and there is a chance that new light may be shed on various matters and great improvements made in radio through experimenting with aërials and counterpoise.

I have already mentioned indoor aërials and while these things really belong in the chapters devoted to vacuum-tube receiving sets, still a few words in regard to them while on the subject of aërials may not come amiss. The *loop-aërial* as it is called is merely a wire coiled upon a frame and as instruments are being improved this type of antenna is rapidly gaining popularity as it obviates all the troubles of erecting an aërial out of doors, especially on hotels and apartment houses where such things are often prohibited. With an ordinary crystal set an indoor aërial or loop-aërial seldom gives satisfactory results unless very near a sending station, as the oscillations coming through the walls of a building are very weak. With a vacuum-tube regenerative set this can be largely overcome, however, by means of "amplifiers" which will be described later. The object of an amplifier is to increase the vibrations and there are two types; one known as the "*radio frequency*" amplifier which builds up the strength of the waves before they reach the detector and the other an "*audible frequency*" amplifier which builds up the sounds after they have been detected. All this will be thoroughly explained in another chapter and until the beginner has installed a vacuum-tube set and has mastered the various instruments it is best to stick to the out-of-doors aërial.

CHAPTER VI

VACUUM-TUBE SETS AND HOW THEY WORK

When we begin to study the vacuum-tube and the instruments which are used with them we will find them very different from either the spark-gap sending devices formerly used in wireless telegraphy or the crystal receiving sets which are still used. But before beginning on this subject, let us review a little of what has been done and see how and why the old spark-gap with its varying oscillations became superseded by the vacuum or audion tube and radio telephony became possible. As with a great many things, there were a number of intermediate steps which the public seldom hears about. Long before vacuum tubes were used it had been discovered that the ordinary arc-light could be used to create high frequency, continuous waves, the arc light being connected with a suitable source of electricity and provided with a simple coil for inductance and a condenser, as shown in *Fig. 40.* The microphone or transmitter was then connected with the aërial through a second coil or inductance. But while this worked, yet it had innumerable faults and wireless telephony was a crude, unsatisfactory thing until the discovery of the marvelous audion bulb. Perhaps no single invention of man has accomplished greater wonders or is more remarkable in many ways than this little tube or bulb of glass that will fit in your vest pocket. In appearance it resembles a miniature incandescent light with the filament enclosed in a netting or grid and with a metal plate about it. *Fig. 41.* But what marvels are contained in that simple affair! It had its beginning when Edison discovered that if an ordinary incandescent light bulb had a plate of nickel near the filament (*Fig. 42*) a current of electricity would pass through the filament in one direction, but not in the other. Why the great and famous electrician did not realize the importance of this discovery is a mystery, but the fact remains that he did not and it was merely considered an electrical toy or curiosity until others saw its possibilities and with a little improving and experimenting produced the audion bulb, and lo, all the problems of radio telephony were solved as if by magic.

The audion bulb or vacuum-tube as it is more commonly called, is a detector, an oscillator and the most remarkable amplifier ever known in one. So magical are its properties that it magnifies a sound a million times and more and, with the aid of the tube and properly arranged instruments, one may hear a fly walk or eat, the footsteps of the tiny creature sounding like the crashes of thunder. By means of this little bulb, the depths of the sea are now easily sounded, for so sensitive is the tube, so tremendously does it amplify or magnify vibrations or noises, that the sound of an object, such as a lead weight, striking the bottom of the ocean thousands and thousands of fathoms below the surface, can be heard, and by measuring the time which the sound requires to reach the surface, the depths may be calculated. During the war, the same little tube saved thousands of lives and many ships and helped destroy many an enemy submarine by being used as a detector of sound by which the presence of another ship, or of a submarine, could be learned when the vessel itself was invisible. In warfare, in peace, in science and in thousands of other ways, the audion bulb will prove literally a magic wand. Already, by means of the tube, it has been demonstrated that insects talk, or at least communicate, by means of vibrations so rapid that the human ear cannot detect them. If, as many scientists claim, all creatures converse, but talk in sounds beyond the range of the human ear, then, by means of the vacuum-tube, we may yet be able to listen in and hear two horses, two mice or even two butterflies or ants gossiping to each other. Such things may seem impossible and visionary, but the audion bulb is so marvelous in its properties that nothing seems impossible in the world of science now. But regardless of all that it may do in the future, its present is beyond dispute and in wireless communication it has revolutionized methods and has brought wireless telephony to a practical, commercial state and within every one's reach. And now let us see how the properties of the vacuum-tube are used in talking through the air.

The simplest form of vacuum-tube receiving set is fully as simple as the crystal receiving set, for it contains but five instruments: the vacuum-tube, a rheostat, the receivers, the fixed condenser and the tuning device, *Fig. 43.* In this particular set the tuner consists of a variable condenser *C*, and as the only other adjustment required to use this set is the tube-filament adjustment by means of the rheostat *R* it is as easy to use as the simplest crystal set with its two adjustments of crystal and coil. But in efficiency and results it is incomparably beyond the crystal set, no matter how expensive or perfect the latter may be, for the vacuum-tube is over thirty times as efficient as a detector than the best crystal detector. In the diagram, *Fig. 43,* it will be seen that the aërial *A* is connected with a simple coil or helix *B*, which is also connected with the ground *G* at a tap near the coil-center *T*. A wire is connected through a battery known as a "B" battery with the telephone receivers *P*. These are in turn connected with the tube filament *F*, which is attached to the rheostat *R* and with a second battery known as the "A" battery. This part of the set is known as the "*filament circuit*" while the wires leading from the aërial through the fixed condenser and grid-leak *GL* to the "grid" of the tube *GR* is known as the "*grid circuit.*" The third circuit, called the "*plate circuit,*" connects the plate of the tube to the coil *B*. It is well to remember these three circuits as they always occur in all vacuum-tube sets, no matter how simple or elaborate they may be. It is also well to bear in mind that in such a set the "A" battery is always attached to the rheostat and filament circuit while the "B" battery is on the plate circuit. Although all the various units of this set may seem new and strange to you at first, in reality, the rheostat, the grid-leak and the tube are the only new things, for the variable condenser has already been described; the coil is a simple one of a single wire, or in other words, a *helix*, and the phone receivers work on exactly the same principles as have been described. The "B" battery is a special, powerful 22 volt battery and made for the purpose, but the "A" battery may be either a 6 volt storage battery or a few dry cells, the storage battery being preferable as dry cells are soon exhausted and are expensive. As the bulbs are complete when bought and as the socket with its connections ready to use needs no explanation, the only part remaining to describe is the *rheostat*. This is an exceedingly simple device, *Fig. 44,* the purpose of which is to regulate the amount of current flowing from the battery to the filament. In a way the rheostat is like a tuning coil, for by moving an adjustable knob with controls on a coil the current is increased or decreased at will or "tuned" to the requirements of the filament. As rheostats are very cheap and are not easily made, there is little need to describe their construction, for no one ever should attempt to make one unless provided with proper tools and a knowledge of electricity.

The *grid-leak, GL,* in the diagram, is usually combined with an ordinary fixed condenser, and while a very important part of the set it is probably the simplest thing about it, for it may consist merely of a few pencil lines drawn on a bit of card or stiff paper and leading from one terminal of a wire to another. Although fixed grid-leaks will answer, a variable grid-leak is preferable. This can be purchased ready made or an ordinary pencil line grid-leak can be made variable by the simple process of erasing or adding lines at will. The operation of such a set is as easy and simple as the operation of a crystal set. In fact, it is easier, for the adjustment of the rheostat corresponds to your adjustment of the mineral detector, the bulb being the detector in this case, and the tuning by means of the variable condenser is even easier than tuning on the sliding coil of the crystal set. One great advantage of the vacuum tube is that it may be used as a detector to receive messages and as an oscillator for sending them. Although the vacuum tube transmitting apparatus or "radiophone" is somewhat more involved than the simple spark-gap sender I have already described, still, having once grasped its principles, it is not at all complicated.

Indeed, a vacuum-tube transmitting set *can* be made with even fewer parts than those already described for a receiving set and with no more instruments than required for the spark-gap set. Such a set is shown in *Fig. 45*, in which the *variable-condenser VC;* the *tube T;* the *rheostat R;* the *coil* or helix *C;* and the *telephone transmitter P*, form the five essentials and correspond to the *spark-gap*, the *induction-coil*, the *tuning-coil* or helix and the *condenser* of the spark-gap radio telegraphy sending set. With the vacuum-tube set, however, a direct current, instead of an alternating current, is used, for the waves or oscillations are made by the vacuum-tube and hence no vibrating induction coil is required. As I have already explained, the vacuum-tube has the properties of a detector in preventing a current from going through it in more than one direction and so, like the crystal, it transforms alternating currents to direct currents. But, unlike the crystal, it has the remarkable power of also changing direct currents to alternating currents, and merely by altering the circuits or wiring of the apparatus, the wonderful little tube may be used to admit or receive vibrations from a sending station or to start them out or transmit them. In the set shown in the diagram, *Fig. 45,* a telegraph key may be installed between the filament and the coil, as shown at *K*, and thus the set may be used for sending dot and dash code signals. But you must remember always to keep this key closed when using the set for telephone work. In using a vacuum-tube sending set, some powerful current must be supplied for the plate circuit and while, on large or elaborate sets, a high voltage electrical current, such as is used for house lighting, the current from a dynamo or generator or some similar source of current may be used and modified to suit requirements,—as will be fully described and illustrated later—the best current for amateur use in such simple sets as those shown above, is that obtained from "B" batteries.

For receiving sets, a 22 volt battery is all that is required, whereas for sending, you should use at least 60 volts. This necessity of using batteries with receiving sets of the vacuum-tube type is one of their great disadvantages, for they are heavy and cumbersome and require constant attention, whereas the crystal sets, requiring no batteries, may readily be moved from place to place. Some day, a simple, inexpensive set will be put on the market equipped with transformers and rheostats to utilize an ordinary electric light current for both filament and plate circuits; but it has not appeared as yet.

Now, having studied types of both crystal and tube sets, it may be a good plan to take up some of the more important instruments used and find out how they are made and whether or not they can be easily and successfully made at home. You will find it much easier and simpler to set up or install sets if you can construct coils, couplers, condensers, etc., yourself and so, before describing various kinds of sets and showing how they are installed, we will learn what we should and what we should not attempt to make ourselves.

CHAPTER VII

MAKING INSTRUMENTS

THE first thing to consider before attempting to make instruments or to install wireless sets is what will be required in the shape of supplies, material and tools. This is not only a highly important matter, but a very difficult thing to answer, for the materials and supplies you will require depend very largely upon what you make or install and also upon how much you may have in the way of odds and ends lying about. Very often, discarded bits of brass, old binding posts from dry batteries, worn-out electric bells and similar things; accumulations of screws and bolts; old brass hinges and washers; brass in bars, pipes or sheets; tin foil, pasteboard boxes and mailing tubes; old telephone or bell wire and innumerable other "trash" which will accumulate about a house—more especially if it is a house with a boy in it—will all come in very handily in making radio outfits. Of course, in some houses, or even among some boys' possessions, there are none of these articles, but as a rule, a very large proportion of the required material may be salved from out-of-the-way cupboards, garrets and junk. How much of this sort of material may be profitably used depends upon the ingenuity of the user. If you are quick to see possibilities and to adapt yourself and your needs to what you have, and if you can handle tools skillfully, you will be able to accomplish far better results with odds and ends and the ordinary household tools than many others less ingenious could bring about with complete tool kits and unlimited supplies of material with which to work.

But, granted you are not depending upon the rubbish about the premises, you will need the following anyway:

Sheet brass or brass strips. For sizes see the directions for making the various instruments.

Binding posts.

Wire terminals or connections.

Sheet copper; thin.

Varnished cambric tubing.

Porcelain insulators for aërial.

Porcelain cleats for lead-in wires.

Hard rubber knobs for adjusting various instruments.

Flexible insulated wire cord, such as is used for telephone receivers.

Tin foil.

Adhesive tape. (Tirro is best. Do *NOT* get the cheap stuff sold in five and ten cent stores.)

Wire; bare and insulated of various sizes. See directions.

No. 14 wire sufficient for aërial and lead-in.

Wood screws. Brass or steel flat-head and brass round-head.

Washers for round-headed screws.

Brass bolts and nuts; small sizes, assorted.

Wire nails, tacks and brads.

Brass-headed upholsterer's tacks. (These make good switch contacts.)

Thumb tacks. Very useful in making tempororay connections for tests.

Emery paper of several sizes.

Paraffine wax.

Good, strong glue.

Sealing wax.

White or brown shellac.

Bakelite or some good insulating fiber.

Plenty of strong twine.

Clothes-line pulleys and rope.

Spring clothes-pins (fine for holding wires together temporarily).

Metal clips such as photographers use.

Stiff cardboard.

Cardboard tubes of various sizes (see directions).

Of course it is not necessary nor advisable to buy all these before you begin work, for you will not need them all at once and as most of them may be bought at any hardware or electrical supply store you can get what you require from time to time.

In regard to tools it is also a question of a person's ability and his handiness with tools as to what he will need in radio work. The most essential tools are, however, comparatively few and inexpensive, and are as follows:

One medium large screwdriver.
A gimlet.
A claw hammer.
Tack hammer.
Cross-cut or panel saw.
Miter-saw and miter box (not absolutely essential).
Hack-saw with adjustable frame and blades.
Brad-awl set with awls, screwdrivers, etc., or an awl and one or two small screwdrivers separately.
Chisels and gouges (not absolutely necessary).
Three-cornered file.
Flat file or rasp.
Round or half-round file.
Plane. Block or smoothing is best for this work.
A small iron bench vise.
Sandpaper.
Bit-stock with bits and augurs.

Hand or breast-drill (geared) with assorted drills.

Flat-nosed pliers.

Round-nosed pliers.

Cutting-pliers. If cutting-pliers and flat-nosed pliers are combined the flat-nose pliers above are not required.

Compasses or dividers.

A tape, yardstick or two-foot rule.

Soft lead pencil.

Carpenter's square.

Soldering iron with solder and flux.

A set of small screw taps and dies. Not essential, but extremely useful.

When buying tools, try to get the best. It is very poor economy to buy cheap tools, for no one can do really good work without good tools and if you care for them properly they will last a lifetime.

Next, learn to read the symbols used on diagrams and drawings of electrical work. Most diagrams which you will find in the radio magazines and in many books do not have the various parts named or lettered, but have them indicated by conventional symbols which mean absolutely nothing to the layman, although they are perfectly plain to the person who understands them. There are a great many of these symbols which are never used, or are so seldom used, in radio work that it is not worth while bothering about them, but those in *Fig. 46* are in common, everyday use and should be memorized so you will always recognize them. If you wish, copy them off on a sheet of paper and pin it over your desk or bench so it always will be handy for reference. Also, while on this subject, let me advise you to have a scrap-book and in it preserve all items or articles and cuts you may see relating to radio. Very often, some hint or some knowledge you can obtain from these will prove very valuable. And now a word or two more about the symbols. You will notice that the symbol used for an inductance coil, for choke-coils, for loose-coupled coils, etc., have two coils side by side. One of these is often represented in darker or in heavier lines than the other. This indicates which is the primary and which the secondary coil•and this should be borne in mind when working from a drawing or diagram. Moreover, because the coils are shown symbolically side by side it does *not* mean that they are to be constructed in that way. It merely indicates that there are two distinct coils and in following the diagrams one coil should be wound over the other if it is a plain inductance or upon two separate tubes so one will fit within the other if a loose-coupled coil.

Another point to remember is that there is always a great deal more space shown between the various parts of a set in a diagram than there should be in the real set. This is to avoid confusion in the drawing. Also, the lines indicating wires are usually drawn very neatly and parallel, with square, sharp corners where the wires turn. This does not mean that you must lay out the set in the same way. In fact, it is far better *not* to run wires parallel any more than can be helped and it makes no difference if the corners are rounded or at angles or if wires are curved or run at angles from point to point. It looks nicer in a drawing to have parallel lines and they are easier to draw that way, but if you look at any apparatus already wired up you will find that the wires go here and there in whichever direction is most convenient.

Finally, comes the important question as to what can be made at home and what *cannot*, or rather, what is *worth while* making and what is not for a good many things *can* be made which require more time and trouble than they are worth. Frequently, there is some simple thing which any boy can make, but which can be bought for a few cents ready-made and is far better. Condensers are among these and while any one *can* make a condenser, yet, unless you are an expert, you will not know the capacity of the condenser you make and it will not be nearly as good nor look as well as the factory-made article which costs but a few cents. However, it is good practice to make such things and there is a certain amount of satisfaction in being able to use your own handiwork. But there are other things which, while they appear simple, require far too much care and skill for the ordinary person to attempt. Very often, the simplest-looking appliance is really the result of long and careful calculations and mathematical problems in order to have it just right for the purpose intended and if you went blindly ahead and made something similar it might be absolutely worthless, even though it was a perfect duplicate in outward appearance. The difference of a few turns or of the size of a wire, the size of a connection or of any one of countless things may make all the difference between an instrument being right and being wrong.

It is impossible to enumerate all the things you can reasonably expect to make or that you should not attempt; but the following list includes the more important things:

WHAT NOT TO ATTEMPT TO MAKE.

Ammeters.

Batteries.

Rheostats.

Induction coils with contact breakers.

Induction coils with thousands of turns of fine wire.

Lattice-work vario-couplers.

Variometers.

Telephone transmitters or microphones.

Telephone receivers.

Loud speakers.

WHAT CAN BE SUCCESSFULLY MADE

Fixed condensers.

Variable condensers. (Not advisable, however.)

Grid-leaks.

Plain tuning coils or helices.

Loading coils.

Plain induction coils with taps.

Loose-coupled coils.

Vario-couplers.

Small choke-coils.

Transformers, both open circuit and closed core. The latter not advisable.

Current rectifiers.

Tuning-coils with sliders.

Mineral detectors.

Spark-gaps.

Switches.
Air-gaps.
Receiving and sending sets.
Amplifiers.

So you see there are plenty of things you can make and while you may not meet with great success the first time you try, and your products may not look as nicely as those in the stores, yet, if you take a little care and trouble, they will serve every purpose and practice will make perfect. Moreover, there is no better way to learn about a thing than to make it and you will have a far better knowledge of radio and the instruments used in wireless by making a few instruments than you could ever acquire by buying your equipment ready-made and merely setting it up or wiring it.

Now, having decided on tools, supplies and what we can make, and having learned the meaning of the various symbols, we will take the various instruments in order and learn how they are made and how to make them.

CHAPTER VIII

HOW TO MAKE VARIOUS INSTRUMENTS

FIXED CONDENSERS

PROBABLY the easiest of all instruments to make is the fixed condenser, but on the other hand, a good ready-made condenser costs but a few cents and has a fixed and definite capacity, so that aside from the fun and experience to be gained in making a condenser yourself, there is very little to be gained by it.

