NATIONAL RADIO INSTITUTE

Complete Course in PRACTICAL RADIO

NRI

Radio-Trician
(Registered U. S. Patent Office.)

LESSON TEXT No. 44

SHORT WAVE BEAM TRANSMISSION

Originators of Radio Home Study Courses
···Established 1914···
Washington, D. C.

Progress in industry depends very largely on the enterprise of deep thinking men, who are ahead of the times in their ideas.—SIR WILLIAM ELLIS.

W3M71030

Printed in U. S. A.

Radio-Trician's

(Registered U. S. Patent Office.)

Complete Course in Practical Radio

NATIONAL RADIO INSTITUTE, WASHINGTON, D. C.

SHORT WAVE BEAM TRANSMISSION

Directional radiotelegraphy is as old as the art itself. Hertz made use of reflectors at the transmitting as well as the receiving end, in order to augment the effect, and to prove that the electric wave which he had discovered, obeyed to a considerable degree, the ordinary optical laws of reflection.

As far back as 1895, when radiotelegraphy was in its infancy, Senatore Marconi investigated to some extent, the practicability of the use of reflectors with the object of increasing the range of a radio station.

The discovery by Marconi of the great increase of range obtained by the use of longer waves, and the use of a ground connection with a vertical aerial, practically stopped development on directional lines for the time being. The demand of the time was for increased ranges and as the first practical application of radiotelegraphy, namely, working to and between ships, required the use of several different wavelengths, directional transmission was more of a handicap than an advantage. For this reason then, the development of directional transmission was dropped, and the need of the day, long wave transmission, received the major part of the development by the scientists and engineers at that time.

Before describing the essential features of the Beam system, it may be helpful to review, briefly, some of the more important factors of the present omni-directional long wave method of transmission which tend to limit its usefulness for long distance communication. By so doing, we shall be in a better position to appreciate the advantages offered by the Beam system.

By the ordinary method of omni-directional (all directions) radio transmission, electrical oscillations are generated in an aerial system from which the energy is radiated in the form of electrical waves which spread simultaneously in all directions. The energy which each wave or train of waves carries is thus dispersed more and more widely as the waves travel further from their source and only a very minute proportion of the total energy carried by each wave can be intercepted at the receiving point. It follows, naturally, that an immensely greater amount of energy must be radiated at the transmitting station than is required to operate the receiver, and that this disparity will get rapidly greater as the distance between the two communicating points is increased.

Apart from the question of ways and means of generating and controlling sufficient power to produce the required results at the receiving station, this characteristic introduces an entirely different problem when several transmitting stations are working simultaneously to different receiving points. Due to the fact that the radiations from each transmitter are spread indiscriminately in all directions, it becomes necessary to provide a means whereby each receiving station can pick out those signals coming from the desired source to the exclusion of all others. In practice, this is accomplished by allocating to each transmitter, a certain definite wave-length, and by tuning the circuit of the receiver to respond only to the wave-length of the particular transmitter from which it is intended to receive.

This power of selection is, however, limited. Due to the rapid interruption of the transmitted wave representing the character and spacing periods of the code, the carrier wave becomes broadened out into a series of slightly different wave-lengths, with the result that each transmitter occupies not a single wave-length, but a band of wave-lengths. According to the frequency of the code interruption, which in turn, is governed by the number of words per minute at which messages are transmitted, this wave-band will become wider or narrower.

At a speed of 100 words per minute, the variation in the frequency of the wave is approximately 50 cycles per second above and below the frequency of the carrier wave and, therefore, the width of the wave-band occupied by the transmission can be taken as 100 cycles. At 200 words per minute, the width will be double, and at 50 words per minute, the width will be half the figure given. Allowance must also be made for possible accidental variation in the length of the carrier wave radiated from the transmitter, due to the swinging of the aerial in a heavy wind, or to defects in the controlling and governing instrument of the transmitter. With a properly equipped installation, it should be sufficient to allow an additional variation of 200 cycles on this account. Altogether, a margin of about 400 cycles should be allowed between each wave-length allocated to a high power station for working at speeds up to 200 words per minute.

Translating these frequencies into terms of wave-lengths, we find that if a station is allocated a wave-length of, say, 10,000 meters (30,000 cycles), it would actually occupy a band of about 130 meters. For a wave-length of 30,000 meters (10,000 cycles) the band will be about 1,200 meters.

$$\frac{300{,}000{,}000}{29{,}800} = 10{,}065$$

$$\frac{300{,}000{,}000}{30{,}200} = 9{,}935$$

$$\begin{array}{r} 10{,}065 \\ 9{,}935 \\ \hline 130 \text{ Meters} \end{array}$$

$$\frac{300{,}000{,}000}{9{,}800} = 30{,}600$$

$$\frac{300{,}000{,}000}{10{,}200} = 29{,}400$$

$$\begin{array}{r} 30{,}600 \\ 29{,}400 \\ \hline 1{,}200 \text{ Meters} \end{array}$$

However, long wave high power stations do not normally exceed 100 words per minute, and it has been found in practice that they can work with a wave-length separation of 200 cycles.

With long wave omni-directional transmission, practical considerations, limit the band of wave-lengths available for long distance telegraphy to waves between 10,000 and 30,000 meters. The lower wave-lengths from 200 meters upwards are required for ship and aircraft services, for short distance point to point services for broadcasting, and for military and other governmental services. Waves above 30,000 meters are unsuitable because of the limitation in the speed of working and the much more severe atmospheric interference on these very long waves. Thus, the available waves on the long wave system are limited to some 100 bands of 200 cycles each.

The amount of power used by the omni-directional long wave transmitting station is also a limiting factor. One of the latest and largest of these long wave stations in the United States is located at Rocky Point, Long Island, and is operated by the Radio Corporation of America. Twelve antennas are used to communicate with various points in the world. Each antenna is supported on twelve 440 ft. steel towers, and the length of each antenna is in the neighborhood of 3 miles. From 200 to 400 kilowatts of power are used, and transmission is carried on at two frequencies, 17.15 and 18:22 kilocycles (17,500 and 16,465 meters). The British Post Office radio station at Rugby (England) has an antenna 800 ft. high supported on twelve masts, and uses about 500 kilowatts of power. The frequency used in transmission is 21.3 kilocycles (14,080 meters). Buenos Aires in Argentine, S. A., has an antenna about 680 ft. high supported on ten towers and uses about 800 kilowatts of power. The station normally works on a frequency of from 18.7 to 24.9 kilocycles (16,000 to 12,000 meters). Many other similar stations are operated in Germany, France, Italy and in other countries.

It has been found that in actual practice, the average speed obtained by the long wave stations is 20 words a minute for a daily average of 18 hours. This very slow average speed attained by long wave-length commercial radio stations is, of course, a decided disadvantage considering the competition of the cable companies and the speed of about 500 words a minute obtainable on the new type of cables now in use.

THE PRINCIPLES OF THE SHORT WAVE BEAM SYSTEM

Having briefly reviewed the various factors and considerations which tend to restrict the wider use of the omni-directional system of long wave transmission, we may turn our attention to the possibilities offered by the new short wave Beam or reflector system.

It was explained in an earlier paragraph that with the present system of omni-directional transmission, the energy is radiated from the aerial in all directions and consequently, although only a very small amount of power is required at the receiving station to operate the receiving apparatus, an immense amount of energy must be generated at the transmitter to enable the necessary amount to be picked up by a far distant receiver.

If, by the use of a reflector, the whole energy of a transmitter is concentrated in a narrow angle of, say, 10 degrees, then provided that the distant receiving point lies within the arc of that angle, it is obvious that it will receive about 36 times more energy than it would if the same power were radiated uniformly throughout the 360 degrees of a circle. This result is illustrated graphically in Figure 1. Thus, all other things being equal, a 10 kilowatt station projecting its radiations in a narrow 10 degree beam becomes, so far as the distant receiver is concerned, the equivalent of a 360 kilowatt station radiating in all directions.

A similar reflecting system can be employed at the receiving station whereby energy can be drawn from a large area of the advancing wave front and concentrated on the receiver, thereby, still further increasing the total energy received.

Another important advantage is gained by using the system of short wave Beam transmission. As explained in an earlier paragraph, the number of long distance services which can be carried out using an omni-directional long wave transmission system are limited to the number of possible different wave-bands which can be accommodated within the

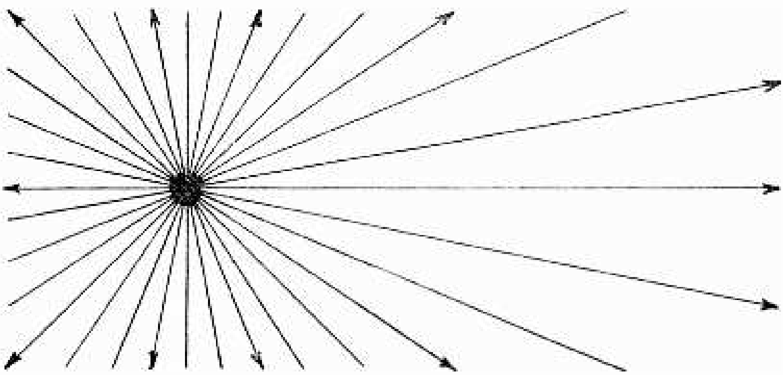

Fig. 1.—Graphic Representation of the Beam Principle.

range of wave-lengths available for the purpose, because each transmitter must be allocated a different wave-band to enable it to work simultaneously with other stations. If the radiation of each transmitter is limited to an angle of 10 degrees, then obviously it would be possible for 36 stations, all transmitting from the same locality and all using exactly the same wave-length, to work simultaneously and quite independently of one another without causing any interference at the corresponding receiving station. Although in practice, the stations would not all be grouped in one locality, the principle holds good whether the transmitters are grouped together or scattered over the space of the world.