To make a fixed condenser suitable for radio work, secure some waxed paper, or prepare it yourself by soaking ordinary heavy writing paper in melted paraffine, and cut three rectangles about 2½ inches long by 2 inches wide. Upon these, draw smaller rectangles (using very light lines), and with a margin of ¾ of an inch all around; in other words, make these outlined rectangles one inch in length and one-half an inch wide. Then cut two rectangles from a sheet of smooth and perfect tin foil, each strip being one inch in length and ½ inch wide. Cut two pieces of flexible, insulated copper wire about six inches in length; scrape the insulation away for half an inch on one end of each piece; fray out the exposed copper strands and flatten the frayed ends out. Place one of these frayed and flattened ends upon one end of one of the paper strips with the exposed copper wires within the outlined smaller rectangle, as in *Fig. 47 A*, and secure the wire in position with a few drops of melted paraffine wax outside the outlines. Then place one of the sheets of tin foil over the wire, using the outlines to center it, *Fig. 47 B;* place a second strip of paper over this and the second sheet of foil on the outlined rectangle on this paper. Then place the second wire upon the foil at the *opposite end from the first wire, Fig. 47 C,* and place the third strip of paper over all. Secure the sheets of paper and wires together by drops of melted paraffine around the edges. Roll the whole into a neat cylinder, wrap the ends tightly with strong thread, *Fig. 47 D,* and finish by wrapping with adhesive tape or by dipping it quickly into melted paraffine and the condenser is complete. Such a fixed condenser is useful in shunting across the wires leading to the phone receivers in a crystal set or for use in connection with a *grid-leak* in a vacuum-tube set. To make a grid-leak and condenser for this purpose you will need two binding posts; those taken from a discarded dry battery will serve very well. Upon a strip of heavy white paper draw one or two lines with a soft lead pencil and at the extremities of these lines make holes through which the binding-posts may be inserted and so arranging them that the space between the posts is about 5/8 of an inch, *Fig. 48 A,* then mark with the pencil about the holes, insert the posts and attach them to a suitable panel or base and connect the wires of the condenser to them, *Fig. 48 B.*

VARIABLE CONDENSERS

These are of two types known as "slide" and "rotary," *Figs. 28 and 29,* but the sliding type is the only one that is worth while attempting to make. Even this is hardly advisable as they are not very expensive and to make one neatly and compactly requires considerable skill and practice. The easiest form to make is that shown in *Fig. 49.* This consists of metal plates, about four by two inches, arranged in a wooden or fiber frame and with similar plates fastened to a handle and arranged to slide back and forth in grooves between the fixed plates. These fixed plates should be connected at one end with a wire led to a terminal and the opposite ends of the movable plates should be connected by means of a flexible stranded wire with another post as shown. Aluminum plates may be used and the whole affair should be very neatly and compactly made. The main difficulty is in arranging the plates so that they are very close together and do not touch. In adjusting the condenser the movable plates are drawn out or pushed in until the desired result is obtained.

PLAIN TUNING COILS, LOADING COILS, ETC.

These are very simple and easy to make and when home-made are exactly as good and are far cheaper than the ready-made instruments. In making ordinary simple coils or helices, all that is required is to wind the proper sized wire for the correct number of turns about a pasteboard tube or a "Formica" tube of the right size. Ordinary cardboard mailing tubes do very well, but the "Formica" fiber tubes are better as they are designed for the purpose and are corrugated or ribbed so that it is easier to wind on the wires and keep them the proper distances apart. In using a cardboard tube, always soak the tube in paraffine before using in order to render it waterproof, or else wind it evenly with adhesive tape. This also helps to hold the wires in position and makes the work easier. In starting the wires make two small holes one near each end of the coil; thread the wire through one of these and let the first turn be fully half an inch from the end of the tube, *Fig. 50.* Leave another half inch at the other end and thread the end of wire through the hole as at starting. You will find it easier to wind a coil if the wire is fastened to some object and you roll the tube upon it, than if you try to wrap the wire about the tube. If the coil is to have a number of turns of wire close together but not touching, a very neat job may be done by winding twine on with the wire, allowing a single turn of twine between each two turns of wire. Then when the coil is completed you can either leave the twine in place or remove it as you wish. Where coils are to be used as loading coils or plain helices it is a good plan to wrap them with adhesive tape when completed as this protects them and helps keep wires in place. Never shellac a coil if it can be avoided. If there is difficulty in keeping the wire in place dip the finished coil in melted paraffine or wrap with tape. Shellac always decreases the coil's efficiency. In the case of tuning coils which cannot be covered, a thin coat of shellac is however advisable, but be sure to use only enough to stick the wires to the coil.

VARIABLE COILS

Plain slider tuning coils are very easy to make and for many purposes are as good for tuning as more elaborate and complicated instruments. To make a slider coil, select a tube or form about seven inches long and three inches in diameter,—the greater the length the greater the range in tuning—and wrap with about 100 turns of No. 22 to 26 double cotton-covered copper wire, but do *not* use *stranded* wire. The wires may be put on with each turn touching the next, but it is far better to separate them by winding a string or twine between the turns. When this is done lay a straight edge along the coil parallel with its axis and draw two lines about ¼ inch apart, *Fig. 51 A*. Then with a knife, scrape off the insulation from the wires between these two lines or, if you prefer, burn it off by means of a red-hot iron. Be very careful that no two of the bare spaces on the wires touch. If you have spaced the wires with twine there will be no trouble, and if you have not, the insulation should keep them separated; but if you find any *do* touch, the trouble may be remedied by winding string on between the wires. The next step is to mount the coil, which should be done either by fastening it between two uprights as in *Fig. 51* or by screwing it or tacking it (through the spaces left bare at the two ends) to cleats on a base. A slide rod and slider must now be arranged which is most easily done by fastening two brass rods between the uprights, *Fig. 51 B.* A small brass block should then have two holes bored through it to allow it to slip on the rods readily. On one side of this, a small piece of spring brass should be fastened so that it bears lightly on the exposed portion of the wires and a set screw placed to bear on a rod as in *Fig. 51 C.* Then the block should be slipped on the rods and the latter fastened in position. Another way, which is a little simpler, is to bend a piece of sheet brass about a square rod and with one end projecting to form the contact with the coil as shown in *Fig. 51 D.* Finer tuning can be accomplished if two sliders are provided, but this is not at all necessary. The wires should be carried through the base, led along in grooves cut in the wood and attached to binding-posts as shown in the figure. Before describing any other instrument it may be well to explain that while I speak of mounting each instrument separately, yet, if you are constructing a set, it is far better to mount them all on one base ready to wire up. But before doing this, study the diagram of the set you are building and mark the positions of the various devices and of the wiring.

TAPPED COILS

Another very efficient and popular type of tuning coil may be made by taking "taps" from the coil and connecting them to the points of a multiple-point switch. To make such a coil, wind the wire on the tube exactly as already described, but at the tenth turn take a twist or loop in the wire. Continue winding and at each tenth turn take another tap or loop. *Fig. 52 TTT.* Then when the coil is completed, scrape the insulation from these loops or taps, connect them with short wires five or six inches long and wind the joints or connections with tape which may also be wrapped about the coil if desired. The coil may be mounted by tacks or screws through the bare ends and the wires from the taps should be connected to the switch contacts to which one end of the coil should also be connected. The other end of the wire from the coil should be led to a binding-post and the switch-arm should be connected with another post as shown in *Fig. 52 A.* Even the switch for this coil may be made at home by using brass-headed upholsterer's tacks driven into the base through a loop in the wire to serve as contacts and with a piece of spring brass pivoted on a round-headed wood screw with a washer above and below it for the switch arm, *Fig. 25 B.*

INDUCTION COILS

Simple inductance coils are a bit more difficult to make, but where there is no need of a multitude of windings, as when used as tuning or transformer coils, they are quite simple. They are exactly like the plain coils except that after the first winding is on, the coil is wrapped with one or two layers of good, heavy, white note paper soaked in paraffine or shellac and a second winding is put on. The number of turns of each will depend upon the set you are making and the proper number of turns, the sizes for the tubes and the sizes for the wire will be found under the directions given for making the sets.

LOOSE-COUPLED COILS

These are induction coils in which one portion or winding can be moved back and forth within the other; *see Fig. 72.* They are no more difficult to construct than single, simple coils, for it is merely necessary to wind two coils so proportioned that the inner or secondary slips easily within the primary, leaving as little space as possible without touching. Care should be used to mount the coils so that the inner or secondary is equidistant from the outer or primary on all sides, as otherwise the coil will not be very satisfactory. The best way to do this is to fit wooden ends to the tube of the secondary coil and while the two discs are clamped together, bore two ¼-inch holes through them. Then provide rods extending from one upright to the other of the mount as shown in *Fig. 53* and attach your rods to these after carefully centering the secondary coil within the primary as illustrated. The wires should be connected as shown. The outer, or primary, coil should also be provided with a slider and rods exactly as described in making a slide tuning coil and if very fine adjustment is desired, the secondary may be tapped at several points and the taps connected by flexible wires to the contact points of a switch as already described. Thus, by making a slide tuning coil and a smaller tapped coil with multiple-pointed switch and assembling the two together as shown you will have an excellent loose-coupled or vario-coupled coil.

VARIO-COUPLERS

Vario-couplers are made on exactly the same principle, but instead of having one coil sliding inside of another they are so constructed that one coil rotates within the other as shown in *Fig. 54*. Although it is scarcely advisable to make these instruments, as the ready-made ones are far better and are not expensive, still, with care, a fairly efficient and dependable vario-coupler may be made. For this you should have two tubes or cores, or, better still, a tube and a *"rotor-form"* which may be purchased ready-made for about one dollar. The outer or stator tube should be about four and one-half inches in diameter and five or five and one-half inches in length. The inner tube or rotor should be small enough to revolve freely within the outer tube without touching anywhere after allowing space for the windings. Commence to wind the outer or stator tube as already described in winding a coil, threading the wire through a hole in one end and making the first turn about ½ inch from the end, as shown in *Fig. 54 A*. No. 26 wire should be used and with the turns of the wire being kept close together but not touching. Wind on 38 turns and then bring the wire around the tube as shown in the cut and continue winding as before for 30 turns more. This will leave a bare space about ½ inch wide on the center of the tube. If you have any difficulty in keeping the wire from slipping, secure it with a drop of sealing wax or adhesive tape and be sure to take off three taps in each of the two series of windings, one at every twelve turns, beginning at the second turn and leaving two full turns without taps at the bottom as illustrated. Finish by threading the wire through a hole and by winding with tape or dipping in paraffine wax. In the open central space a ¼-inch hole must be drilled, as shown, to accommodate the shaft of the rotor which should be of ¼-inch brass rod. To wind the rotor is not at all difficult as no taps are taken. Use No. 20 wire, and wind on 25 turns to form what is known as the "tickler" coil, running the wire through a hole and securing it and leaving free ends at least 6 inches in length, *Fig. 54 B*. At the opposite end of the rotor wind on 42 turns of No. 20 wire to form the secondary coil, *Fig. 54 C,* also leaving free ends to the wire. Fasten the ends of the wires where they pass through the form by glue, sealing wax or tape and finish by dipping in paraffine or by a thin coating of shellac. Bore a hole through the exact center of the rotor form to accommodate the brass shaft and proceed to mount the instrument. To do this, make a Bakelite or fiber panel,—the exact thickness or size does not matter, but the smaller the better as long as it will accommodate the vario-coupler,—and bore a hole for the shaft ¼ inch in diameter at a point two inches from one end and three and one-quarter inches from one side, *Fig. 54 D.* Then slip the rotor inside of the stator tube, pass the brass rod through both and secure the shaft to the rotor by glue, sealing wax or nuts on the inside. If you are a clever hand with tools, you will no doubt prefer to use nuts threaded on the shaft, but sealing wax or glue will do just as well. Be sure that when the shaft is turned the rotor revolves freely without touching the stator. Pass the shaft through the hole made for it in the panel and fasten the outer or stator tube to the panel by means of screws or tacks through the bare ends. Fit a knob or handle to the end of the shaft and arrange the opposite end, by means of a washer and pin or a washer and nut, so that it cannot move out and in and thus allow the rotor to touch the inside of the stator. A washer also should be placed between the knob and the surface of the panel. In the lower corner of the panel make six holes for contact points as shown, using either real points or round-headed brass bolts with nuts on the inner ends, and on the other side drill six holes for binding-posts. These should be connected with the primary, secondary and tickler wires while the contact points on the switch are connected with the six taps on the primary coil, using flexible wire to allow the rotor to move freely. The other primary wire should be connected to the switch-arm post. Then the whole should be fastened to a base and is ready for use, *Fig. 54 E.* In connecting this vario-coupler to the set the aërial is led to the primary wire binding-post, the ground is connected to the primary led to the switch-arm, and the secondary and tickler posts are connected as shown in the diagrams of the sets using vario-couplers.

VARIOMETERS

These also may be made at home, although I do not advise or recommend it, for the entire efficiency of a variometer depends upon the accuracy and care with which it is made, and unless one is skillful and has had experience it is a hard job to make one of these instruments accurately. In a general way they are very similar to the vario-coupler. Use two tubes, one about four inches in diameter and three inches long, the other about three and three-quarters inches in diameter and short enough so that it can turn readily within the other tube without touching and with as little space as possible to spare. Before beginning to wind these, find the exact centers and bore holes for the shaft as it is much better to do this before winding than later, for if a mistake is made you can use a new tube and you will not have wasted your labor of winding on the wire. Having done this and tested the accuracy of your work by placing the shaft temporarily in place and turning the inner tube, you may proceed with the winding. Start with a hole as already described, but leaving only ¼ inch of bare space on the tube. Use No. 24 double, cotton-insulated wire and put on about twenty turns, keeping the wires separated. Then skip a space, as when winding the vario-coupler rotor, and put on another twenty turns, finally running the wire through a hole and fastening it and leaving five to seven inches of free end. Wind the larger tube in exactly the same way and *being sure to wind in the same direction.* When both are wound, mount the smaller tube within the larger one as you did with the vario-coupler and finally connect one end of the stator wire to one end of the rotor wire, leaving plenty of free wire to enable the rotor to move easily. Lead the other two ends to binding-posts as shown, but taking care to leave that leading from the rotor loose enough to permit motion of the rotor without dragging or binding, *Fig. 55.*

CHOKE COILS

Choke coils are merely simple coils wound on a form, and with an iron core, and for most purposes it is far easier to use an old spark coil, screwing the contact-breaker down tight and using the secondary wiring only, than it is to make them.

TRANSFORMERS

All that is needed to make transformers is unlimited patience, a great quantity of wire, a knowledge of electricity, a knack in using tools and in winding on wire and the desire to do something at home which can be better made in a factory. In other words, I do not approve of any amateur attempting to make these instruments. In the first place, a transformer is of little use and may lead to irreparable injuries to other instruments or to the user if it is not accurately designed and wound for its particular use. In the second place, there are often several thousand turns of fine wire to be wound on and the wire and time used amount to more than a really good transformer will cost if bought ready-made. Finally, after you have gone to all the trouble and expense, you will find very often that the transformer does not give satisfaction and all your time and labor have gone for nothing.

CURRENT RECTIFIERS

These are used in rectifying currents of electricity in sending sets where an alternating current is transformed to a direct current and as they are easy to make and are simple affairs they properly fall in the list of instruments and fittings which can be made at home. A very good rectifier may be made from pint Mason fruit jars, some strips of sheet aluminum and lead and some ordinary Mule Team Borax. The sheets or strips of metal should be about five inches long and one inch in width and should be placed in such a way that they alternate as shown in *Fig. 56.* The jars should be filled three-quarters full with a solution of a pound of borax to ten pints of water. Dissolve the borax in a separate receptable and in filling the jars be sure there is no sediment or undissolved borax in the bottom of them.

CRYSTAL DETECTORS

These are so extremely easy to make that any person should succeed and while an excellent crystal detector may be bought for a dollar or two, still one may be made which will serve every purpose and will not cost over fifty cents.

The only materials required are binding-posts from discarded dry batteries, a little strip brass about 1/16 inch thick and ½ to ¾ inch wide, a small piece of sheet brass or copper, some fine brass "cat whisker" wire and a bit of galena crystal.

The whole affair is so plainly shown in *Fig. 57* that an explanation or description is scarcely required. The upright *A* is merely a strip of brass fastened to the base by means of a screw and a binding-post *B*. The "cat whisker" is wound around a lead pencil to form a spring as shown at *C*. The cup *D* for holding the crystal is a square or rectangle of sheet copper or brass with the corners bent up to hold the galena and with one side fastened to the base and binding-post *E*.

HOW TO MAKE A REALLY EFFICIENT CRYSTAL DETECTOR

Although a crystal detector is a very simple piece of apparatus and while almost any home-made detector will work, yet a great deal of the success of a crystal receiving set depends upon the efficiency of the detector. A really good detector must possess several important features which are often lacking in cheap, ready-made instruments and are always absent in roughly-made "cat whisker" affairs such as the average novice or amateur devises. Not only must a detector have perfect contacts and connections throughout, but it must be capable of adjustment in various directions and must be rigid, for in order to obtain good results, the most sensitive spot on the galena crystal must be found and this can only be done by "feeling" over the crystal with the fine wire or "cat whisker" contact. If the latter is fixed it is practically impossible to "feel" over the crystal unless the latter is moved about, which is clumsy and unsatisfactory. Furthermore, even when the most sensitive spot is found and the contact made, a very slight jar or vibration will throw off the contact and a new adjustment must be made. Of course, any one who is accustomed to using machine tools and possesses a set of screw-taps and dies can make a good detector, but there are many amateurs and beginners who are not familiar with metal working and who do not own taps and dies and do not care to purchase tools merely for the purpose of making such parts of their sets as they would like to make themselves. The detector shown in the accompanying diagrams has been designed especially for those who wish to construct their own instruments, but who are not skilled in the use of metal-working tools or do not possess them. If made neatly and according to the following directions, this detector will be found fully equal to any of the ready-made instruments and far better than the majority. Moreover, it may be made for a total expenditure of less than seventy-five cents and the only tools needed are a small iron vise, a screwdriver, a pair of flat-nosed pliers, a soldering iron, a jackknife, a small hammer, a file, a hacksaw and a few drills. A breast drill or an ordinary bit-brace with some bit-shanked twist drills will answer all purposes. Even if you have to purchase the drills to fit your bit-brace the cost of the detector should not be over $1.25 or $1.50, and such drills are almost a necessity if you intend to install or make a radio set. A pair of tinsmith's shears will be a great help, but are not essential. The materials required are some sheet brass of about 1/32 and ⅛ inch in thickness, a brass rod ⅜ inch in diameter, a short length of fine phosphor-bronze, brass or platinum wire; a few 5/32 or ¼ brass screw-headed bolts with nuts, a few brass lock-washers or spring-washers of the same size as the bolts; two binding-posts and some knurled thumb-nuts to fit the bolts or some binding-screws and nuts from old dry batteries; a piece of wood or fiber about ½ to ¾ inch thick and 4 inches square and a piece of brass tubing with an inside diameter to slip easily over the brass bolts.

This sounds like quite a formidable list, but as the pieces are all small the whole lot amounts to very little. If you have a pair of tinner's shears

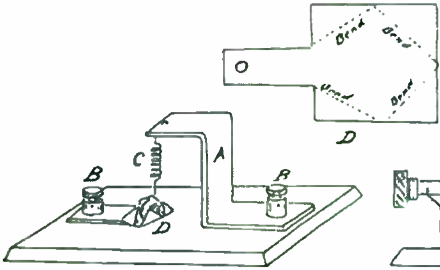


Fig 57

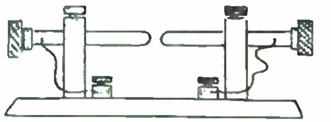


Fig 59

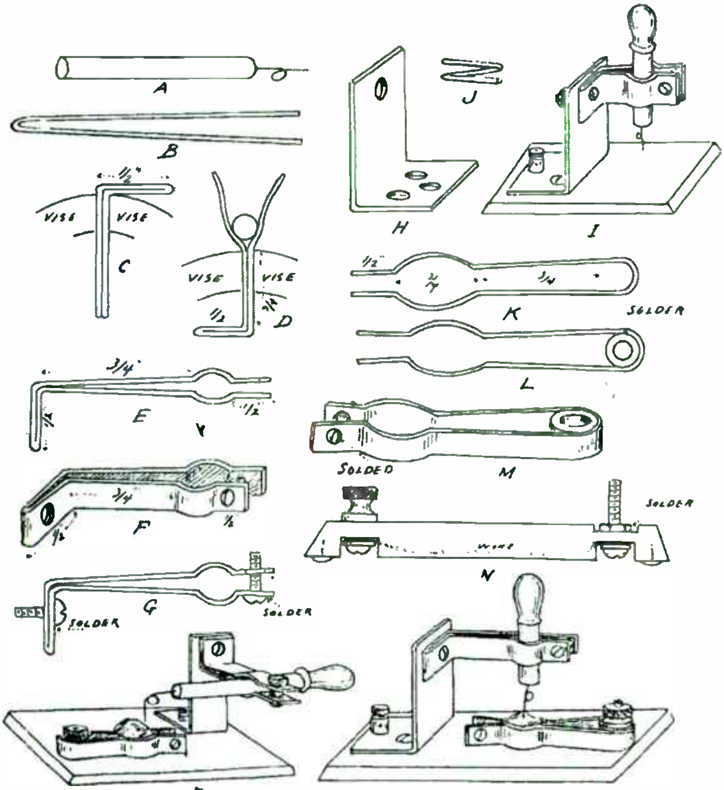


Fig 58

(which may be purchased for $0.50) you can easily cut the thinner brass yourself, but if you do not, you can get the nearest tinsmith to cut it for you or can manage with a hack-saw and file.

The first thing to make is the rod carrying the contact wire or cat-whisker. This is the ⅜-inch brass rod 2¼ inches long. In one end of this drill a small hole and in this insert the fine wire which should be bent as shown at *Fig. 58 A* and should project from the rod about ½ an inch. Solder this wire in position and turn to the next part. This is the holder for the rod and consists of a strip of brass about 5 inches long, ½ inch wide and from 1/32 to 3/64 of an inch thick. Bend this back upon itself at the center as in *Fig. 58 B*, which is best done by holding the strip in the vise and bending it sharply over, tapping with a hammer along the fold until a right angle is formed and then bending the sides down close together by hammering along the bend. Next, grip the folded strip in the vise with ½ inch of the folded end projecting and bend it over at right angles as shown in *Fig. 58 C*. Then place the strip in the vise with the free ends projecting, and with the top of the vise jaws ¾ of an inch from the right-angle bend. Spread the free ends apart and force a brass or iron rod or bolt ¼ inch in diameter between them, as shown in *Fig. 58 D*. By gently tapping with the hammer and bending back the ends with pliers, form the two sides of the strip as in *Fig. 58 E*. The strip, when removed from the vise, should now appear as in *Fig. 58 F*. Round and smooth off the sharp corners and edges, by means of a file and bore holes, the size of your brass screw-headed bolts (or of the terminal screws from the old dry battery) through both sides of the brass as shown. In boring the hole through the free ends, secure the ends in the vise or you will have trouble. Also, make one of these holes in the free ends a trifle larger than the screw. Insert the brass screws or bolts through these and solder the heads firmly to the brass strip, *Fig. 58 G*. Now take a strip of ⅛-inch brass three inches long and about ¾ of an inch wide and make a good, sharp right-angle at ¾ of an inch from one end, and in this bore four holes the size of the brass screws or bolts. Three holes in the short leg of the angle as shown and one near the upper end—about ⅜ of an inch from the end—as shown in *Fig. 58 H*. Round and smooth off sharp corners and edges and attach the strip to a neatly-made and finished panel or base of wood, fiber or Bakelite. Use two round-headed wood screws to secure the brass strip to the base and in the third hole on the short angle place a binding post or terminal screw. Then assemble the contact rod and holder as shown in *Fig. 58 I*, attaching the holder to the upright by the screws and using a spring washer and knurled thumb-nut as in the figure and a similar nut and washer on the screw that holds the two free ends of the holder together. If you have no spring-washers you can readily make excellent ones by cutting sections from a brass spiral spring as shown at *Fig. 58 J*. Then slip the rod through the holder and slip the rubber bulb to an ordinary medicine dropper over the end as shown in *Fig. 58 I*. By tightening on the thumb-nut at the free ends of the holder, the rod will be held firmly, and by loosening it, it may be turned or moved back and forth as desired. The spring-washer and nut which secure the holder to the upright may be adjusted so that the holder is immovable or swings freely or stays at any intermediate point. Now make the crystal-holder by bending a strip of the 1/32-inch brass ½ inch wide in the form shown in *Fig. 58 K*. Make the semi-circular band or fold at the center around a ¼- or ⅜-inch rod and in the bend solder a short section of brass tubing with an inside diameter that fits snugly over one of your brass bolts but that does not bind, *Fig. 58 L.* If the hole in the tube is too small it may easily be enlarged by running a drill through it, but if too large it cannot be made smaller, so if you cannot secure just the right size get a tube a trifle too small and bore out the hole to suit. Bore a hole to take one of the screws through the free ends as shown, making the hole on one side a trifle large for the screw, to allow some play, and solder the head to the other side, as you did with the rod holder, and fit a washer and thumb-nut on the screw as in *Fig. 58 M.* Now place the crystal holder upon the stand or panel with the crystal grip under the end of the contact rod when the latter is in the position shown in the cut, *Fig. 58 I,* and in line with the upright as shown in *Fig. 58 O.* When in the proper position, mark where the hole in the brass tube comes and after removing the holder bore a hole through the base to take one of the brass bolts, countersinking a space to take the nut on the upper surface of the panel. Bore a similar hole near one of the corners of the panel and countersink both holes on the under side to accommodate washers and screw-heads, *Fig. 58 N*. Insert a long screw in the hole to secure the crystal holder, placing two washers between the head and the lower surface of the panel and with a wire between them as shown. Screw the upper nut down tightly by holding it with the pliers and turning the screw-headed bolt with a screwdriver, and solder the nut firmly to the bolt. In the other hole, place a binding-screw as shown in *Fig. 58 N* and connect the wire as indicated, cutting a groove in the bottom of the panel for the wire so that all will be flush on the bottom. It is a good plan, however, to place a leather-headed upholsterer's tack at each corner as this will give a firm bearing and will prevent slipping. If you have any trouble in working at these things with the upright and contact rod in place, you should remove them as soon as the position for the crystal holder is marked. Finally, assemble the crystal holder as in *Fig. 58 O*, place the crystal in it and clamp it tightly and the detector is ready to connect and use. With this detector, adjustment is very easy and the contact wire may be moved over every portion of the crystal, as the three motions obtainable with the contact rod, combined with the swing motion of the crystal holder, give a wide range of positions. By keeping a slight tension on the spring washers under the thumb-nuts the parts may be moved for "feeling" and yet will not be jarred out of position. By tightening the nuts, the parts may be securely locked in any position desired. The whole affair is very compact, the base being but 3 x 3½ inches in size. Some people prefer a detector with horizontal contact-rod and to make this it is merely necessary to shorten the upright support to 2 inches and alter the relative positions of upright and crystal-holder accordingly, *Fig. 58 P.* An ordinary rubber bottle stopper makes a very good handle in place of the medicine dropper bulb, if preferred.

SPARK GAPS

These are no longer used to any extent, but any one who desires to make one may readily do so by taking two battery zincs, fitting them with wooden or fiber handles and mounting them in a fiber or wooden support as shown in *Fig. 59.* Carbons from arc-lights may be used in the same manner, or if a small gap is required, use hard zinc, or, better still, silver, rods.

Now, having learned what instruments you can expect to make and how to make them, we will turn our attention to receiving and sending sets and how the various instruments I have described are used in setting them up. But first let me impress upon you the absolute necessity of making all wire connections properly. Scrape the wires clean and bright, twist them together as shown in *Fig. 31 C*, Chapter V, and if possible solder them, finally covering with a varnished cambric tube.

CHAPTER IX

SIMPLE RECEIVING SETS AND HOW THEY ARE MADE

THE SIMPLEST CRYSTAL RECEIVING SET

The simplest possible receiving set consists of only three instruments: tuning coil, detector and telephone receivers, *Fig. 60;* but it is not by any means as efficient as the somewhat more elaborate sets which will be described later. It is a wise plan, however, for the beginner to start with the very simplest sets, especially if he wishes to make the various instruments himself and then, as he becomes more accustomed to using tools and more familiar with the manipulation and the principles of his instruments, he can add to them or make better sets. Very often, the same parts, or instruments, may be used in another set and so nothing is wasted.

But neither should the maker or owner of a simple crystal set expect too much from it. If near a broadcasting station such a set as the one shown in *Fig. 60* will receive music and voices very well, but it cannot be depended upon for more than 25 miles, and with such simple apparatus it is not possible to tune out interferences as well as with better sets. One advantage of this set is that all the parts, with the exception of the telephone receivers, may be made at home. The coil may be either a plain coil with a single slider, or a coil with two sliders, or a coil with taps and a switch, all of which have been described. In the case of a single-slider coil the set is wired as in *Fig. 60,* whereas, with a double slider, it is wired as in *Fig. 60 A.* To many people, the cost of a set is a very important item. Although, with the varying prices of supplies, it is impossible to give the exact cost of a set, the approximate cost of this set should be about $5.80 to $8.50 if all parts are made yourself, the cost being divided as follows:

Aërial and ground wire...........	$0.80	to	$1.50
Aërial insulators	.60	"	1.20
Other wire, etc..................	.25	"	.50
Miscellaneous supplies	.15	"	.25
Telephone receivers	4.00	"	5.00
	$5.80	"	$8.50

If the detector, coil, etc., are purchased ready-made and are simply put together or assembled, the set will cost about $9.00 to $13.00, as follows:

Fixed condenser	$0.35	to	0.50
Aërial and ground wires	.80	"	1.50
Insulators	.60	"	1.20
Detector	1.25	"	2.00
Coil	1.50	"	2.50
Receivers	4.00	"	5.00
Air gap	.25	"	.25
	$8.75	"	$12.95

Such a set will be about equal to a set which bought ready-made in a case will cost from $15.00 to $20.00, but as these ready-made sets seldom include the receivers, the aërial and aërial fixtures in the price, the actual saving would be from $14.00 to $16.00 if the parts are made, or from $11.00 to $12.00 if the parts are bought and connected.

A BETTER CRYSTAL RECEIVING SET

The set illustrated in *Fig. 60,* and described above, will be greatly improved by the addition of a variable condenser as shown in *Fig. 60 B* and which will add about $5.00 to the cost of the set, for, as already mentioned, it is not advisable to attempt to make a variable condenser.

A VERY GOOD CRYSTAL SET

By using a variometer with the preceding set in place of a coil, as shown in *Fig. 61*, you will have a very excellent receiving set at a very moderate price, for you can purchase an excellent instrument for four or five dollars, so that even if you purchase all the parts ready-made, the completed set should not cost over \$16.25 to \$20.50, and by making the detector and some other parts yourself the price may easily be reduced to from \$15.00 to \$18.00, which is far lower than you can get a really efficient ready-made crystal set even without the receivers.

A SET WITH LOOSE COUPLERS

By using the same set as above and substituting a loose coupler or loose-coupled coil in place of the plain tuning coil, a very efficient crystal receiving set may be made, *Fig. 62*. This will add about \$3.50 to \$7.00 to the cost of the set if it is purchased and the other instruments (with exception of phones and variable condenser are made) or from \$2.50 to \$4.50 if the various instruments are purchased ready-made. If, on the other hand, you make the loose-coupled coil as described in a preceding chapter, you should be able to make the entire set for from $10.00 to $18.00. Such a set will do excellent work and, in fact, is about as perfect as it is possible to make a crystal set. It will be fully equal to the ready-made sets selling for $25 to $35, and if anything better is desired you should make a vacuum tube set.

THE SIMPLEST VACUUM TUBE SET

This set, *Fig. 63*, is as simple as a good crystal set, for it contains but six instruments and all but the receivers, tube, variable condenser and rheostat are easily made. Moreover, it possesses the great advantage of having but three adjustments,—the variable condenser coil and rheostat. The cost of this set, if you make the coil, fixed condenser and grid-leak should be about as follows:

Aërial, ground wires and air-gap..	$1.00	to	$2.00
Aërial insulators	.60	"	1.20
Vacuum tube	5.00	"	6.50
Vacuum tube socket	.50	"	1.50
Rheostat	.50	"	1.50
Wire and supplies	.50	"	.75
Receivers	4.00	"	5.00
Variable condenser	4.00	"	5.00
	$16.10	"	$23.45

To this must be added an "A"-Battery, which will cost from $10.00 to $12.00, and a "B"-Battery at a cost of from $2.00 to $4.00, so the complete cost of the set will be about $28.00 to $40.00. This will, however, do as good work in receiving as a ready-made set costing anywhere from $30.00 to $50.00 without batteries or from $42.00 to $66.00 complete. I have already described how to make a fixed condenser and grid-leak, but the coil for this set is somewhat different from the coils described, although even more simple. It consists of a tube about three inches in diameter and 2 inches long wound with about forty-five to fifty turns of No. 26 double cotton-covered copper wire with a tap taken off at the tenth, twentieth and thirtieth turns and led to the contact points of a four-point switch as shown and as described in Chapter VIII, *Figs. 52-53.* In wiring or setting it up be sure to follow the diagram exactly as to wiring and be *very* sure to have the *positive pole* marked "P" or "+" of the "B"-battery connected with the plate of the tube and the negative pole marked "N" or "—" connected to the receivers. Also, remember and connect the positive pole of the "A"-Battery to the rheostat and the negative pole to the ground, as shown in the diagram. The whole set should be neatly mounted on a wooden, fiber or Bakelite panel or base, keeping the set as compact as possible; if you are handy with tools you can build a neat case or box with a hinged cover to hold it, placing the adjusting knobs of the rheostat and variable condenser on the outside.

A SET WITH VARIABLE SLIDER COIL

The same general arrangement as in the last may be used with a slider or variable coil. The only difference is in the wiring of the coil, which is very plainly shown in the diagram, *Fig. 63 A.* The slider coil used is the same as described in Chapter VIII and the only advantage it has over the preceding is that it may be tuned a trifle finer.

A SET WITH TWO ADJUSTMENTS

Although the foregoing sets have but *three* adjustments, it is possible and practical to make a set with only *two, Fig. 63 B.* However, it must be confessed that this set has a tendency to buzz if an amplifier is used with it. If used merely as a detector set with head phones it does excellent service and if well made and carefully tuned it will render fairly clear amplification to two steps, but beyond that it is not satisfactory. The coil is a plain, tapped coil with 46 turns of wire on a tube three inches in diameter and two inches long and with a single tap at the 23rd turn.

ANOTHER SIMPLE VACUUM TUBE SET

This set, shown in *Fig. 64,* is almost as simple as the last and is far more efficient. In fact, it is fully as good as many of the regenerative receiving sets sold for from $60.00 to $75.00 without batteries, bulbs or phones, and yet you should be able to make it, even if you purchase many of the instruments, for from $29.00 to $41.00 without batteries or $40.00 to $55.00 complete, the price being divided as follows:

Aërial and ground wires..........	$1.00	to	$2.00
Other wires and supplies	.50	"	1.00
Insulators	.60	"	1.20
Air gap	.50	"	.60
Tube and socket	5.50	"	7.50
Rheostat	.50	"	1.50
Receivers	4.00	"	5.00
Vario-coupler	4.00	"	5.00
2 Variometers	8.00	"	12.00
Variable condenser	4.00	"	5.00
	$28.60	"	$40.80

About the only part that can be made is the vario-coupler and it is not really advisable to make this, as by doing so you cannot save over $3.00 and the results will be far better with a factory-made instrument. In making up this set, as in making up any set of instruments, it is a very wise plan to place them on a sheet of paper or thin cardboard and arrange them as they should be wired, marking pencil lines to indicate the wires and connections. Then, by moving and shifting them about, you can arrange them to the very best advantage to fit on a neat base or in a case. When all is arranged satisfactorily, mark where the binding posts, etc., should go and then, by using this as a guide or pattern, you can make the holes for the various attachments in the fiber, wood or Bakelite base, without marring it or making unnecessary holes. Such a set as this will permit almost any amount of amplification or increasing by means of amplifiers (to be described later on) so that it may be made to receive messages loudly enough to be heard all over a room. The only disadvantage to this set is that it has five different adjustments. However, after you once have it adjusted to the waves you wish to pick up, the various knobs or dials may be marked so that there will be very little trouble in picking the messages up the next time.

REGENERATIVE RECEIVING SET WITH SLIDE-TUNER

Another very excellent regenerative vacuum-tube set is shown in *Fig. 65* and in which a double-slide tuning coil and a variable condenser take the places of the vario-coupler and variometers in the last set. This gives one less adjustment to be made. If the coil is homemade the cost of this set will be considerably less than for the preceding, for you can deduct the price of the two variometers, or from $8.00 to $12.00, and for the vario-coupler, or from $4.00 to $5.00, thus bringing the cost of the set without batteries from $16.00 to $23.80. By adding another variable condenser in the ground circuit, as shown by the dotted lines, the set will be improved and the cost will still be below that of the preceding set. A really good double-slide tuning coil is not a very easy instrument to make, however, and if this is purchased ready-made it will cost from $5.00 to $8.00; so, with two condensers, the set will cost very nearly the same as the vario-coupler set, and as the results obtained are practically the same it is largely a matter of choice as to which you should make.

ANOTHER REGENERATIVE VACUUM TUBE RECEIVING SET

In this set (*Fig. 66*) the vario-coupler described in *Chapter 8, Fig. 55,* is used and if well made, or if a ready-made vario-coupler is used, you will have a regenerative receiving set that is about as perfect as can be made by an amateur. This set complete, if you make the vario-coupler, should not cost over $18.00 to $24.00 without batteries; and if the vario-coupler is purchased ready-made, the set, without batteries, should still come within $23.00 to $30.00, according to the quality and grade of supplies and the number of fittings, such as binding-posts, terminals, knobs, dials, etc., that you use. In making this set, as in the last, draw the outline or pattern of the various parts and wiring on cardboard or paper so that you can make it compactly and neatly, for a set of this sort,—or any of the regenerative sets for that matter,—is worth a little care and trouble. Of course if you wish, you may set up the receiving set temporarily on a piece of board and when you are quite sure that it is con-

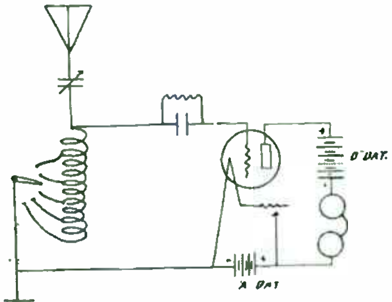


Fig. 63

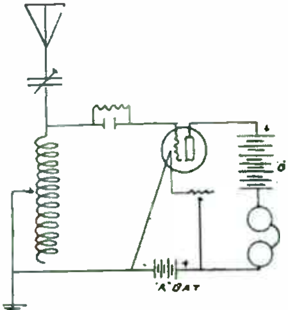


Fig 63A

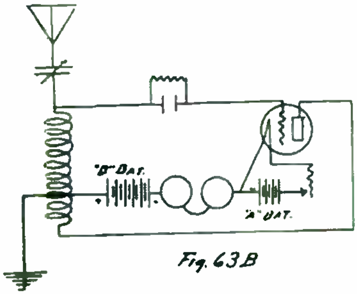


Fig. 63B

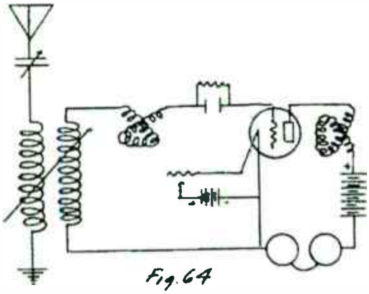


Fig. 64

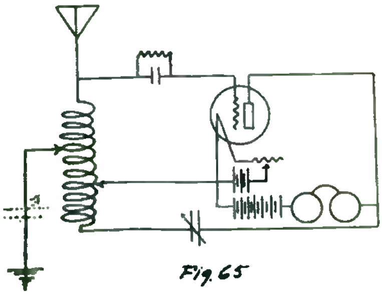


Fig. 65

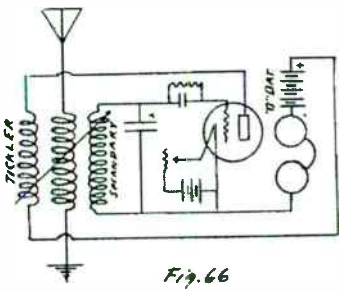


Fig. 66

nected properly you can take it down and install it upon its permanent base or in a cabinet.