With short wave Beam transmission, a great many more working wave-bands are available than with the long wave.

For example, allowing as an outside figure a wave-band of 45 cycles which would suffice for facsimile telegraphy or simultaneous telegraphy with one or more high speed telegraph channels, approximately 700 stations could be worked on waves between 10 and 100 meters.

We must also take into consideration the effect of the reflectors at the receiving station in screening the receiver from radiations emanating from some source outside the arc of reception. Thus, with the Beam system of transmission and reception, the number of possible services which can be carried on simultaneously is many times the number of suitable wave-bands which can be provided within the limit of the total wave range obtainable.

One of the principal advantages gained is that the speed in signalling is increased, due to the utilization of short waves. The larger antennas take an appreciable time to charge and discharge, while the smaller antennas take a much shorter time. There exists no theoretical reason why with a wave-length of 100 meters, the possible speed should not be 200 times as great as that obtainable with a wave-length of 20,000 meters which is approximately what some of the principal omni-directional transmitting stations now use.

The greatest advantage of the short wave Beam transmission, however, is that the amount of power necessary to communicate between two specified points is relatively small compared to the amount of power used in the omni-directional long wave transmitter.

EARLY DEVELOPMENTS OF THE SHORT WAVE BEAM TRANSMITTER

There are, broadly, two general classes of directional aerial systems:

A. Those having the general characteristics and their directional power or polar curves nearly independent of their dimensions. The directional result is obtained by opposing the effecting of a number of aerials, or parts of an aerial with suitable phasing adjustment; the degree of opposition being a function of the direction. Systems of this class may be made small compared with the wave-length employed; for the purposes of position finding, and as receiving systems enabling interference to be eliminated from several directions, they have already been developed to a considerable degree. The simplest example of this class is the well-known "frame" or "loop" aerial. By employing a sufficient number of aerials the system may, theoretically, be given any desired sharpness of directional power without making the dimensions large; this can, however, only be done with a large sacrifice of receiving or radiating power.

B. Those having the general characteristics and their directional power or polar curves depending on their dimensions relative to the wave-length employed. In this class, the directional result is obtained by adding the effects of a number of aerials, or parts of an aerial, when working in the required direction. The underlying principle is that the effects, for the required direction, are integrated over a wide front in proportion to the wave-length. Such systems can, therefore, only have small dimensions when using short waves, and this fact makes their development difficult.

There are several examples of this second classification. Some of them are:

(1) Reflector systems in general.

(2) Systems composed of lines of aerials, at right angles to the working direction, correctly adjusted as regards phase. In this, may be included the Alexanderson long aerial with its feeders. Also, the multiple tuned type of antenna falls under this classification.

(3) The Beverage long, horizontal receiving aerial. This aerial and equivalent arrangement form a class by themselves, but have the characteristics that the directional power is a function of the dimensions.

The reflector system will be dealt with in this lesson text. Investigations were commenced by Senatore Marconi in Italy in 1916, with the idea of developing the use of very short waves, combined with reflectors, for certain war purposes. The waves used were 2 meters and 3 meters. Very little interference was experienced with the use of such short waves, except from the ignition system of motor cars and motor boats. At Senatore Marconi's suggestion, a coupled-circuit spark transmitter was developed, the primary having an air condenser and spark gap in compressed air. By this means, a moderate amount of energy was obtained, and the small spark gap in compressed air proved to have very low resistance.

The receiver used was a carefully picked crystal, while the reflectors employed were made of a number of strips of wires tuned to the wave-length, arranged on a cylindrical parabola with the aerial at the focus. The transmitting system was arranged so that it could be revolved and the effect studied at the receiver. It was assumed that the waves left the reflector as plain waves of uniform intensity, having a width equal to the aperture of the reflector, and the measured polar curves agreed very well indeed with the theoretical curves. Figure 2 shows the calculated curves for apertures of 1, 2, 3 and 5 wave-lengths.

Reflectors having apertures up to five wave-lengths were tested, and by the use of two reflectors with apertures of three and one-half wave-lengths, one at the transmitter and one at the receiver, the working range was increased about three times.