The next thing you will want to do, after you have made a really good receiving set, is to have a loud-speaker or a set that may be heard throughout a room without listening at the telephone receivers. To do this, you must make an amplifier which is not at all difficult.

CHAPTER X

AMPLIFIERS AND HOW TO MAKE THEM

MANY people seem to think that if they purchase an expensive receiving set they can receive the music and songs from the broadcasting stations and by adjusting the instruments may sit about a room and hear the concerts as plainly as if reproduced on a phonograph. But no receiving set made will accomplish such results unless it is fitted with some sort of a sound magnifying device or "amplifier." Many of the better ready-made sets are provided with amplifiers enclosed in the same case with the receiving set and hence the person who does not understand the principles and limitations of radio telephony thinks it is the set itself which produces the loud sounds. By means of amplifiers, the sounds from even a simple and cheap regenerative tube set may be built up to almost any extent,—loud enough to fill a hall or theater if desired,—but it must always be borne in mind that every interference, squeal, buzz and rattle will be magnified exactly as much as the desired sounds, and for this reason, the better the set and the more accurately and finely it may be tuned, the better the results when amplified. Very few persons realize the amount of amplification necessary to make the faint sounds in the receivers audible throughout a room, but some idea of the increase in sounds obtained by these devices may be gained from the fact that in order to magnify or increase the sounds twenty times the energy must be increased 400 times and as it is necessary to magnify the sounds about 400 times to make them clearly audible in a room, an energy amplification of 160,000 times must be employed.

There are two methods used in amplification; *radio frequency* amplification and *audio frequency* amplification, and for best results the two are combined. Radio frequency amplification consists of building up or increasing the vibrations or waves before they reach the detector, whereas audio frequency amplification depends upon building up the waves after they have passed the detector and before they reach the phones or other sound producing devices.

Amplifiers are neither very expensive nor complicated and any one may easily install them by purchasing the necessary instruments, such as transformers and bulbs. Although it is possible to make a radio frequency transformer or an amplifying transformer at home it is a very difficult and painstaking job; and even if you are skillful and *do* succeed, the results will never be as good as with a standard ready-made instrument, to say nothing of the cost, which will in all probability amount to more than the price of the ready-made instrument. The great difficulty in making these devices is that the least fault in them will be magnified hundreds or thousands of times, and so take my advice and leave the making of these instruments to the experts and the factories and do not undertake them yourself. They are not expensive, a good amplifying transformer costing from $4.00 to $7.00, or about the same as an ordinary spark coil, while a radio frequency transformer costs from $6.00 to $10.00.

For ordinary purposes, however, an amplifying transformer alone on an audio frequency amplifier is very satisfactory. Amplifying is usually done in "steps," that is, in order to increase the sounds, the amplifiers are added in units, each complete unit forming one step, and thus the sounds may be built up to any extent. As each successive unit is an exact duplicate of the one preceding, it is merely necessary to build as many as may be required and to connect one to the other. For ordinary household purposes, a two-step amplifier is all that is required, for this, equipped with a "loud speaker," will produce sounds loud enough to be plainly heard throughout an ordinary room. Loud speakers are devices very similar to the reproducer of a phonograph and may be bought for from $5.00 up. Do not try to make them as it does not pay and you cannot obtain good results by doing so. But you *can* add an ordinary megaphone or phonograph horn to the set, which will add considerably to the loudness of the sounds.

In making the one-step amplifier illustrated in the diagram, *Fig. 67*, or in making any other amplifier, be very sure to make every connection tight and perfect, to have all binding-posts and screws tight, to have no loose wires or parts that can move or vibrate and to keep wires well apart where they cross. Also, keep wires from running parallel as far as possible. To neglect any of these matters will be to result in failure or to hear terrific howls, squeals and buzzes drowning out the sounds you wish to hear. A loose wire will sound like the roar of an express train; a loose screw will cause a deafening noise like the sound of the subway trains and a wire or other part, touching another, will produce crashes like thunder. Don't forget that with the vacuum tube amplifier it is possible to hear flies walking, to hear the molecules in a bar of iron moving about, to hear crystals forming, and even to hear the sounds made by tiny insects as they communicate with one another by means of their antennæ, and that noises you do *not* wish to hear are increased just as much as those you *do* want to hear.

To make this one-step amplifier you will require an amplifying transformer, and a vacuum tube (purchase an amplifying tube (H.-P. or U.-V.201) for this, for while an ordinary tube *will* do, those made for the purpose are better), a tube-socket, a rheostat, two jacks and a plug. Also a 45-volt "B" Battery. Jacks and plugs may be made, but they are cheap and it is better to purchase those ready-made, especially for an amplifier. The total cost of the amplifier should not be over $15.25 to $26.00 according to the grade of material and quality of instruments, as follows:

Wire, posts, etc..................	$.50	to	$.75
Transformer	4.00	"	7.00
Tube	5.00	"	6.50
Socket	.75	"	1.50
Rheostat	.50	"	1.50
2 jacks	1.00	"	1.50
Plug	.50	"	1.00
"B" Battery	3.00	"	6.00
	$15.25	"	$25.75

The same "A" Battery that is used to operate the receiving set is also used to operate the tube on the amplifier, although it is economy, and better results will be obtained, if separate batteries are used for receiving set and amplifiers. The wiring is very simple as will be seen, and by means of the plugs and jacks the set may be connected or disconnected from the amplifier instantly. When using the receiving set with phones it is merely necessary to pull the plug on the phone receivers (P) from the Jack *2* and place it in Jack *1*. This will spread the outer arms of the jack apart and thus break the connection between amplifier and receiving set. In the same way, if you wish further steps of amplification, it is merely necessary to duplicate the one shown,—connecting the next step at the point marked "2nd set"—and when you wish to disconnect this from the first, place the plug in Jack No. 2. When connecting successive steps of amplifiers *be sure to see that the transformers are at right angles to one another.* This will break up the magnetic fields and prevent the roaring and squealing which otherwise would ensue. *Also, keep the grid wires from transformers to grids as short as possible.* Although a grid-leak is not essential, it is a good plan to use one in each amplifier. When you have everything ready and planned out, mount the amplifier on a fiber or Bakelite base and enclose in a neat case and be *very sure* that there are no loose or poorly made joints in the case. Remember also, that while one step of amplification may not increase the sounds to any great extent a second step will increase them tremendously, for each successive step magnifies the already magnified sounds. Thus, if the first step increases the sounds only 20 times, the second will increase these 20 times, or 400 times the original sounds in the receivers.

CHAPTER XI

INDOOR AËRIALS AND VARYING WAVE LENGTHS

HOW TO MAKE AND USE INDOOR AËRIALS

VERY often it is difficult or impossible to install an out-of-doors aërial. Hotel and apartment house owners object to them; there are often too many wires strung about to permit putting up an aërial, you may be surrounded by higher buildings and there are a thousand and one other reasons why an out-of-doors aërial may not be practical or desirable. In such cases, very good results may be obtained by using an indoor aërial or a loop aërial.

Of course, the results with an indoor aërial, no matter what the design, are never as satisfactory as with an out-of-doors aërial, unless amplification is used; but even with a small and simple crystal set it is possible to secure quite satisfactory results. With a regenerative set the results will be correspondingly better. Ordinary indoors aërials may consist of wires run around a room or along a hallway near the ceiling, of a wire dropped down an air shaft, a court or even the dumbwaiter shaft; of a tin roof, of the electrical wiring system of a house or building, of an iron bedstead or of an iron bed-spring. But in using any of these, care must be taken that they are not "grounded." The electrical wiring of a building is grounded as a rule; a tin roof will be grounded by the waste pipes and gutters; a wire in a shaft may be grounded by touching the walls and, under certain conditions, a bed or spring may be partly grounded also. Hence it is always a wise plan to insulate any such objects used and to insulate any wires you may install for an indoor aërial. In case of a tin roof, the leads to the waste pipes must be insulated, which is a rather difficult matter and as a roof cannot be insulated in rainy weather this makeshift should only be used in case of absolute necessity. Also in setting up any outfit, you should be sure that the water or gas pipes which you use as ground connections are not insulated. Very often these pipes are insulated with non-conductors at some one or more joints. If after connecting your instruments you find they do not work, it is a wise plan to try a different ground, for in a great many cases the whole trouble lies in an insulated pipe line. Hence, in order to be sure, it is better to use a direct ground wire if possible,—either connecting the wire to some well grounded object, such as a pipe or iron post, or by burying a copper plate or a copper boiler or even an iron receptacle filled with charcoal and placed at least five feet under ground. If the ground is moist, an iron or brass rod or pipe driven into the earth will do very well.

When using an indoor wire around a room, along a hallway or in a shaft, the set should be connected in the same way as for an out-of-doors aërial, but for a loop aërial the hook-up should be different. The diagrams, *Fig. 68*, show how this is done. It must be borne in mind, however, that a *loop aërial cannot be used with a crystal set with success* and while a good regenerative or tube set will give good results when near a sending station, still for really satisfactory work, at least two stages of amplification should be used. *Fig. 68 A* shows the installation of a loop aërial with a tube set using a variometer and variable condenser. The loop consists of No. 22 cotton insulated copper wire wound on a wooden frame about 8 ft. in diameter, the wires being spaced about 1 inch apart with a total of from ten to sixteen turns.

The frame should be made of wood, as shown in *Fig. 68 B*, each arm or spreader consisting of two wooden spokes connected by a strip of wood which is notched to receive the wires as shown at *C*. By using fiber or Bakelite strips better results may be secured. On the extremity of one spreader there should be two binding posts *D.D.*, to hold the two ends of the wire and the connections to the receiving set. One of these takes the place of the ordinary aërial connection, while the second serves as a ground, as there is no real "ground" used with the loop aërial. The whole should be arranged to swing or turn on a pivot, either by means of an upright run through cleats on one arm *E*, or by a projecting peg or stick pivoted in a base, *F*, or if preferred, the loop may be suspended to the ceiling or to a hook. This is necessary as loop aërials are strongly directional and by turning the loop about, a considerable amount of interference may be eliminated and the desired station's signals may be brought in much more clearly. Indeed, so marked is this feature of these devices that they are used on shipboard to locate the position of other vessels and are known as "radio compasses." Another advantage is that all indoor and loop aërials eliminate a great deal of the "static" which is exceedingly troublesome in warm weather.

INCREASING WAVE LENGTHS OF RECEIVING SETS

As the ordinary receiving set is limited to wave lengths of no very great variation, and as the users frequently wish to bring in messages of greater wave lengths than their instruments permit, it is very useful to know how to increase the wave length range of your instruments. This can be accomplished to a certain extent by means of a loading coil attached to the wire from the aërial, *Fig. 69*. In this way a set which normally will not pick up or receive waves of over 500 meters in length will be able to pick up waves of nearly 1,500 meters. Although a simple single coil will help, it is far better to use an adjustable coil such as a honeycomb or duolateral. The coil may be arranged to be cut out when not required by placing a switch, as indicated, or it may be provided with jacks and plugs as shown. Still better results will be obtained if you have a number of coils of various sizes which may be switched or plugged in or out as shown in *Fig. 70* and which amount to honeycomb coils. But you must remember that increasing the wave lengths of your set in this way will decrease the set's efficiency to some extent. Also bear in mind that if your set uses a double coil or coupled coil tuner the loading coil should also be coupled with the same relative ratio of secondary to primary as the tuning coil in the set.

REDUCING WAVE LENGTHS

Just as many people wish to increase wave lengths on sets which are limited, or where the aërial is too small to pick them up, so others are anxious to shorten or decrease the wave length of their sets. Oftentimes a very long or large aërial will be put up which makes it impossible to cut down to the shorter waves by the tuning apparatus. In all such cases the wave length capacity of the set may be reduced by installing a variable condenser of about .001 M.F.D. between the lead-in and the set, as shown in *Fig. 71.* By providing a switch or plugs, this may be thrown out or in as desired, as illustrated in *Fig. 71*, or the set may be provided with a loading coil to increase the wave lengths and a variable condenser to decrease them, as shown in *Fig. 71.* Then by means of the switch *S*, or of jacks and plugs, the set may be used in its normal condition, with reduced wave lengths, or with increased wave lengths as desired.

It is very entertaining and interesting to experiment with such devices and a great deal of value may thus be learned, and any person with a good set may have a lot of fun and may discover unlooked-for results by installing various devices and instruments in this way.

But no matter how interesting the receiving set may be, sooner or later you will grow tired of listening to others and will want to send out messages yourself. To make and use a sending set is not difficult, but you must remember that to install a sending station you will need a license and that you will be under rules and regulations which you cannot violate with impunity.

CHAPTER XII

RADIOPHONES OR SENDING SETS AND TRANSFORMERS

A VERY SIMPLE SENDING SET

This is probably the simplest effective sending set or radiophone that can be devised and a glance at the diagram, *Fig. 72,* will show that it is fully as simple as an ordinary crystal receiving set and consists of but five parts, if used for radio telephony, and six parts if used for transmitting both radio telegraphic and radio telephony messages. Of course such a set is very limited in its range or distance, but with it there should be no difficulty in sending a message for five or six miles, and under very favorable atmospheric conditions, several times as far. The total cost of this set with batteries will be about as follows:

Aërial, ground wire, insulators, etc.	$2.00	to	$3.50
Tube or bulb and socket..........	5.50	"	7.00
Rheostat	.50	"	1.50
Variable condenser	4.00	"	5.00
Microphone or transmitter	5.00	"	6.00

Key and switch	1.50 to	2.00
"B" Battery, 60 volts	6.00 "	8.00
"A" Battery	10.00 "	12.00
Lightning switch	2.00 "	1.50
	$26.50 "	$46.50

The coil can be made at home at a cost of a few cents and the whole may be mounted on a base or enclosed in a case according to your taste and ability. The coil consists of a cardboard or Formica tube about two and one-half inches in diameter wound with about 35 turns of No. 16 double cotton covered copper wire with a tap taken at the eighteenth turn, as described in Chapter VIII. The number of turns on the coil may be varied slightly, but 35 is about right. The "B" Battery used to supply the plate current may be from 60 to 120 volts, but a 60 volt battery will prove amply sufficient for ordinary use. For use as a telegraphic set, the switch, *S*, should be opened, thus permitting the current to travel by way of the key, *K*, which is an ordinary telegraph key. When using as a phone set, merely close the switch and key. Remember, however, to disconnect the phone when not in use. This is best done by having the phone provided with a plug to fit a jack or socket in the ground circuit. Also, be sure that the positive (P or +) of the "B" Battery is connected with the plate circuit as shown. This is very easy to remember if you bear in mind that Positive (P) goes to Plate (P) in every case. Then the connection of the negative pole will take care of itself.

ANOTHER SIMPLE SENDING SET

Although this set, *Fig. 73,* appears more complicated than the last at first sight, yet it is just about as simple. Moreover, it is a far more efficient set as it has a modulation transformer added. Otherwise the parts are almost as few as in the last. The coil can be made as readily as the one described for the preceding set, but is a bit different. It should be about three inches in diameter and two inches long, wound forty-two or forty-four turns of No. 26 cotton covered copper wire and with a tap taken off at the center, or on the twenty-second turn. The radio-choke is made by winding about twenty turns of No. 28 wire on a tube about two inches long and one inch in diameter while the modulation transformer is an ordinary spark coil such as is used in Ford cars or in motor boats with the contact breaker screwed down. The "B" Battery for the plate circuit should be at least 60 volts while the "A" Battery is a 6 volt battery as usual. The cost of this sending set should be not more than $35.00 to $45.00 including batteries, as follows:

Aërial, ground wires and fittings...	$1.00	to	$1.50
Miscellaneous accessories	1.00	"	2.00
Tube and socket	6.00	"	7.50
Transformer (spark-coil)	2.00	"	2.50
Double pole switch	.50	"	.75
Variable condenser	4.00	"	5.00
Phone	4.00	"	5.00
2 fixed condensers	.75	"	1.00
Rheostat	.50	"	1.50
"B" Battery, 60 volts	5.00	"	7.00
"A" Battery, 6 volts.............	10.00	"	12.00
	$34.80	"	$45.75

By making your own fixed condensers from $0.75 to $1.00 may be saved, but it is scarcely worth while to attempt it. For using this set as a radio telegraph sender with dot and dash code, a telegraph key may be attached to two contact points of a switch as shown at *K* by dotted lines and a "chopper" should be added to the circuit at the point marked C with a single pole switch, S, which is thrown open when using the key. As in the case of all sending sets, the switch to the microphone or telephone transmitter should be thrown off when the set is not in use, as otherwise the battery current will injure the phone.

AN EFFICIENT 5 WATT SENDING SET

This set, *Fig. 74*, is a much more advanced and efficient set than either of the preceding, but it is not by any means complicated and costs but little more to build than the others. With this set you should be able to transmit by telephone for at least twenty miles and by dot and dash code to nearly ten times as far. The parts which may be made at home are the inductance, the current rectifier, and the grid-leak. In making the inductance, the primary should be of No. 18 cotton covered copper wire making about eight turns on a tube about three and one-half inches in diameter while the secondary should have 25 turns with a tap at the twelfth or thirteenth turn. Keep the turns well apart,—nearly half an inch. The rectifier has already been described in Chapter VIII and requires no further description. Although it is possible to make the transformer for the current it is not advisable to attempt it, as ready-made instruments are not very expensive and are far better. While the set, as shown in *Fig. 74*, is designed to operate on a 110 volt alternating current, such as is used for house lighting, yet it may be simplified and the cost considerably reduced by using a 60 to 120 volt "B"-Battery for the plate and an "A"-Battery for the filament, as shown in *Fig. 75.* In either case, the set may be used with dot and dash signals by adding a buzzer coil at *B.C.* and a key and switch at *K.S.* Then by merely shifting the switch on the phone circuit to the contact with the buzzer, and by opening the switch on the grid circuit, you can use the key *K.* As with the other sending sets, *always* disconnect the phone from the connections to batteries when not in use. Also when using a sending set *always turn on the filament battery before turning on the high voltage plate current.*

To make this set, arranged as in Fig. 74, will cost from $66.00 to $83.00.

Aërial, ground wire and fittings....	$1.00	to	$2.00
Ammeter	7.00	"	8.00
Variable condenser	4.00	"	5.00
Ford spark coil	1.00	"	2.00
Rheostat	.50	"	1.50
Switches	1.00	"	1.50
Key	.50	"	1.00
Buzzer	2.00	"	2.50

Choke-coil (old spark coil)	.50	to	$1.00
5 watt Radiotron bulb	8.00	"	8.00
5 watt Radiotron socket	.75	"	1.00
Microphone	3.00	"	5.00
Lead and aluminum strips	.60	"	1.00
Jars for rectifier	.75	"	.75
Current transformer	25.00	"	30.00
Fixed condenser	.25	"	.35
6 volt battery	10.00	"	12.00
	$65.85	"	$83.10

To make the same set using "B"-Batteries for the plate and another 6 volt battery for the filament, will cost approximately $11.00 to $13.00 less or about $55.00 to $70.00 complete, for the cost of the two extra batteries largely offsets the deduction for current transformer, rectifier parts and choke coil. It is, however, a much simpler set to install and use and in many ways is preferable, especially if the set is not used steadily.

HOW TO MAKE A CURRENT TRANSFORMER

Many amateurs and boys are very anxious to make use of the ordinary house-lighting alternating currents for their sets and while I know of no ready-made sets that are equipped with transformers for reducing and altering the 110 volt alternating current so it may be used for both plate and filament circuits on sets, yet this is quite a simple matter to accomplish by means of current transformers and filament heating transformers. Such things are quite expensive instruments, however, and for experimental purposes quite efficient transformers may be home-made. The simplest type of transformer to make is the one shown diagramatically in *Fig. 76* and which is also used in the sending set described above and illustrated by *Fig. 74.* To make such a transformer is not difficult, from a mechanical point of view, but as I have already explained, it is hard to get them just right and you should not be disappointed if your attempts are unsuccessful at first. To make a transformer suitable for the set described (*Fig. 74*), you will need about one pound of No. 22 enameled wire and two pounds of No. 28 enameled wire. You will also require about 150 pieces of soft sheet iron each seven by five inches cut in "L" shape *Fig. 77.* These can be secured at any tinsmith's, or you can purchase the iron at a hardware store and cut it to size and shape yourself with tinner's shears. These should be bound together with string or twine around each of the "legs" of the iron near the ends in order to prevent the pieces from slipping while winding the wire. Also wrap one or two layers of shellac coated or paraffine soaked paper around the iron to prevent the wire from being cut or broken at the corners and to obviate any chance of rust injuring the enamel covering. Start winding the primary wire (No. 22), and wind on 425 turns on one leg of the "L" covering each layer with paper before winding on the next. Then begin on the other "leg" with the secondary (No. 28) and wind on 2,550 turns, separating each two layers with paper. The final winding should be of No. 22 wire on the same leg of the "L" as the primary, making forty turns and taking a tap at the twentieth turn. In use, the primary wire is connected with the alternating current, the secondary with the rectifier and the last or filament winding is led to the rheostat and grid as shown. The size of the transformer and the number of turns as given will be right for the set illustrated, but for other sets and different currents these must be varied to suit conditions. Roughly, the proportion is about six times as many turns in the secondary as in the primary. The greatest difficulty lies in winding the thousands of turns of fine secondary wire smoothly and without kinking or breaking the wire. To do this well, a lathe of some sort should be used, or a device in which the iron core may be held and revolved while the wire is fed on. If you have no lathe, a makeshift may be arranged by rigging up a grindstone, a sewing machine or in fact any piece of machinery which will provide a revolving hub or axle to which the core may be attached. When the winding is complete remove the string used to secure the iron in place and slip the two "L"-shaped pieces together to form a hollow rectangle as shown and bind firmly and securely with twine and adhesive tape around the shorter sides of the rectangle.

CHAPTER XIII

HINTS ON USING RECEIVING SETS

While radio sets are exceedingly simple things to use, yet many people make mistakes which either prevent the sets from operating satisfactorily, if at all, and very often cause serious damages which necessitate an expenditure of time and money to repair. Therefore it is far better to know what you are doing and why you are doing it when you adjust or use your instruments.

As a rule, if you follow the directions provided with the set, you will have no trouble, but if you make your own set it is a different matter. Moreover, the printed directions often fail to tell you what to do if anything goes wrong and besides it is a mighty good thing to know just what happens and why it occurs when you turn a knob or handle on the set.

Even when the user knows what he or she is doing, ignorance of just how to do a certain thing or to make a certain adjustment often leads to trouble or at least unsatisfactory results. One important point to remember is to move the adjustable parts of a set very slowly and gradually. It is a great mistake to move a tuner or a variable condenser back and forth wildly. The way to do is to move the dial, knob or handle very gradually, for if it is moved quickly you may pick up the desired signal, and then by the impetuosity of your movements, lose it. It is even more important to be careful in adjusting the rheostat. Many people think that the brighter the filament glows the better the set will receive and send, but this is a great mistake. Burning the filament too brightly merely shortens the life of the bulb, and bulbs are expensive things. The way to adjust a rheostat is to turn the knob gradually until the filament is glowing brightly and then back off a bit until the signals come plainly and clearly. Another item to bear in mind in using vacuum tubes is that the tube may be paralyzed if too much current is turned on the filament suddenly. If accidentally you should do this and the filament suddenly dies out, do not turn the knob wildly back and forth, but merely turn it back and wait. Then, in a half minute or so, the bulb will recuperate and you can adjust it properly. But it is better to begin with the simplest things and take them in order and as the crystal receiving set is the simplest of all we will begin with that. In using a crystal receiver the first thing to do is to find a sensitive spot on the crystal. Galena varies a great deal and therefore you should have a number of pieces on hand and try out several until the most sensitive one is found. This is readily determined by the clearness and loudness with which the signals come in. At first, you will hear a confused jumble of noises in the head-phones,—squeaks, buzzes, rattles and possibly fragments of music or voices. This shows that your set is not "tuned" and is bringing in signals from various stations or "interferences." To obviate this, adjust the tuning device slowly and carefully until the signals you wish are at their very clearest. Then, if your set has another adjustment, such as a variable condenser, adjust this until you get the very best results. Then mark the various dials so you can readily pick up the signals from the same station when you wish to hear them again. By thus tuning your set to various stations and marking the dials or knobs for each, tuning will be greatly simplified. A very easy way of testing the crystal detector is to install an ordinary buzzer,—made by taking off the gong from an electric bell,—and connecting it near your set as shown in *Fig. 78* When this is connected it will set up vibrations in your set, and by turning the crystal about until the sounds are loudest, you will be able to locate the best spot on the crystal.

A little more care is required in adjusting a vacuum-tube set. First, turn on the rheostat slowly and gently until the filament glows brightly and sounds come in. Then back off a bit and adjust the tuning device. If there are other tuning devices, adjust them in order until you receive the loudest and clearest sounds possible from the station you are tuning for.

In case there are buzzes or squeals, go over the set very carefully and systematically, searching for loose wires or connections, broken wires, rubbed insulation, wires that touch some other part of the set, etc. Sometimes in making up a set, a screw will go too deeply and touch some wire or connection on the bottom of the base and such things will cause a lot of trouble and are very hard to find.

If you do not pick up sounds, either with a crystal or a tube set, you may be sure something is wrong. If it is a ready-made set, the chances are that the difficulty lies in the aërial, the lead-in, or the ground. First, examine the connections to your set and be sure they are properly made and that each wire is led to the proper binding-post or connection. I have known of several cases where people have been so anxious to use their new sets that they have forgotten to clean the insulation from a lead-in or a ground wire and have then condemned the set and have it taken back to the maker or seller, who of course was quite unable to locate the trouble after the connecting wires had been removed. If the connections at the set are all right, examine the connection of your ground wire to the pipe or other "ground." This connection must be good. Have both the wire and the object to which it is connected scraped clean and bright and if possible make a soldered joint. If this is not practical, wrap the wire about the pipe, wind fine copper wire over it, cover with tin foil and then wrap the whole tightly with adhesive tape.

If the trouble is not here, follow the pipes down to be sure they are grounded; or if this is difficult, try a new ground on some other pipe. Gas pipes, steam pipes and water pipes are frequently insulated, either intentionally or accidentally, and drain pipes or waste pipes usually end in earthenware pipe before entering the ground. Steam pipes often make very poor grounds.

If convinced that your ground is all right, examine your lead-in wire. Be sure that it is properly insulated and does not touch any object, even when the wind blows. Follow up to the aërial and be sure the latter is well insulated and that there is a good connection between it and the lead-in wire. I have known of many novices making the mistake of connecting a lead-in to the guy-wire instead of to the aërial, and as an insulator came between, of course there was nothing doing in the receiver.

If you hear some sounds and not others, or hear dot and dash signals and no music, you are either too far from the station sending the music or your set is not adjusted to the station's wave length. On some days you may hear much better than on others. This cannot be avoided and the set is not to blame, as climatic conditions have a very great effect on radio transmission.

If it is a question of wave length, which may be determined by listening to the signals you receive and locating them by their call letters and then finding if they are farther away than the broadcasting station, you may increase the wave length of your instrument by adding a loading coil or reduce it by adding a condenser as described in a preceding chapter.

If you are using an amplifier with your set, be very careful to have good tight connections, as every sound in either receiving set or amplifying set is tremendously multiplied.

In using tube sets, be sure and keep the voltage of your battery up. If possible, have two sets of storage batteries and then you can use one while the other is being recharged. You *can* recharge your own batteries if you purchase or make a recharging outfit, but if you take my advice you will not attempt to make your own recharging apparatus until you are well beyond the novice stage.

Always keep a battery voltmeter and hydrometer to test the batteries. But do not mistake an ammeter, such as used on the set, for a battery tester.

Don't waste time trying to get results with cheap telephone receivers. It is much better to pay more and use 2000 or 3000 ohm receivers. In sending, if you use an oscillation transformer, put a wave meter in your aërial connection and first tune the primary to the wave length desired.

Then tune the secondary to the same wave length and finally tighten or loosen the coupling to secure maximum resonance, as shown on the wave meter. In using galena crystals be sure to test a number of pieces to secure the most sensitive. Very often, too, crystals may be vastly improved by washing them in alcohol or ether, especially after they have been handled.

In connecting up a set, bear in mind that the positive pole of a battery (P or +) should be connected with the plate (P) circuit and that the receivers should be in series with the batteries.

In using a sending set, be very careful not to turn on the high voltage plate current until after you have lighted the filament with the lighting current. Otherwise the tube may be irreparably injured.

Also, remember to throw off the switch or disconnect the plug, which connects the microphone or transmitter with the rest of the set. This will prevent the battery current from demagnetizing the magnets in the phone. Also, bear in mind that the current from a "B" Battery is powerful and that to touch a wire or connection from such a battery may result in a severe shock. Hence keep all wires well insulated and out of reach; to have a "B" Battery on the floor or within reach of children, household pets or even grown-ups is to invite trouble and possible disaster. Place such batteries out of the way on a shelf or in a drawer or cupboard and lead the wires where they cannot be touched accidentally.

Finally, use care in all things. Although so simple, yet radio apparatus is very delicate and must be treated and handled accordingly. The vacuum-tube or audion-bulb is one of the most delicate pieces of apparatus ever devised, but with ordinary care it will last a long time.

CHAPTER XIV

SOME USEFUL DON'TS TO REMEMBER

DON'T expect too much of a crystal set. They are excellent for beginners and for short distances only.

Don't be discouraged and condemn your set if you do not have success at first trial. Very often the fault is in some connection or in yourself.

Don't expect to become an expert by using a small crystal set.

Don't experiment until you know why and what you are doing.

Don't be satisfied with testing one piece of galena crystal. Get several pieces, or a couple of pounds and test many. Galena varies greatly in sensitiveness.

Don't expect to make a loud speaker from a crystal set. It cannot be done satisfactorily.

Don't try to add a vacuum-tube to a crystal set. The two do not go together.

Don't try to add an amplifier to the crystal set. It is not possible.

Don't expect to get very good results with a crystal set if you use an indoor aërial.

Don't attach one end of your aërial to a tree or tall pole unless you guy the pole immovably or provide a coiled spring between aërial and tree, as otherwise the wind will sway the support and break or stretch the wire.

Don't put up an aërial between tall buildings. Place it as high as possible.

Don't use house wiring, pipes or such things for an aërial with a sending set.

Don't forget that a license and examination are required in order to put up any sending set.

Don't stretch an aërial across a street without a permit.

Don't install an aërial without an air-gap or lightning-switch.

Don't place the air-gap or lightning-switch indoors.

Don't put in the air-gap or lightning-switch without a separate ground wire to it.

Don't use friction tape for out-of-doors work. Use varnished cambric tubing.

Don't run wires parallel in making up sets. Run them at angles.

Don't forget that gas, water and steam pipes are often insulated from the earth.

Don't forget that a loop-aërial requires no ground.

Don't forget that a counterpoise is often better than a ground.

Don't paint a coil or any portion of the wiring or connections in a set. Paint contains lead or other minerals and will injure or short circuit the instruments.

Don't try to use a tin can or metal tube in making a coil.

Don't forget that it is impossible to say just how far a set will receive certain signals or messages. It depends on a great many conditions.

Don't forget that a good contact between the galena and holder may be obtained by wrapping the crystal in tin foil, leaving the upper part of crystal exposed.

Don't try to solder galena crystals to the cup or holder, it reduces their sensitiveness.

Don't forget to make good, clean connections on all wires. Solder all such when possible, and cover with varnished cambric tubing.

Don't attempt to operate the filament of a vacuum-tube on a high voltage circuit.

Don't forget that where a coil has two windings, both must be wound in the same direction.

Don't forget that the secondary winding of a coil is of smaller wire than the primary winding.

Don't forget that if you use a slider tuning coil and have poor results the trouble may lie in the contact between the slider and the slide rod. Try connecting the wire directly to the slider, using flexible wire.

Don't try to test your phones with batteries. Wet a piece of paper; connect the phones with one pole of the battery and touch the wire from the other pole and the wire from the phones to the piece of wet paper. If there is a sharp click in the phone receivers they are all right.

Don't forget that for a makeshift you can make a high voltage microphone from an ordinary telephone transmitter by removing the carbon granules and substituting larger ones which are sold in electrical supply stores.

Don't forget that grid-leaks are not used on crystal sets.

Don't forget that a loading-coil increases wave length and that a variable condenser decreases wave lengths on a receiving set.

Don't expect to tune as closely on a crystal set as on a tube set or as closely on a cheap set as on a more expensive set.

Don't forget that the more adjustments you have for tuning, the more you can tune out interferences.

Don't expect to entirely tune out static. It has never been done.

Don't try to use any radio set in a thunder or electrical storm. You won't get any results and you may be killed.

Don't forget that a vacuum-tube is thirty times as efficient as a crystal detector.

Don't think because a friend can send ten miles and you can receive twenty-five miles, that you can hear him if he is thirty-five miles away. Your receiving distance is from instrument to instrument, and his sending distance will not alter it.

Don't forget that very often 2000 or 3000 ohm receivers will vastly improve a cheap receiving set.

Don't try to use two or more crystal sets on one aërial at the same time.

Don't forget that you can vary a pencil grid-leak by adding or erasing lines.

Don't forget that a lead-in counts as an aërial, so the longer it is the better up to certain limits.

Don't forget that a single long aërial wire is better than a number of short wires.

Don't forget to run the aërial at right angles to any steel structure or electrical wires that are near.

Don't forget to have the lead-in end of your aërial towards the station you wish to hear the most, or towards the one that is farthest away.

Don't think that aërials have to be horizontal. For receiving, they may be in almost any position.

Don't forget that for sending, a many-wire aërial is better than a single wire.

Don't forget that for sending, a counterpoise is preferable to a ground.

Don't think you can get as good results from any crystal set as from a tube set. The cheapest tube set is better than the best crystal set.

Don't forget that for each step of amplification you will require another tube.

Don't waste time, trouble and materials trying to make some part of a set that may be bought ready-made cheaply, or that must be made according to mathematical calculations and with an expert knowledge of electricity.

Don't expect too much for your money. Radio sets cannot be made cheaply.

Don't fail to ask questions of dealers and manufacturers. Every piece of apparatus is made for a special purpose and you can save time and money by asking advice as to which to use.

Don't believe all the claims made for every ready-made set. Dealers are in business to sell their goods, and while some are honest and reliable, others do not hesitate to exaggerate or even mislead.

Don't imagine that price necessarily means quality. Expensive cabinets and trimmings may add a lot to price without adding to efficiency.

Don't fail to find out if when a set is advertised to receive at a certain distance, whether it means code telegraphic signals or radio telephone messages.

Don't forget that every maker claims his goods are the best. Investigate several before buying.

Don't add to others' troubles by sending unless you have good reasons or are sincere in your experiments. The worst interferences are those from nearby sending stations of novices.

Don't forget that the broadcasting stations publish daily programs and that the air is free to all for receiving.

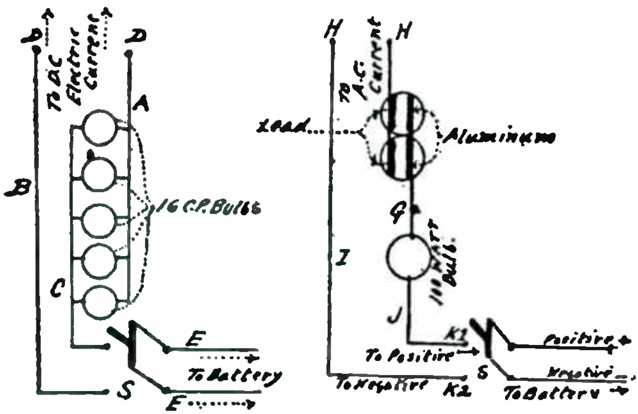
CHAPTER XV

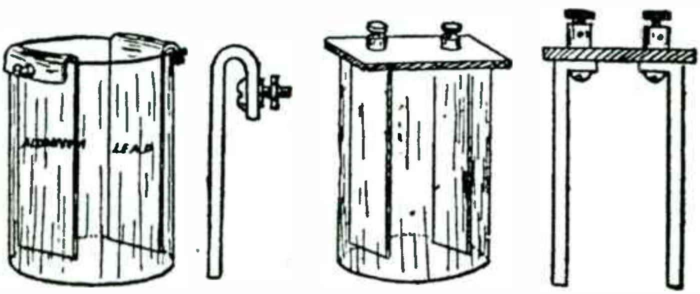
HOW TO RECHARGE BATTERIES

It is not at all a difficult matter to recharge your own storage batteries or certain makes of "B" batteries if a little care is used. To be able to do this yourself is a great convenience, for it is always a great nuisance to have to send your battery out and wait for it to be recharged just when, as likely or even more likely than not, you will want to use your set.

Those who do not wish to rig up their own recharging apparatus may purchase them ready made, but even though the ready-made outfits are not expensive you can save several dollars by making your own, to say nothing of the pleasure and pride which you will feel at making everything yourself.

The first thing to be done is to ascertain the kind of current which is used in the house lighting current you are to employ. In the majority of cases, this will be found to be alternating current,—usually of 110 volts,—but in some places a direct current is used. Either one may be employed for recharging the batteries, but the apparatus you must make to do the recharging will





depend upon which sort of current is available. If your current is direct current the outfit will be very simple, whereas, if alternating, it will be a trifle more complicated.