Further experiments were continued during the year 1917. With an improved compressed air spark transmitter, a 3 meter wave-length and a reflector having an aperture of two wave-lengths and a height of 1.5 wave-lengths, a range of over 20 miles was obtained by a receiver without a receiving reflector. During these experiments, a phenomenon of wave propagation was discovered which up to that time had not been realized. This phenomenon was the very rapid increase in the strength of the electrical field with heights above the ground. The rate of increase appeared to be a fraction of the height divided by the wave-length, and while not very noticeable with waves of several hundred meters, it was very marked with waves of a few meters length. In the year 1919, experiments were commenced with a vacuum tube transmitter, with the idea of producing a directional telephone system. A wave of 15 meters was selected, which, while well within the capacity of the tube available, allowed a simple reflector to be used without too large a structure. After several trials, a single tube transmitter was developed taking about 200 watts with a 15 meter wave and giving 1 ampere in the center of a half wave aerial.

After all small practical difficulties were solved, very strong speech was obtained 20 miles away. The strength was such that shadows produced by the small hills and buildings were hardly noticeable, unless the stations were close behind them. The next point was to test the maximum range and, particularly, to find whether such waves would carry over the horizon, and whether there would then be a rapid falling off of the signal strength. During the test following, speech was received 70 nautical miles, and it was proved that there was no rapid loss of the strength after passing the horizontal line.

As a result of these early experiments, it was decided to test the range of a short wave reflector system, solely over land and where no large bodies of waters intervened between the transmitting and receiving station. A short wave reflector transmitter, using a 15 meter wave-length, was erected, and the tests were commenced in February, 1921, to a portable receiver on an automobile. Very good speech was received up to 66 miles, and fair speech at a slightly greater distance. A reflector receiving station was then erected 97 miles from the transmitter.

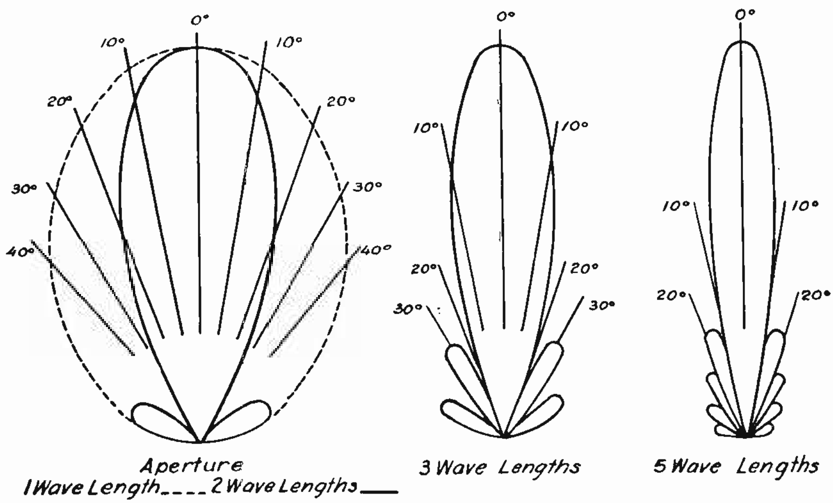

Fig. 2.—Illustrating How Width of Beam Depends on Aperture of Reflector.

The transmitter consisted of two medium size power tubes working in parallel. The power delivered to the tubes was usually about 700 watts (4,000 volts, 175 milliamperes). The aerial wires were a little longer than half a wave-length, and the entire antenna system had a radiation resistance in the order of 90 ohms. The efficiency, input to tubes, to aerial power, was between 50 and 60 per cent, and about 300 watts were actually radiated. With the reflectors up at both ends, speech was very strong and of very good quality. It was usually strong enough to be just audible with a one-quarter to one-half ohm shunt resistance connected across the 60 ohm telephone receivers.

With both reflectors down, the speech was usually only just audible with no shunt resistance connected across the head-telephones. Average measurements indicated that the energy received when both reflectors were up was about 200 times the energy received when not using the reflectors. Thus, to get the same strength without reflectors as with them, a 140 kilowatt tube transmitter of the same efficiency would be required. Local measurements of the polar curve taken near the station show that the electrical field in front of the reflector antenna was increased approximately four times by the use of the reflector, and that the same order of increase was obtained during reception. The increase of energy received, due to the use of a reflector at the transmitting and receiving antennas should, therefore, be four squared times four squared ($4^2 x 4^2$), which equals 256 times.

It was at first thought that it was impossible to concentrate the waves radiated into a beam which would carry over a considerable distance. Some engineers believed that after the beam had been radiated into space, and had traveled for some distance, the concentration or beam effect would be lost; that the waves would gradually broaden, start going in all directions and, gradually, lose the directional or beam effect entirely. However, this theory was disproved by further tests, and in nearly all cases, the received signal was at least 200 times greater by the use of a reflector at the transmitter and receiver.

THE U. S. BUREAU OF STANDARDS TEST

One of the most important problems of Radio communication is the interference between different transmitting stations. The Radio waves which are transmitting Radio telephone messages usually occupy a broader band of wave-lengths than the waves which are transmitting Radiotelegraph continuous wave code signals. There is a definite and not very large limit to the number of Radiotelephone transmitting stations of any considerable power which can operate in a given locality without serious interference, employing the usual type of antennas and transmitting apparatus. In the past, commercial Radio communication has been almost entirely carried on by the use of wave-lengths greater than 200 meters and non-directive antennas which radiated about equally well in every direction. On short wave-lengths, a narrower band of wave-lengths is required to transmit a given sound in Radiotelephony than is required at long wave-lengths.

At the present time, many Radiotelephone transmitting stations are transmitting music and other entertainment broadcast for reception by a large number of receiving stations located in all directions from the transmitting station. For such broadcast transmission, directive antennas are not suitable, but the use of directional antennas for the reception of broadcast Radiotelephone messages offers a means of reducing interference difficulties at a receiving station.

Directive antennas for transmission are, however, desirable for point to point communication; that is, communication from one transmitting station to one receiving station. Transoceanic and much of ship Radio traffic is practically all point to point communication. There are many cases in which communication is desired between points not easily accessible, so that Radio communication is the only practicable means. The use of directive transmission greatly reduces the interference which such communication ordinarily causes. There are some new kinds of point to point Radio communications which are now being developed, such as the transmission of photographs by Radio, and the remote control of mechanisms by Radio, all of which can advantageously be carried on by directive short wave transmission. The enormous increase in the use of Radiotelegraphy and Radiotelephony during the past few years has increased the demand for apparatus capable of being operated with a minimum of interference. Directive transmission should make possible such communication, with a minimum amount of power, as well as with the least interference.

It is also possible to use antennas of marked directional characteristics for reception, and thus to reduce interference in reception caused by undesired transmitting stations.

A serious difficulty in Radio communication is due to "strays," which are stray waves caused by atmospheric electrical disturbances. These disturbances are frequently so severe, particularly during the summer months, as to make satisfactory reception impossible. It is generally true that strays are less severe on short wave-lengths than on long wave-lengths, and at such short wave-lengths as 10 meters, it has been found that strong strays are not ordinarily encountered. Strays of some kind come from a particular direction and can be practically eliminated by the use in reception of an antenna of marked directional characteristics. More serious difficulties are experienced from strays when a large antenna is used; a very small antenna is used for short wave-lengths of 10 meters. For several reasons, therefore, a system of communication on 10 meters, which employs a directional antenna, greatly reduces the difficulties due to strays. The problem of the generation and directive radiation of waves of the order of 10 meters resolves itself into; (1) the development of a

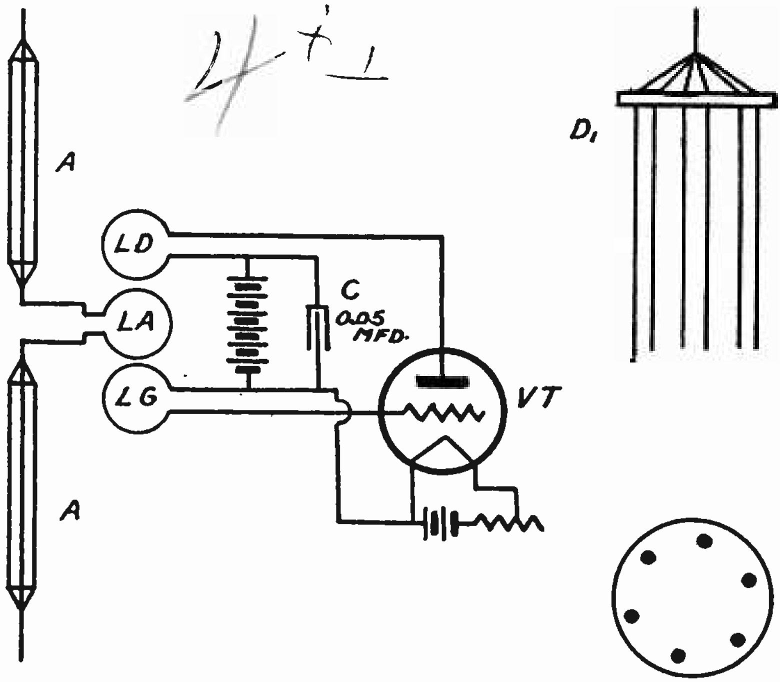

Fig. 3.—Experimental Beam Transmitter Circuit.