To arrange an outfit for recharging with direct current, examine your battery until you find the mark indicating the charging rate in amperes, or if you cannot find it ask the dealer or maker from whom you bought the battery, for this is a most important matter. Having determined this, obtain as many ordinary sixteen candle power carbon filament incandescent lamp bulbs and sockets as there are amperes in the charging rate and connect the batteries as shown in the cut, leading the wire *A* to a terminal or binding post. To another post, beside this, attach the wire *B* and fasten the other end of this and the end of the wire *C* to the two contact points of a double pole switch as shown. The next step is to determine which of the two wires, *B* or *C*, is the negative and which is the positive, for you must be extremely careful to have the negative wire attached to the negative end of the battery and vice versa. To find which wire is positive or negative connect the wires from the electric light circuit to the binding posts *D D*, leaving the switch *S* open, and connect two wires *E E* to the switch arm posts. Then fill a jar or glass with water in which salt has been dissolved, dip the two wires *E E* in the water, being sure that they cannot touch, and throw on the switch. By watching the bubbles which will rise from the ends of the wires you may easily recognize the positive wire and the negative wire, for the most bubbles will rise from the negative. Then, mark the binding post on the switch to which this wire is attached so you will always know which it is, and throw off the switch. Connect the two wires *E E* to your battery, fastening the negative wire to the negative post and the positive wire to the positive post, and throw on the switch. The length of time which will be required to charge the battery will depend upon the extent to which it has been used and the best way to determine when it is fully charged is to use a voltmeter, being sure to throw off the switch when testing. Do *not*, as is sometimes recommended, use a double-throw, double-pole switch which may be used to throw the charging current into the battery or the battery current into your receiving set. If you always remember to throw the switch and are extremely careful such an arrangement may be all very well, but accidents *will* happen and if, by chance, the switch should be short circuited or a contact made with the set while using it, serious results might follow. It is only a moment's work to disconnect the wires *E E* from the set and connect them with the charging switch and it obviates all danger.

Instead of a couple of binding posts at *D D* you may use an ordinary electric light plug if you wish and then, by using a flexible cord with attachments such as is used for drop lights or electrical flat irons or stoves, you can make the connection quickly. In this case, however, be sure to mark which of the two plug holes on the cord is negative and which positive so that no mistake will be made. Remember also to switch off the electric light circuit from the wires in the house when tapping them for the wires to the posts *D D*, and insulate the joints or connections where the wires to *E E* join the house wires with adhesive tape wound around them.

To charge a battery with an alternating current you must first make a rectifier, which is merely two one-pint fruit jars filled with a borax solution in which aluminum and lead plates are immersed. The aluminum and lead strips should be as long as the jars are high, about an inch in width and about one-eighth of an inch thick. By bending over half an inch or so of one end of each, these strips or electrodes may be suspended in the jars with binding posts attached to them as illustrated. The best method is to fasten them to Bakelite or hard rubber squares by means of binding posts as shown in the cut, spacing them far enough apart so they are close to the opposite sides of the jars as shown. The jars should then be filled with a solution of borax and water in the proportion of about one pound of borax to a quart of hot water. Stir the borax until thoroughly dissolved, keep adding more borax until the water refuses to dissolve it and then allow it to settle. Then, pour the clear liquid into the jars, being careful not to pour in any of the sediment, and fill the jars to within an inch of the tops. Each jar should contain one lead and one aluminum strip, the aluminum being the positive in each case. The two binding posts of the two lead strips should then be connected with one wire *F* and the two aluminum binding posts to another wire *G*.

Connect the wire *G* to a 100 watt light and carry another wire *J* from the light to the contact of a double-pole switch, fastening the wire *I* to the same contact point and then turning on the electric light circuit let the current flow for a few hours to "form" the plates. Be very careful not to put your fingers in the jars or touch any wire or terminal during this time or you may get a dangerous or perhaps fatal shock.

After the current has been running for several hours,—over night will do very well—turn off the current and disconnect the wire *I* from the switch contact *K1* and connect it to the other one *K2*. Then, connect your battery to the switch-arm posts, being very sure to have the positive post of the battery marked "+" led to the side which will connect with the wire *J* from the aluminum plates, and turn on the current and the switch and let your battery be charged. If the battery is all run down it will take a very long time to recharge it as only a very small current will pass through the rectifying jars. The rate of this will be somewhere around two amperes and hence, if you have a forty-ampere hour battery and it is completely exhausted and the normal charging rate for the battery is six amperes the current must be kept on the battery for about twenty hours. In other words, at a six-ampere charging rate it would require about seven hours to recharge the battery to the forty-ampere state, and as only about two amperes are being delivered through the rectifier it would take three times as long, or twenty hours. Hence, if you do not wish to have your battery held up for a day or more you should recharge it every day or two, attaching the battery to the charging apparatus at night and letting it run until morning. In this way you will not be delayed and your battery will always be fully charged.

In addition to recharging, your storage battery must also be kept filled with water to about half an inch above the plates which are visible through the filler holes. Use only pure *distilled* water for this purpose and use nothing but clear water in refilling the rectifier jars as the solution evaporates. When, after considerable use, the plates of aluminum become thin and eaten away replace them with new strips. Aside from this there will be nothing to replace and the only expense in recharging your battery will be the cost of the electrical current used, which is very small. But *always* remember and be careful not to touch any of the wires or exposed metal or the liquid in the jars. And *be sure* to keep the outfit where children cannot reach it, even when not in use.

CHAPTER XVI

LEARNING CODE AND CODE SIGNALS

ALTHOUGH it is not necessary to learn to read or understand the dot and dash signals of the telegraphic codes in order to use radio telephones, yet, in order to operate a sending station, the government requires the would-be operator to pass an examination in code. Moreover, code signals are far more common than phone messages and usually come clearer and sharper, and if you can read or understand them, it adds a great deal to one's enjoyment of listening-in.

There are several codes used, but only two are in common use. These are known as the *Morse* and *International*. The former is practically universally used on land and for wire telegraphic work and is also used to some extent on coastwise vessels, but the *International* is used in all the big stations, for transatlantic messages and by nearly all ships. Of the two the *International* is far the easier to learn as there are no spaced dots and dashes as in the *Morse*. In addition, there is the *Navy* code, used by naval vessels and stations. While it is a good plan to learn all of these three codes, still the first and most important is the *International* for the majority of signals you will hear are in that code. Of course you must not expect to be able to send or to receive rapidly as soon as you have learned the codes. That will only come with practice. A very good plan is to accustom yourself to thinking of the dots and dashes as sounds rather than as marks, or in other words, think of the dash as "dah" and the dot as "dee." You will thus find it much easier to recognize "dee dah, dah dee dee" as the call "A, D" than if you were thinking of .---.. which means the same thing. But no matter how expert you may become, you will never be able to read or understand all the signals which you hear, even if they are being sent in plain English, for the big companies send and receive by means of mechanical devices which no human being can approach in speed. These machines are somewhat like typewriters and stock tickers combined. When a message to be sent is received from a customer, the operator strikes off the letters upon a machine like a typewriter, but instead of printing letters on paper this machine makes marks or perforations on a paper strip in the form of dots and dashes. In other words, the typebar of the key "A" would bear a dot and dash instead of the letter and so on with all the alphabet. Thus, if the message, as written, began "New York" and the operator struck the keys N E W Y O R K the impressions made upon the strip would be -. .-- -.-- --- .-. -.- *Fig. 78 A.* The dashes being indicated by dots out of line or "staggered" and the dots by dots in line as shown. This strip is then run through a machine which makes the electrical contacts through the perforations in the strip and thus sends the dots and dash signals speeding through space. At the other end the incoming "dees and dahs" are recorded upon another strip and appear again not as dots and dashes but in the form of a wavy or irregular line *Fig. 78 B.* Then another typewriter-like machine is employed and by striking the keys the message is translated into words once more. Just as the sending machine bores dots and dashes on the typebars connected with letters of the keyboard, so the receiving typewriter bears letters on the typebars connected with a keyboard bearing dots and dashes. So by striking the dots and dashes as they appear upon the receiving strip, the code is transformed to letters. In this way, great speed is obtained and great accuracy secured, for there can be no mistakes made by carelessness in sending or receiving, although of course as sometimes happens, a mistake *will* creep in by the typist striking the wrong key. It is a very important matter to have messages in code as accurate as possible, for if the message is sent in some telegraphic code or a private code, it may require a long time and cause great loss of money before the mistake can be rectified. Moreover, it often happens that the alteration or transposition of a single letter in a code word may give it an entirely different meaning from the one intended. So you see the importance of accuracy where messages that mean life and death, the losing or making of fortunes, the affairs of state, the fates of governments or even peace or war are being rushed back and forth through the air by means of the buzzing "dahs" and "dees" that you hear in your radio telephone receivers.

The best way to set about learning the code is to learn a few letters at a time, rather than to attempt to memorize the entire alphabet. For example, if you learn A, B, C, D, you can then form the words BAD, CAB, CAD, DAB, and when you have learned to send and receive these rapidly, learn E, F, G, H. Then you can go ahead with other combinations in the same way, as ABE, ACE, BAG, BED, BADE, BEE, BEG, ACHE, CAGE, DEAD, etc. As soon as you have learned to send and receive a few simple words you will be able to make short sentences and in the meantime keep adding new letters. In this way, you will be greatly surprised to find how soon you can learn, for you will become so accustomed to associating combinations of "dahs" and "dees" with certain words and syllables that you will not think of them as being made up of dots and dashes meaning separate letters, any more than you think of "DOG" being made up of three letters. In other words, you will recognize certain "dahs" and "dees" coming in over your instruments as meaning certain sounds,—a sort of shorthand so to speak. Neither will it be necessary for you to send out your practice messages and letters to confuse and trouble others, for by installing a buzzer near your instruments and then listening at your phones and sending the dots and dashes on the buzzer, you can hear them on your set, or if you have a friend who is learning at the same time, you can take turns at sending messages on the buzzer and listening, either with the phones or without them, and holding a sort of competition to see who can send the most words correctly and can receive and translate them without mistakes. Indeed, you will find that two or three persons can learn the codes much faster and more readily when working together than when learning them separately. The numbers are very easy to learn, for the first five *begin* with the same number of dots as the numerals themselves, followed by the same number of dashes in reverse order, while the *last* five have the *dashes first* and the *dots following,* or in other words, are the first five reversed, and thus, by remembering that from one to five begin with from one to five dots and that from six to ten begin with from one to five dashes, you will have no trouble.

In addition to all the letters of the alphabet, the numerals and the punctuation marks, there are certain signals or sentences which are so widely and commonly used that combinations of letters or of dots and dashes have been adopted for them. Moreover, every sending station, whether amateur or professional, has its call number, as for example the Westinghouse broadcasting station which is WJZ; the Chicago station KYW; etc. While the letter "V," which is often a puzzle to beginners, is the test call letter. The government issues lists of all call letters and these are also published by the radio periodicals, so that by keeping the lists at hand you can always tell what station is calling or is being called. But of course you should learn the calls of those you most frequently hear or wish to talk with so that you can recognize them without looking in the lists. After you become really expert, you will be able to recognize many stations by the "tone" or some other peculiarity of their signals, just as you recognize the sound of a friend's voice over an ordinary telephone. When you can do this, you can feel that you are really beyond the novice stage and can qualify as a real radio operator.

TELEGRAPHIC CODE

	International	Morse	Navy
1	· — — — —	· — — ·	
2	· · — — —	· · — · ·	— — · —
3	· · · — —	· · · — ·	· · · —
4	· · · · —	· · · · —	— — — ·
5		— — —	· · — —
6	— · · · ·		— — · ·
7	— — · · ·	— — · ·	· — — —

	International	Morse	Navy
8	---..	-....	-...
9	----.	-..-	.--.
10	-----	-	-..-
A	.-	.-	--
B	-...	-...	-..-
C	-.-.		.-.
D	-..	-..	---
E			.-
F	..-.	.-.	---.
G	--.	--.	--..
H			.--
I			
J	.---	-.-.	.---
K (also go ahead)	-.-	-.-	-.-.
L	.-..	-	--.
M	--	--	.--.
N	-.	-.	
O	---		-.
P	.--.		.-.-
Q	--.-	..-.	.-..
R (also received O.K.)	.-.		-..
S			-.-
T	-	-	-
U	..-	..-	..-
V	...-	...-	.---
W	.--	.--	..-.
X	-..-	.-..	-..-

Y	-·--		
Z	--··		----

	International	Morse	Navy
Comma	·-·-·-	·-·-	
Semicolon	-·-·-·		
Colon	--- ···		
Period		··--··	
Exclamation	--··--		
Interrogation	··--··	-··-·	
Apostrophe	·----·		
Inverted commas	·-··-·		
Hyphen	-····-		
Parenthesis	-·--·-		
Underline	··--·-		
Double dash	-···-		
Bar for fractions	-··-·		
Attention call before commencing to send.	-·-·-		
General enquiry call	-·-·---·-		
From (D.E.)	-···		
Warning of high power	--··--		
Please repeat	··--··		
Go ahead. Proceed (K)	-·-		
Error			
Position report to precede all position messages, as from ships (T.R.)	-·-·		

Wait	.–...
Understand	...–.
End of message	.–.–.
End of transmission	...–.–
Received O.K.	.–.
Distress call S.O.S.	... ––– ...

CHAPTER XVII

HANDY HINTS AND USEFUL KINKS

THE boy who sets out to make his own instruments and his own radio apparatus will find, before he goes far, that to succeed he must be able to do a great many things well. He must be able to solder, to cut screw threads, to work metal and he must be a fairly good carpenter. Moreover, he will find that he will constantly be up against problems which seldom confront the maker of other things. He will, in fact, have to be a regular Jack of all trades and master of all to a limited extent. A great many things can be learned only by experience and many problems must be solved by one's own common sense and ingenuity. Every worker and every tradesman has his own personal kinks of his trade and short cuts which have been evolved through necessity and no two workmen are alike in the ways in which they do many things. You will find that, from time to time, some new scheme or new device occurs to you, that you will constantly be devising new and easier ways of doing things and that as your skill and knowledge increase with practice you will be able to perform seemingly difficult tasks with ease and will often be able to make some substitute answer for something else, to use some one tool in place of another which you do not possess, and that while working at your radio sets you are constantly training mind, eye and hand and are really inventing many little things as you go along.

Nevertheless, there are a great many short cuts, kinks, makeshifts and useful ideas which are known to craftsmen and are in daily use which may save you a great deal of trouble, time and thought. If you know a few of these, others will come all the easier as occasions arise and you will be surprised to find how simple and easy it is to accomplish results which would have completely stumped you previously.

HOW TO SOLDER

One of the most important things for the radio fan to learn is to use a soldering "iron" properly. If you watch a tinner or a plumber at work it seems very simple and easy to solder a joint or a couple of wires, but if you go blindly at it without some knowledge of the art you will find that to do a good job at soldering is by no means as simple and easy as it looks. To be sure, you may succeed in soldering the two pieces of metal or the two wires together, but the chances are that the joint will be weak, that it will be rough and uneven with big, irregular lumps of solder sticking to it and that your patience and temper will both be exhausted before the simple undertaking is accomplished. And yet, when you know how, soldering is one of the simplest matters in the world.

In order to solder even the simplest things you must have a soldering iron or "copper," a bar or stick of "half and half" solder and some flux. The "copper" should be a fairly large and heavy one, not the largest size by any means, but a copper that will weigh from one and one-half to two pounds or, if it is to be used out of doors, a trifle heavier. Such an "iron" with a good sharp point will do just as fine work as a small one while the small "coppers" will not retain the heat long and will require constant reheating, which is a great nuisance. The solder may be bought at any hardware store or tinsmith's. If to be used on small jobs the strips or "wire" form is most convenient whereas, for general work, the large bars are to be preferred. For a flux do *not* use resin.

This does very well for soldering tinware and brass for rough work or repairing household utensils, but it is dirty, mussy stuff and when used on electrical work it will often form a coating or film which insulates or partly insulates the pieces which are joined. The best flux is a mixture of chloride of zinc and sal ammoniac. This may be purchased at the plumbers' or tinsmiths' shops, but it may be very easily made at home. To make the chloride of zinc, place a few ounces of muriatic (hydrochloric) acid in a jar or large bottle and throw in small pieces of sheet zinc, or else immerse a zinc from a battery in the acid. Keep adding zinc (if the small pieces are used) until no more is dissolved, or if a battery zinc is used, let it remain in the acid until no more is dissolved. Then add small pieces of sal ammoniac in the proportions of about 2 ounces of sal ammoniac to each quart of the chloride of zinc.

Having prepared the flux, the next step is to "tin" the "copper." This is not difficult, but is most important, for unless the "copper" is well tinned you cannot do a good soldering job. Heat the copper until, when touched to the solder, the latter melts readily and then, with a flat file, rapidly go over the copper for an inch or so from the tip until clean and bright. Then rub the copper over some sal ammoniac upon a piece of clean tin or a flat board and then rub it in the solder. If your copper is good and hot the solder will at once stick to the copper in little globules which must be spread evenly over the copper by rubbing it on the sal ammoniac and board. The copper, if properly tinned, should now be smoothly covered with a film of bright silvery solder, but if it is not, you must reheat it, clean it, rub it on the sal ammoniac and solder again until the whole tip is evenly tinned. Very often, tinning is made easier by swabbing a little of the flux over the copper in place of the clear sal ammoniac. In using the flux do *not* use a brush of hair, but a stick with a cloth swab on the end or a plain stick with a flattened and shredded-out tip.

When the copper is properly tinned you are ready to solder. Clean the parts to be soldered and scrape them until bright, swab on a little flux, have the copper good and hot, but not *too* hot or the tin will be burned off. Rub the hot copper on a board or woolen rag sprinkled with sal ammoniac and touch it to the bar or strip of solder. Instantly, a little drop of solder will adhere to the tip of the copper and by rubbing the latter along the joint or the wires to be soldered the solder will leave the copper and adhere to the objects you are soldering. For fine work, a single application will usually leave enough solder to make a firm joint, for you must always bear in mind that it is not the *amount* of solder on the joint which makes it strong, but the perfection of the adhesion of the solder to the other surfaces, and the less solder there is the better. To bring this about, the parts joined must be hot and the solder must flow freely. If the parts are cold or the copper is not the right temperature the solder will pile up in a thick, pasty mass, but will not adhere to the surfaces to be joined and all must be done over again. If the objects to be joined are small, such as wires or small bits of metal, the heat of the copper and molten solder will be sufficient to heat the parts so the solder will adhere firmly, but if the parts are large, thick or heavy you may have to heat them by repeatedly placing the hot copper upon them or even by means of a blow torch or a spirit lamp or gas stove flame. Only practice can tell you when the iron or copper is the right temperature and you will have to learn to judge of this yourself, especially as the temperature of the copper must be varied more or less according to the work. If you are soldering lead, zinc or soft metals the iron should be cooler than for harder metals, while for iron and large work it must be much hotter than for brass or smaller work. Sometimes, too, if there is a large joint, opening or hole to be filled it is an advantage to use the copper fairly cool, just hot enough in fact so that the solder sticks to it in big, pasty masses. These can be placed in the opening and when it has been filled the surface may be smoothed off by running the copper over it after heating it to a higher temperature. However, as the metals most frequently used in radio work are copper and brass and as these are the easiest of all metals to solder, you should have very little trouble. If you attempt to solder zinc, use a flux of chloride of zinc without the sal ammoniac, and if you are to solder iron or steel use pure muriatic acid. Iron is very difficult to solder unless first tinned and in order to do this the iron must be clean and bright and heated very hot. Then it should be smeared with pure muriatic acid and tinned with a hard solder or by rubbing a piece of block-tin pipe over it. Another good way to tin iron for soldering is to heat it well, smear with acid and place tin foil upon it. As soon as the iron is tinned proceed to solder as usual. Almost all metals, with the exception of aluminum, may be soldered in the same way and for aluminum you must use a special solder which may be bought of automobile supply dealers and which does not require any flux whatever.

BORING METALS

Brass, copper, iron, steel and other metals are easily drilled if you use oil or grease as a lubricant. Do not try to drill too rapidly and when nearly through the metal go very slowly as a drill may easily be broken by trying to turn it too rapidly as it pushes itself through the surface.

SOAP AS A LUBRICANT

In boring or sawing wood, fiber, etc., soap is far better than any oil. Also, if screws are soaped with ordinary kitchen soap they will enter the wood easily without danger of ruining the head slots, and moreover, they may be readily removed at any time.

WORKING GLASS

Although you may not be compelled to use much glass in your radio work yet now and then you will find glass a very useful material. A glass panel for a mount is very nice as everything may be seen through it, and as glass is one of the best non-conductors of electricity it is often very desirable about a set. Indeed, the only reason that glass is not more widely used is because most people consider it so difficult to work. It is harder than steel and very brittle and yet, if you know how, you can work glass as easily as hard wood or soft metal. This may seem a most surprising thing, but in the big glass factories you may see workmen boring, sawing, planing and turning glass just as if it were wood. The whole secret lies in the lubricant used upon the glass to make the tools cut and to prevent the glass from chipping or splintering. For cutting sheet or plain glass in forms with straight edges the best method is to use a "diamond." This need not be a real diamond, for a ten cent carborundum "diamond" will do just as good work as a real stone, if not better. Before attempting to cut the piece of glass you wish to use, practice upon some worthless odds and ends, for even to cut a straight strip of glass with a diamond requires quite a little skill and knack. The main thing is to learn to draw the diamond quickly, evenly and smoothly along a rule or straight edge and to keep a uniform angle and uniform pressure on the tool as you do so. If the tool is cutting properly it will give out a clear, musical sound, whereas, if it is merely scratching, it will give a grating, scratchy sound. *Never* draw the diamond over the same mark a second time as this merely chips and ruins the tool. If the first cut is not right make another one close to it. When the line is properly cut it will appear clear and sharp upon the glass, whereas, if it is merely a scratch, it will appear whitish and opaque, like ground glass. If the line has been really cut the glass should snap apart evenly along the line with a little pressure or strain upon the two sides. Only practice will enable you to cut glass and break it in this way.

It often happens, however, that a small piece of glass must be cut into a circle, oval or other shape. This is best done by means of ordinary scissors or shears, or by cutting-pliers. The shears should be dull and the *glass should be kept under water while cutting.* This is the whole secret and you will be surprised to find that you may readily clip glass into any form in this manner. An even better method where the glass to be cut is fairly large is to use a pointed, red-hot iron. Mark the line or form to be cut with chalk, or by pasting a strip of paper upon the glass as a guide, and start the cut with a file or diamond. Then, by touching the red-hot iron to the spot and moving it quickly along the guide line, a crack will follow after the iron and the glass will cut evenly and cleanly. This is a particularly good method to use in cutting bottles, jars or flasks into other forms for vessels, receptacles, etc. With a hot iron, a round bottle may even be cut into a spiral, like a glass corkscrew and you will be surprised to find that in this form, glass is quite elastic and that the coil-like strip may be stretched out for some distance, exactly like a coiled metal spring. Glass also may be cut, smoothed, filed or sawed as well as drilled, by using a mixture of camphor and turpentine as a lubricant, while it may be even more readily worked by the use of dilute sulphuric acid in place of the turpentine and camphor. When using the acid, however, you must remember to *always wash the tools thoroughly after using, immerse them in a strong solution of washing soda and water, dry them by heat and wipe them with an oiled rag or they will soon be ruined by rust and corrosion.*

ATTACHING METALS, ETC., TO WOOD

Although you will find that sealing wax and good glue will serve very well for fastening many parts of your set together, yet you will often have occasion to fasten rubber, metal, celluloid or other materials to wood or fiber and you will discover that the best glue and prepared cement have their limitations. If you wish to fasten metal to wood, use a cement made as follows: Dissolve fifty parts of acetate of lead (sugar of lead) and five parts of alum in a little water. In another receptacle, dissolve 75 parts of gum arabic in 2,000 parts of water. Into the latter, pour 500 parts of flour, stirring constantly, and heat gradually to the boiling point. Mix the two while stirring and it is ready to use.

To cement celluloid to wood, use: Shellac 1 part; spirits of camphor 1 part; alcohol and camphor (90 per cent.) 3 to 5 parts. Keep in a tightly corked bottle. To fasten rubber to wood, use a cement made of: Shellac 1 oz., gutta percha 1 oz., sulphur 45 grs., red lead 45 grs. Melt the shellac and gutta percha together and then add the sulphur and red lead while stirring constantly and use while hot. To cement metal to metal, as two pipes or a bar in a pipe, or to make a waterproof joint, use a mixture of litharge and glycerine formed into a thick paste or a mixture of red lead and molasses. The latter will stand all sorts of chemicals.

CLEANING FILES

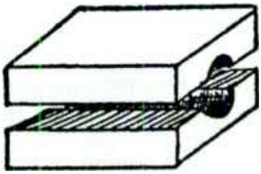
When files are used for wood, brass, copper, zinc, solder, lead, etc., they soon become so clogged and filled with the substances that they are useless. Much of this trouble may be avoided if the files are first rubbed with chalk before using. But even after being thoroughly clogged up they may easily be cleaned and made as good as new by immersing them in weak acid. Use sulphuric acid for grease or wood and muriatic acid for the various metals. Do not leave the files in the acid too long, a few hours will do, and then wash thoroughly in clean water, rinse in a strong soda solution, dry by heat and rub with a well-oiled rag. Not only does the acid eat out or dissolve the particles between the teeth of the files, but it also sharpens the teeth and makes them cut better.

CUTTING RUBBER

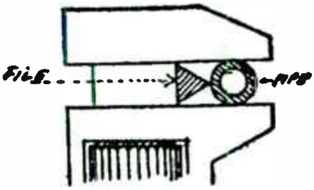
Rubber is very useful material in radio work. You will find rubber stoppers to bottles make excellent knobs or tips to electrodes, adjusting rods, etc., and that block or sheet rubber is very useful as an insulator in many places; but if you have ever tried to cut rubber with a knife you will know how hard it is to make a neat, smooth, straight cut. But if you use a sharp knife and keep the rubber wet with cold water, or cut it under water, you will find that it cuts like cheese.

EMERGENCY PIPE WRENCHES

If you wish to hold a pipe or rod securely and have no pipe wrench you may make a very good substitute by means of a three-cornered file and an ordinary monkey wrench, as shown in the cut. If you have no monkey wrench or do not wish to mark or scar the tube or rod, you can hold it firmly enough to cut a screw-thread upon it by wrapping it with a doubled cord or rope, as illustrated. Wind the rope around the rod or pipe in the direction in which it is to be turned and slip a bar or stick through the loop. Then, by holding the cord in place with one hand and by turning on the lever with the other hand, you can exert a tremendous pressure. If the rope shows signs of slipping, dampen it with water. If the pipe or rod is to be held and a screw-thread cut upon it or a nut or fixture screwed upon the end, merely hold the cord and lever so there is a tension on the rope. Be sure in this case to have the rope wound in the opposite direction from which you are turning the nut or die.



TO HOLD ROD IN VISE



EXTEMPORIZED PIPE WRENCH

HOLDING PIPE OR ROD WITHOUT SCARRING

BREAK DRILL FROM PIPE

If you wish to hold a tube or rod in a vise, do not clamp it in the vise jaws. It will be impossible to hold it securely without scarring or flattening it, but by boring a hole a trifle smaller than the diameter of the pipe or rod through a wooden block and then sawing the block in two, you may clamp the pipe between the two sections of wood in the vise and hold it immovably without danger of injuring it.

DRILLING BRICK OR MORTAR

When putting up aërial or other wires, it is often necessary to drill holes in bricks, cement, mortar, concrete, etc. Although this may readily be done by a small cold chisel and hammer, it is easier and neater to bore a hole by means of a drill. This may be a "star" drill which may be bought ready-made, but a very efficient tool may be made by filing notches in the end of an ordinary iron pipe and then bending the teeth outward slightly. The pipe should be heated until red-hot and dipped into cold water to harden or temper it. Such a drill will, of course, wear down and become dull very rapidly, but it is easily sharpened by means of a three-cornered file and will penetrate soft brick and mortar without trouble.

STRAIGHTENING WIRE

In electrical work, it is very important to have the wires absolutely free from kinks, snarls and tangles. Not only is wire wasted by allowing it to become tangled, but a kink or twist will often result in a crack or break which is invisible under the insulation, but which will render the set useless. If you take the fastenings from a coil of wire, the coil will at once come apart and will soon become tangled, but if you merely loosen the fastenings, or replace them with slightly larger ones, and then slip the end of the wire out over one fastening you can use the wire without danger of tangling by slipping the fastenings around and around the coil, just as a key is slipped on a key-ring. As the coil decreases in size, smaller fastenings should be used, so that they will not slip together and allow the coil to capsize or twist over on itself.

If you wish to straighten wire, attach one end to some fixed object, such as a hook, nail or vise and then pull steadily and strongly on the other end until you feel the wire give slightly. Then the wire will be found perfectly true and straight. Be careful, however, that there is no kink or twist in the wire before doing this, as otherwise it will break at the kink. Wire up to the size of ordinary telegraph wire may be straightened in this way, but for large wires, the length must be considerable. To straighten shorter lengths, or larger wire, tap it with a mallet or hammer while turning it about on a smooth surface and when fairly straight roll it between two boards until perfectly smooth and straight. Large wire also may be straightened by "whipping" it down upon a flat floor or bench.

MAKING WOOD WATERPROOF

In electrical work, and especially in radio work, a very little moisture in the panel or base on which instruments are mounted may interfere a great deal with the efficiency of the apparatus. To avoid this, specially prepared compounds, fibres, etc., are used extensively but it would be cheaper and easier to use wood in many cases, were it not for the fact that wood will absorb a great deal of moisture. For this reason, wood is avoided as is cardboard, although the latter may be made practically waterproof by soaking in melted paraffine wax. It is very easy, however, to treat wood or pasteboard with chemicals in such a way as to make these substances impervious to water or moisture. The chemicals which give the best results are either a solution of zinc chloride, or a mixture of boracic acid 6 parts; ammonium chloride 5 parts; sodium borate 3 parts, and water 100 parts. After soaking in this, dry the wood thoroughly and shellac, varnish or finish as you see fit.

FIREPROOFING WOOD

It is also an easy matter to render wood or other inflammable materials fireproof by means of chemicals. By that I do not mean that the wood will not burn, but it will not blaze or glow and will merely char, even when exposed to great heat. The following are all good for rendering wood fireproof: A solution of 10 to 20 parts of potassium carbonate in 100 parts of water. Tungstate of soda solution. Ammonium phosphate 100 parts; boracic acid 10 parts; water 1,000 parts. Ammonium sulphate 135 parts; boracic acid 5 parts; sodium borate 15 parts; water 1,000 parts. It is best to soak the wood or paper in these solutions, but if several coats are brushed on it will serve. Where the surface cannot be treated except with a brush, a solution of sodium silicate (water-glass) hot, 100 parts; Spanish white 50 parts and glue 100 parts will form a covering which will resist intense heat.

MAKING GROUND AND FROSTED GLASS

If you ever wish a piece of ground glass or a piece of glass which is partly clear and partly ground or frosted and do not have real ground glass on hand, you can readily get the same effect on ordinary glass. If plain ground glass is required, put a piece of putty in a muslin rag, twist the cloth tightly and tie in the form of a pad.

Clean the glass thoroughly and then rub the putty-filled rag over the glass and finish by patting it gently against the glass. Allow the thin layer of putty to dry until hard, and then cover with a thin coat of transparent varnish. When dry, this will withstand washing, steam and ordinary heat. A very beautiful mother-of-pearl surface may be given to ordinary glass by mixing a concentrated solution of salt and water with dextrine and applying to the glass in a thin coating with a soft brush. After drying, varnish with white shellac dissolved in alcohol. If a plain center or border or lettering on the glass is desired, merely paste on paper strips or patterns before treatment and then remove the paper afterwards, or make a stiff paper stencil and treat the surface of the glass through this.

LETTERING HARD RUBBER, ETC.

Where dials or knobs are used for adjustments it is a good plan to have them plainly marked or lettered in some way. The ready-made sets are neatly numbered and lettered in white on black, or vice versa, but any boy may get just as good results by using white ink, such as is used in show-card writing and then varnishing with a thin coating of shellac or Valspar varnish. If you are skillful you may cut the marks or letters in the rubber or Bakelite and then, by rubbing in white lead and after it is dry rubbing off that which adheres to the surface, the letters and marks will come out clear and white. Another method is to inlay the marks with metal. By using small brass nails cemented into holes and then cut off and filed and smoothed flush with the surface, very neat and attractive effects may be obtained. You may do this in the simple manner of one, two, or more nails to mark the various points at which the dials should be set, or you may outline letters or numbers with small brass nails, or even fine brass wire, set into the Bakelite in the same way. For pointers or hands to use on dials old clock hands will be found very useful. In fact, old discarded or useless clocks, especially alarm clocks, are veritable treasure troves for the maker of radio sets. There will be any number of little brass shafts, wheels, dials, pointers, nuts and screws, bolts and knurled thumb-nuts for which you can find a use in your work.

HARDENING AND SOFTENING BRASS

In many places in radio work you will need soft, easily-bent brass and in other places stiff or spring brass. To bend the latter is very difficult without breaking it, but by proper treatment, the soft brass may be hardened and the hard brass softened to suit requirements. This is done by heating and cooling. To soften hard or spring brass, heat to a cherry red and dip into cold water. To harden soft brass, heat to cherry red and allow to cool slowly. This is exactly the reverse treatment as for steel which is hardened by plunging into water while hot and is softened or annealed by allowing it to cool slowly. Copper may be treated in the same way as brass. Of course the soft brass hardened in this manner will not be as hard or springy as the real spring brass, as the alloys used in making brass of various kinds are varied to suit requirements, but you can make soft brass far harder and you can soften hard brass so it may readily be bent and can then reharden it, which is oftentimes a great convenience and saving of time.

MAKING COIL SPRINGS

Although you will have little use for coil springs as such in making radio instruments, yet you will find that sections of small coil springs of brass wire are often very useful and even necessary. It is not necessary to buy springs or to have them on hand, for it is a very simple matter to make them as required. Use spring brass wire and after straightening the wire as already described above, clamp one end against a brass, steel or wooden rod in a vise. A large wire nail, a bolt or even a lead pencil will serve, and if you are to make many springs it is a good plan to have rods or sections of brass tubing with a hole bored through near one end in which to hold the wire. Use a rod a trifle smaller in diameter than you wish the inside of the finished spring and merely wind the wire tightly around the rod in a spiral, keeping the turns close together or wide apart, depending upon the tension you wish to have in the spring. Then, when the rod is slipped out of the coil, your spring will be complete. Short sections of a turn or two of such wire springs are very useful as spring washers on adjustment screws, on terminals and in many other places, as they hold the nuts or thumb nuts in position and prevent them from working loose. They may also be used on switches to keep an even pressure on the switch arm, under adjusting knobs to keep the knobs in position where desired and in dozens of other places about a set.

DULL FINISH ON BAKELITE

Many persons object to the highly polished, glossy surface of Bakelite and hard rubber used as panels or mounts for radio sets. It is a very easy matter to transform these to velvety dull finished surfaces by going over them with emery cloth or fine sandpaper and then rubbing with a slightly oiled rag, using linseed oil. Remember, always to rub with the sandpaper in one direction only.

SECURING TERMINALS AND WIRES

In making up sets on panels or bases on which the connecting wires are carried from one terminal or binding post to another on the under side of the panel it is often a good plan to pour sealing wax over the ends of the posts and over the connecting wires. This prevents the posts and screws from becoming loosened and it also protects the wires from injury or from accidental contact with other objects. Of course the wax should not be applied until the set is all done and has been tested and found in perfect order.

WINDING COILS

Although a simple coil with comparatively few turns of wire may readily be wound by hand, yet when it comes to secondary coils or even an ordinary coil with many turns of wire, it will be found much easier to put on the windings by revolving the tube or core by some mechanical device. If you are fortunate enough to own a lathe, the core may be placed on that and wound. In order to attach the tube to the chuck it should be fitted over a wooden core and pinned upon the latter through a hole near each end of the tube. If a lathe is not available, a geared drill or even an old egg-beater secured in a vise or clamped to a bench or table may be made to serve. If a drill is used, the best way to attach the tube to the drill is to fit a wooden core as described and then, in the center of one end, drill a hole and insert a slender screw. Then cut off the head of the screw and insert this in the drill-chuck. In order to use the egg-beater the metal strips that whip the eggs must be removed and the central shaft attached to the tube or the metal strips may be drilled and attached to the wooden core fitted in the tube by means of small screws. Even an old sewing machine, a bicycle or a grindstone may be used for revolving the tube while winding on the wire. In order to wind a coil well one person should rotate the tube and wind on the wire while another pays out the wire as needed. But if you intend to make your own coils it will pay you to buy your wire on the spool. These spools or reels may then be attached to a spindle or axle such as a long nail bolt or stick and the wire reeled off readily without any danger of kinking or snarling. Arrange the spool on its spindle so that it binds a very little, that is, so it will not wobble or whirl about and thus unroll more wire than is drawn from it. In winding a coil, if you wish the wires separated evenly you should wind on a string, cord or rope at the same time with the wire. Then when the coil is complete the cord may be removed. By this method coils may be made of bare wire which is an advantage in making variable tuning coils, as there is no need of scraping off the insulation when making taps or using a slider. If the wire is wound on the coil tightly there will be little danger of the turns slipping together, but to overcome this, a very thin coating of white shellac may be given or the coil may be immersed in melted paraffine wax. Of course the wires must be thoroughly cleaned and all wax or shellac removed where contacts or connections are made.

SAWING METAL

It is very easy to saw any metal with a hack saw, but in order to do this without breaking the teeth from the saw blades you must be careful. In the first place, do not try to hurry matters. By exerting too much pressure on the saw or trying to cut too rapidly you will merely injure the saw. In the second place, always go very slowly and carefully when nearly through the cut or teeth will snap on the sharp edges of the cut. If sawing a pipe or tube, hold the saw at an angle to the rough, sharp edges of the cut on the pipe and in sawing thin or strip metal do not attempt to cut through on the edge, but use the saw on the broader flat surfaces. As soon as a tooth in the saw is broken you must use only that portion of the saw which is still whole or, if several teeth are gone, discard the saw, for as soon as one tooth goes others will follow in rapid succession if used on the injured spot.

CHAPTER XVIII

HOW PICTURES ARE SENT BY RADIO

I HAVE already mentioned that pictures have been successfully sent by wireless, although the process has never been perfected until it is a commercial success or is in general use. A great many people cannot understand how a picture or image can be transmitted, either by wireless or by wire, even though they can readily understand how words or dot and dash messages may be sent. But it is not at all difficult to understand, once the principles are understood. It may, therefore, be of interest to explain in a few simple words how this most remarkable of all feats in radio is accomplished and which, even before this book is printed, perhaps, may be as well perfected, as cheap and in as common use as ordinary wireless telephones are to-day.