10 meter electron tube generator (of suitable power); (2) the development of an efficient directive reflecting system for Radio waves of this wave-length, and (3) the development of a 10 meter receiving apparatus.

A circuit diagram of a 10 meter Hartley type transmitter is shown in Figure 3. The plate coil LD consists of a single turn 17 centimeters in diameter for plate coupling, and the grid coil LG is a similar coil for grid coupling. The capacity between the elements of the tube, together with these coils, forms the oscillatory circuit. It is this internal capacity of the tube which largely determines the upper limit of the frequencies obtainable with a given tube.

The radiating system, (the antenna) shown at A in Figure 3, is coupled to the generating circuit by means of the coil LA, which is similar to the coils LD and LG. The antenna A consists of two sets of vertical wires. Each set consists of six parallel wires arranged in a circle, as shown at D_1 in Figure 3. These wires are spaced about 3 centimeters apart and are 1.8 meters in length.

The Reflecting System

There are several ways of obtaining directive transmission, but one of the most effective methods for short wave-

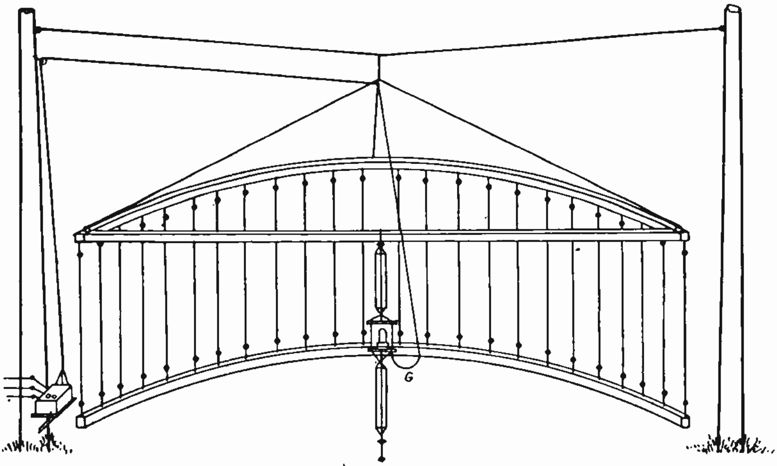

Fig. 4.—Illustrating Construction of Reflector.

lengths consists of the use of a reflector of proper design in the form of a section of a parabolic cylinder. The wave from this form of reflector is somewhat similar to a parallel beam of light which has passed through a slit in an opaque screen. From theoretical consideration for a parabolic cylinder having a line source situated in the focal axis, the reflected rays will all be parallel and will be parallel to the axis of the parabolic cylinder. This ideal result, however, is only approximated in practice.

Figure 4 illustrates the reflector used. It is in the shape of a segment of a parabolic cylinder and is made by suspending forty wires from a frame constructed in the form of a parabola. Each of these wires is tuned to 10 meters and spaced 30.47 centimeters (1 ft.) apart. The frame is suspended from a rope stretched between two poles, so that the reflector may be rotated through 360 degrees. The suspended wires are insulated from the frame and from each other. The focal distance was made one-quarter of a wave-length; that is, 2.5 meters (8 ft. 2.4 in.). With this distance determined, the parabolic frame may be constructed. It is important to have a frame of this shape in order to maintain the proper phase relation and to obtain maximum reflection. The reason for this will be made clear by reference to Figure 5, which may be considered a simplified plan view of Figure 4. The filament rheostat, the ammeters in the filament and plate supply circuits, and the plate and filament supply batteries are mounted on a small unit shown at the left in Figure 4.

In Figure 5, the 10 meter electron tube generator is shown at the focus "O" at a distance of one-fourth of a wave-length from the vertex E. The curve BEJ is parabolic. Each wire along BEJ re-radiates the energy received from O by virtue of the fact that it is tuned to O. Since any distance ODN or OCM is equal to OE plus EO, it is evident that the re-radiation from all the wires along BEJ will reach the aperture BJ in phase with each other. It is evident, therefore, that reinforcement takes place in the direction OP and interference in the direction EQ. Except for leakage, as shown at OK, practically all energy is reflected over a small angle in the direction of OP. By extending the parabola, as shown at A and L (increasing the aperture), this leakage is reduced, thus giving a narrower beam. The type of reflector illustrated was built for experimental use, and while it gives the dimensional values and electrical characteristics, the general mechanical design

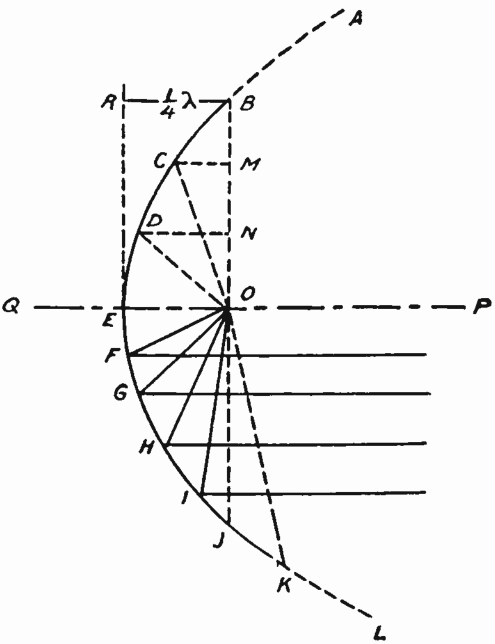

Fig. 5.—Showing How Phasing is Attained.

should be made more rugged for practical use and in permanent installations.

Figure 6 shows the schematic wiring diagram of the receiver used. An external heterodyne was employed so as to receive the continuous wave signals. However, a regenerative set of the usual design which would cause the detector tube of the receiving set to oscillate, may be used and thus eliminate the external heterodyne circuit. The antenna (A, La and A, Figure 6) used in picking up the energy of the receiving apparatus was a single wire tuned to the incoming wave frequency and coupled at the center by means of the coil, La, to the secondary coil, Lg, of the receiving set. The total length of this antenna wire including the single turn coil, La, was

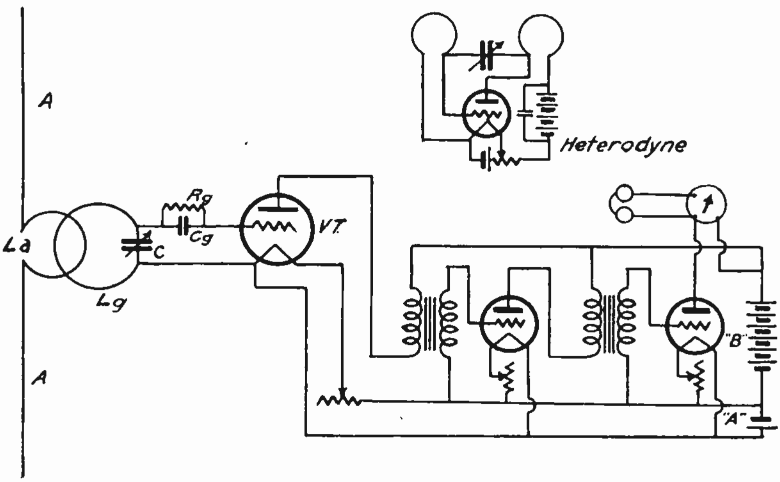

Fig. 6.—Schematic Wiring Diagram of the 10 Meter Receiver Used.

4.37 meters (13 ft. 4 in.). The diameter of the single turn coil, La, was 30.48 centimeters (1 ft.). This antenna was made from a single piece of No. 12 B and S gauge copper wire. The condenser, C (.0005 mfd.), grid leak (2 megohms), and condenser, Cg (.00025 mfd.), and the tube VT were mounted on the support with the secondary coil, Lg, in as close proximity to it as possible. Since this apparatus was attached to the frame supporting the coils La and Lg, it was suspended in the air with it when the signals were being received.

Figure 7 shows a view of the complete receiver ready for operation. No attempt was made to use a reflector system at the receiving end since the main problem was the radiation of a sufficiently narrow band or beam with as little leakage as possible. After all of the constructional details of the transmitter reflector system have been determined, it would be an easy matter to construct a reflector system for the receiver according to the dimensions of the reflector system at the transmitting

Fig. 7.—View of Complete Short Wave Receiver.

end. With the use of such a reflector system at the receiving end, the signal strength would be increased in proportion.

RESULTS

A great many experiments were performed in order to determine the best possible type of reflector. From the results of these experiments, it was learned that the proper length of the reflecting wires must be determined while they are in position on the parabolic frame, as the capacity effect of the neighboring wires made necessary a slightly shorter length of wire for resonance than when they were oscillating. From the data obtained, it was determined that the correct length of the forty reflecting wires should be 4.39 meters (14 ft. 5 in.) and that they should be placed 30.48 centimeters (1 ft.) apart. With this arrangement, it was found that the beam was sufficiently narrow, and that very little radiation took place through the rear of the reflector.