There are two methods which have been used in sending pictures by electricity, for both may be used either with or without wires, one of which is accomplished by physical-electrical means and the other by mechanical-electrical means. The first, which was the first to be perfected to any extent and which is the most complicated and the most practical, probably, depends upon the remarkable properties of the metal or element called selenium. Nearly all metals are conductors of electricity, but some are much better conductors than others, or, in other words, the electrical currents pass through or over them more readily than over others. Copper, for example, is an excellent conductor; iron is not so good and German silver is a poor conductor. Those which are poor conductors therefore are said to offer more resistance than others. Some materials, such as galena or lead sulphide, are conductors to currents flowing in one direction and offer great resistance to currents flowing in the opposite direction. Nearly all of the conductors vary in the amount of their conductivity or resistance according to their temperature, but as far as known, only one, selenium, varies according to the amount of light upon it, and varies so greatly that its resistance to an electrical current when in darkness is almost twice as great as when exposed to light. By taking advantage of this property and using a surface of polished selenium known as a "selenium mirror" it is possible not only to transmit a picture reflected upon the mirror to a distant point by electricity, but to transmit the likeness of a person or any other object reflected in it. Indeed, if the apparatus could be perfected, it would be possible for persons using telephones to see the moving counterparts of the persons to whom they were talking. This sounds like a dream or like magic, but it can and has been done. All that is necessary to accomplish this astounding result is to equip a selenium mirror with a vast number of contacts on the back and to so arrange these that the varying degrees of resistance over the contacts, brought about by the varying degrees of light upon the image reflected in the mirror, will conduct varying currents of electricity to a device upon the other ends of the wires (or through the ether) and which will then reproduce the original image. But it is such a complicated and expensive apparatus and the results are so unsatisfactory, that it has been relegated to the realm of interesting scientific experiments rather than as a practical device and up to the present it has never become of commercial importance or even of immediate promise for every day use. The other method is very different and is much simpler.

This, as I have said, is a mechanical electrical process and pictures have been transmitted across the American continent by this means and have appeared in newspapers in New York a few hours after they were taken in Chicago or the far western states. The first successful attempts to transmit pictures by radio were made in 1908 by Mr. Hans Knudson, who succeeded in sending radio pictures even before any practical way had been devised to transmit them over wires. Mr. Knudson's process, however, was very crude and was quite different from the later mechanical-electrical devices. Briefly, it consisted of preparing a gelatine photographic plate with a film several times thicker than the ordinary film used on a plate and the photograph to be reproduced was taken upon this plate in a camera provided with a screen of parallel lines. This, of course, broke the picture into lines, just as an ordinary half-tone engraving is broken up into tiny squares by the screen through which the negative is taken. Then, after the negative had been developed and was partly dried, it was sprayed or dusted with iron powder, and as the light portions of a plate coated with a gelatine film dry more rapidly than the darker parts, the iron adhered to the darker portions of he plate. The plate was then placed upon a movng stand with a metal point attached to a spring esting upon it and which moved at right angles o the motion of the plate. To this was connected battery and spark coil, so that when the vibratng needle touched the iron dust on the negative t made a circuit and when it passed over a bare pot of gelatine the circuit was broken. This, of ourse, produced intermittent currents or waves vhich were received by another instrument proided with a vibrating needle like the first, but vhich bore upon a plate of smoked glass. Thus he second needle produced scratches on the moked surface corresponding to the lines upon he original negative. The later method, which ave far better results, was quite different as far s the preparation of the photograph was conerned, but was somewhat similar in the way it vas transmitted. In this process the photograph s taken through a screen which breaks the picure up into dots, just as any half-tone engraving vill appear to be made up of dots if you examine t through a lens. You will also notice that the lots appear to be nearer together where the larkest shadows appear and further apart where here are lighter shades, while on the white or lightest portions there are no dots. After the negative, broken up in this way, is made, a print is taken upon a positive film coated with gelatine treated with bichromate of potash. As bichromate of potash has the property of rendering gelatine waterproof, or non-absorbent, when exposed to light, the positive, when developed, will be composed of dark dots which are hard and waterproof, and light spaces which are soluble. In this way, it becomes possible to partly dissolve and remove the light parts of the picture, leaving the dark spots raised, or in relief. The picture is now ready to be transmitted, which is done as follows: The positive is placed upon a drum or cylinder, *Fig. 79, A,* close to which is a carrier and metal point or needle, *N*. This is adjusted so that it barely touches the lower portion, or light spaces, of the picture on the drum and is so arranged, by means of an automatic screw-shaft, that it moves along its own width with each revolution of the cylinder. To this needle are connected batteries, *C,* and a coil, *D,* with a device for breaking the circuit each time the needle-point touches a raised spot representing a dark dot on the picture. This causes the core of the coil to be magnetized and demagnetized each time the circuit is made and broken, and hence, the circuit breaker, *E*, is attracted and repelled, producing sparks at the gap, *F*, which create wireless waves, just as an ordinary telegraph-key produces sparks at a gap and sends the dots and dashes on electrical waves. At the receiving end is a similar apparatus, *Fig. 80*, with a drum, *A*, revolving at the same speed as that on the transmitting device. Upon this is fastened a sheet of paper with a pencil or crayon, *P*, close to it, and attached to an iron bar, *B*, pivoted to a carrier, *C*, and with an electromagnet, *D*, below. The whole carrier is supported on a screw-shaft, *E*, which moves the pencil along at exactly the same speed as that on the transmitter. Connected with the electromagnet are batteries, *F*, with an interrupter or contact-breaker, *G*, in the circuit above a coil, *H*. You can thus readily understand, by looking at the diagrams, how each time the needle on the sending machine touches one of the raised dots on the picture and sends a spark across the gap, thus creating a wave, the wave will be received at the receiving instrument and by means of the coil, *H*, will cause the key, *G*, to open and close the circuit to the magnet. Then, each time a current of electricity flows through the wires from the battery, *F*, the magnet will draw the iron bar, *B*, towards inwards and thus will bring the pencil to bear upon the paper and will leave a black dot. As a result, each black dot on the original picture will be reproduced upon the paper with exactly as much space between the various dots as on the original. Of course the picture thus reproduced will be broken up into dots, just as an ordinary half-tone engraving is broken up, and consequently the pictures appear rather coarse; like very coarse engravings in a newspaper. But in a way this is a great advantage, for in using them to reproduce as cuts for illustrations, they can be done by the zincotype or line process instead of by half-tone, which is much cheaper and quicker. Moreover, if the pictures sent are of large size they may be photographed and reduced in size, when the effect of dots is lost and they appear as uniform and soft as an ordinary photograph or a good half-tone. In sending pen-and-ink drawings and similar pictures, the reproduction is very perfect. There is room for vast improvements in this or similar processes for sending pictures by radio and as the instruments are really very simple it should be a fine and interesting field for amateurs and boys who wish to experiment. Very often, most valuable and interesting discoveries are made by novices and it is not at all beyond the range of possibility, or even probability, that the first really commercially practical apparatus for sending pictures by wireless will be invented by a beginner or a boy.

CHAPTER XIX

THE ROMANCE OF RADIO

It is a common saying that modern science, invention and progress are driving romance and adventure out of the world. But wireless cannot be charged with this, for romance and radio go hand in hand and while it may not lead to thrilling, hair-raising adventures, still, in the silent night, the wireless operator sends forth his invisible messages, speeding them through the ether far and wide to no one knows where, to have them greet the ears of far-off listeners, perhaps hundreds or thousands of miles distant in strange lands or beyond vast oceans. Surely there is nothing more romantic or more filled with adventure than this interchange of thoughts, words and speech between human beings separated by continents and oceans; this being able to converse, regardless of distance, space or matter; this feeling that your voice or your messages are filling the universe, are speeding around the globe with the speed of light, are penetrating solid walls, immense mountains,—perhaps the very globe itself, and may even be heard in the distant stars. And what more thrilling adventure than suddenly to hear the words or signals of some utter stranger in some unknown, distant country; to hear the sharp dots and dashes coming in from some tropic land and to realize that you are talking with some fellow man who sits in a thatch roofed, open station beneath rustling palms with the great tropic moon gleaming on a coral beach, while all about outside your steam-heated room the gales howl and the snow drives and piles in great, white drifts beneath the bare limbed trees? What more exciting and wonderful and filled with mystery and romance than to feel that in some polar, frozen waste in the far away arctic regions some lonely, worn, half-starved explorer is listening to your idle chatter with some neighbor? Yes, there is one thing more thrilling and speaking louder of adventure, of danger and of excitement, than all of this; the sharp, frenzied "S. O. S." that means some tossing, storm-lashed ship is in dire distress, that the water is sullenly rising within her hold or that fire unquenchable is dooming her and those upon her to awful destruction unless that fevered three-letter signal meets with quick response. And at that wide-flung call for aid, that despairing, pitiful plea for help sent from the wildly tossing mast heads of the stricken ship, all other calls and chatter cease and breathlessly you listen to catch the answering call, the cheering message from other ships, each and all turning their prows, shifting their courses, speeding with churning screws and belching funnels towards their invisible, helpless comrades. As through the hundreds of miles of space the "dee, dah, dee" of the signals come to your ears, and with fast-beating heart you hear those frenzied calls, the plea for speed, the dry dot-and-dash, unemotional statement that she is sinking fast; the expressionless, mechanical sounds that mean life or death to scores, nay hundreds of your fellow men, women and children, you can almost picture the scene, so vividly do the sounds bring it before you. You can see the black, heaving seas with their hissing crests of white, the scudding, low-hung, lowering clouds, the stinging spray and icy gale-driven sleet. You can picture the stricken ship,—a tiny thing upon that vast, tumultuous waste,—rising sluggishly to the great, angry seas, sinking deep within the foam-flecked hollows; her ice-sheathed masts cutting wide arcs against the murky sky, her decks almost awash, huge green rollers pouring cataracts of yeasty green water over her plunging bows; her rails riven, splintered and bent, her rigging torn and shattered and her lifeboats stove, while yet between the trembling masts the tiny strands of wire hold their own and keep that God-forsaken, pitiful wreck in touch with all upon the sea and land. And from that sagging, all but invisible wire that now is worth a thousand times the value of that sinking hull and all its precious cargo, your thoughts speed down to the little room below, a tiny cubby-hole from whose shuttered ports a light glimmers in fitful gleams. There, calm, unperturbed, a smile upon his face, his phones clamped to his ears, the wireless operator sits, bracing himself against the sudden lurches, the sickening rolls of the ship and between his messages, his pleas for help, his laconic statements of the constantly gaining water, he taps off jokes and jests;—a hero to the last, a man who can stare death in the face and laugh; a humble, unknown, unnoticed "Sparks," but upon whom, when the hour of disaster comes, the lives of thousands may depend. Perchance, as you listen, you may hear his last clear message dwindle off into nothingness, his last word cut in twain and you will shudder at your set as you realize that poor brave "Sparks" has met his end, —the death of a hero,—faithful to the last, sticking to his post as sullenly, as doggedly and as honorably as the captain facing the hurricane and freezing brine upon the bridge. Or again, your heart may throb and your pulses quicken as you hear the comforting messages speeding back and forth between the sinking vessel and those rushing to her rescue, you will visualize the faint, far-off specks of light that appear and disappear between the mountainous seas and you can almost see the straining eyes of those hardy, dauntless men upon the bridge, as facing the tempest, they stare at those twinkling spots of red and green and white that are racing with death, pitting steam against the elements. And when, at last, you know by the messages in your ears that the lights are close, that against the blackness of the night those upon the doomed ship can trace the blacker outlines of another ship, your pulses leap with delight and joy that help has not come too late. There, rising and falling, bringing cheer and hope beyond words to the frightened, praying, white-faced multitude upon the hulk, gleam tier after tier of lighted ports, while crowds press to the rails of the savior's decks, braving the storm and wind to see those whom they have raced to succor. From the davits, the lifeboats drop; you can almost hear the creak of tackle and falls, you can almost see the tiny, buoyant craft bobbing over the great billows, and when, after what seems an interminable space, you hear "Sparks' " "all hands safe" and then silence, you breathe a sigh of deep relief.

Forgetting the receivers still upon your ears, you lean back in your chair, exhausted with the strain, trembling with excitement, for you have been there—there far out upon the storm-tossed winter sea—as truly as though you had been there in person. You have listened into the most thrilling and dramatic tragedy the world knows; have heard word for word all that has passed between the ships, and when, the following morning, you read the staring headlines in the papers telling of the rescue it will seem tame and colorless indeed in comparison to the story brought to you so vividly, so intimately the night before.

And there are many other romantic things to hear, many another adventure brought to your ears in the still watches of the night through the silent air. A potentate may die, and, glancing at your watch or clock, you may find that it yet lacks hours of the time when his soul sped; you know of his death before it has taken place by your time. A battle may be won and you know of it a few seconds after the victory. A disaster which rocks the world occurs and you learn all its details while the unsuspecting, unheeding throngs about go on their ways, never dreaming that friends and loved ones have gone to an awful death while they laugh and dance and amuse themselves. A thousand things there are to thrill the radio operator and to bring romance and adventure to him; a multitude of things denied to others less fortunate and, best of all, he is ever standing upon the brink of the unknown, upon the verge of tremendous wonders, undreamed of mysteries, incredible surprises and unfathomable mysteries. From out of the air will come some message from the other side of the world, borne like a stray spirit for thousands of miles beyond your normal range, a waif of the ether, a wisp of words carried no one knows why or how to your ears. Or again, while chatting with a fellow operator in a nearby town, you may suddenly be interrupted by a call from some one asking who you are and where, and as you reply and repeat the queries to him your eyes will almost pop from your head and your mouth will gape with astonishment to find that some one in Europe, South America or on the Pacific has heard your neighborly gossip as plainly as though they were in the next street.

Such things happen, and happen fairly often at that. Freak messages we call them, but are they? Who can say that if we but knew the secret, the key, we should not find these were normal messages and our limited ones are the freaks? Who dares claim that it is not possible to talk with the other side of the world with the smallest, weakest instruments? Radio is still in its infancy; we know practically nothing of its laws, its rules, its limitations or its possibilities and these "freak" messages set us thinking. Not so long ago, in far-away Scotland, James Miller sat at his instruments in Aberdeen and to his listening ears came the sound of a man's voice. For a space he paid no heed,—some one near by, within Britain's borders no doubt, and then, as he "tuned in" half absent-mindedly he stiffened with wonder; incredulous, unbelieving, for he was listening to an amateur 3,500 miles away,—Hugh Robinson of Keyport, N. J.—talking to a neighbor a few miles distant. To the listener there in Scotland came clearly and plainly the words of the conversation in New Jersey and borne to Aberdeen through the ether came the strains of music from Robinson's phonograph. And the marveling thrilled Scotchman was not the only one who listened in to Hugh Robinson's gossip and music on that night. Far out upon the tossing Atlantic, 1,900 miles from land, the operator upon a speeding ship also gaped with wonder as he heard the voice and music from Keyport, while in the harbor of Tela, Honduras, a ship, riding at anchor near the palm-fringed coast, heard, brought through the moonlit air, the same words and the same music as greeted the ears of the Aberdeen listener.

And why and how was this? What was the reason? Why were Robinson's words and music carried by some magic to Scotland, to the middle of the Atlantic, to Honduras, while others, talking and signaling and no doubt playing music that same night were unheard? No one can say; no one can offer an explanation; it is one of the unsolved mysteries, the romances of radio. Robinson himself has no more knowledge of how it happened, no more of a theory than anyone else. He was using a small set, a set supposed to be good for only 100 miles, a set operated by an ordinary lighting circuit, and yet it sent his words and music across the Atlantic. And if this were the only time such things have happened we might consider it a freak, a chance, a thing which might never happen again; but the trouble is, Robinson's experience was *not* unique. In Glenbrook, Conn., a man, using a little one kilowatt amateur outfit, was talking to friends and entertaining them with his phonograph while, all unwittingly, he had another audience at Georgetown, British Guiana, two thousand five hundred miles from his New England home. The steamship *Gloucester* nearly one hundred miles from New York, was heard in California and the words of songs and the music on the steamer off our Atlantic coast came as clearly to the operators at Santa Catalina Island in the Pacific as to those in New York City. If such things can and do happen accidentally and unexpectedly they can be made to happen purposely and intentionally if we only know how. Years before the radio telephone had become a practical or commercial thing, while experimenters were still groping with the speaking arc and before vacuum tubes were dreamed of, I was on a ship off the southern coast of the island of Santo Domingo. It was evening, a calm, beautiful tropic night with heat-lightning playing among a bank of low clouds upon the western horizon, and I was seated in the wireless room chatting with my friend "Sparks." As he talked, he idly and half unconsciously ran his slider back and forth upon his tuning coil. Suddenly, and to our utter amazement, a burst of music filled the room, the unmistakable music of a military band. Uncomprehendingly we sat silent, gazing at each other, while, to our wondering, half incredulous ears, came the dreamy air of "Sobre las Olas," filling the little room with harmony, pulsing in rising and falling notes, and as clear and distinct as though the band were upon the deck below. Presently the sounds ceased and breathlessly we waited. Then, once more, slightly fainter than before, but still clear as a bell and easily recognizable, came the unmistakable languid tune of "Las Marienetas." There in the tiny, stuffy wireless room over one hundred miles from any port, we sat, listening to the band, drinking in the sound of horn and cymbal, of drum and cornet, of saxophone and trombone, until suddenly,—as quickly and unexpectedly as it had begun, the sound ceased. No tuning could bring it back, no adjustment could recall it. The phantom music had gone, had vanished into the ether whence it had come unheralded and unexpected,—a "freak" message. And this was not over a modern radio telephone, but over an old-fashioned wireless telegraph set, with a crystal detector. For hours "Sparks" and I discussed it, trying to reason it out, striving to fathom it, but all theories failed utterly. Atmospheric conditions were bad, there were lots of static in the air and we could not even get the station at Santo Domingo City on account of the electrically charged atmosphere. At last we gave it up; but two days later, when we reached port and made enquiries, we found that on the night and at the time we had heard the music the military band had been playing in the plaza and had played "Sobre las Olas" and "Las Marienetas" in turn, just as we had heard it. To this day it remains a mystery as to how the music was carried to us upon the ship one hundred miles distant. Was it by some strange, unknown waves which emanated from the band and caused some vibration in the government station a few hundred yards away? Was it owing to the heavily static charged air, or were we standing at the very brink of an astounding discovery which we could not discern? Some day all these things will be answered, all these puzzles solved. Every amateur, every boy, every novice and beginner who buys, makes, installs or uses a sending or receiving set is helping to solve these mysteries, is aiding in unraveling the puzzles, is doing his bit towards answering the unanswerable questions. Great discoveries and great inventions are usually the result of accident and very often come from amateurs or beginners. Countless thousands of boys and men had watched tea kettles boil and had seen the lids jiggling up and down, but only Watt grasped the reason and gave us the steam engine. Millions of apples had dropped from trees and thousands had fallen on people resting in the shade, but Sir Isaac Newton was the first to link a falling fruit with the law of gravitation. Primitive man had lifted weights and had handled sticks since the world began, but it took thousands of years for man to combine the two when Archimedes discovered the lever, and so we might go on indefinitely. At any time, on any day, or any night, some amateur, some schoolboy, may find the key that unlocks the secret of these freak messages. It may be very simple, most things are when once we know how—but it is worth striving for, and the more people there are using radio the more chances there are of freak messages and the greater the likelihood of some one stumbling upon the reasons and causes, the conditions and the laws which govern them and make it possible for an amateur set at times to transmit words and music from continent to continent across three thousand miles and more of ocean.