The best results were obtained by increasing the aperture of the reflector to 1.5 wavelengths. In doing this, the para-

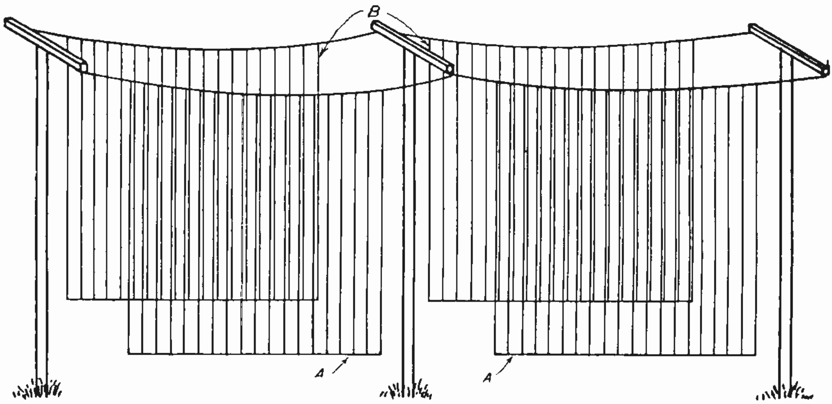

Fig. 8.—Simple Marconi Beam Antenna and Reflector.

bolic frame was extended and ten tuned wires were suspended 1 ft. apart on each extension. This increased the number of reflecting wires from forty to sixty. All of the sixty reflecting wires were 14 ft. 5 in. long. It was determined that this type of reflector gave the best results. There was practically no leakage in the rear of the reflector, and the reflected wave was slightly narrower than with any of the other arrangements.

The results of these experiments prove that certain requirements must be met before efficient directive transmission can be obtained. These are: (1) The source of the wave to be reflected should be placed exactly at the focus; (2) the reflecting wires should be tuned to resonance with the source, and (3) the width of the reflected wave front is dependent upon the size of the aperture employed.

FURTHER DEVELOPMENTS OF THE MARCONI BEAM ANTENNA

During the years 1923 and 1924, the Marconi engineers conducted numerous experiments, which have an important bearing on the present type of installation. As a result of these experiments, an entirely different type of antenna was developed. It was determined that it was not necessary to have a parabolic shaped antenna and reflectors in order to concentrate the outgoing waves into a narrow beam. By properly spacing the reflector wires from the antenna wires, and by using a feeder system which maintained the same relative phase at every point of the antenna wire, a straight antenna could be used and the same results accomplished as when using the parabolic shaped antenna.

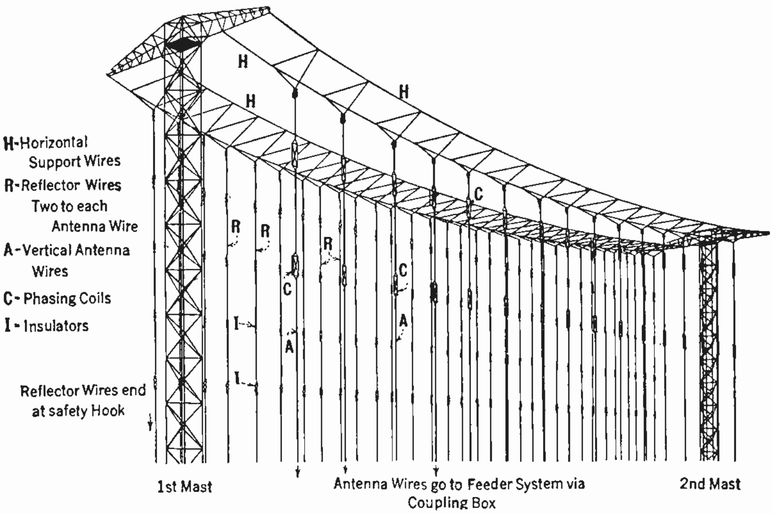

Fig. 9. Courtesy of Radio Broadcast.

Figure 8 illustrates this type of antenna. It approximates as nearly as practicable to a uniform current sheet in which the current is maintained in the same relative phase at every point. It is set up at right angles to the direction it is desired to work. The directional property or degree of concentration of radiated energy of such a current sheet is a function of its dimensions relative to the wave-length and its normal bidirectional. It can be made unidirectional by placing a second similar sheet which acts as a reflector parallel to the first and at the correct distance behind it.

Practically, the aerial consists of a number of vertical wires which may or may not be connected together by horizontal wires. The aerial is fed simultaneously at a number of feeding points by a special feeding system from the transmitter to insure that the phases in all the wires are the same.

A second system of wires placed parallel to the first and at one-quarter of a wave-length behind acts as the reflector and makes the system unidirectional. Figure 9 clearly illustrates the construction of such a system. Figure 10 illustrates the feeder system used. By maintaining the same distance from the transmitter to each antenna wire and in conjunction with the phasing coils, C, as shown in Figure 9, the same relative phase is maintained in all aerial wires. Herein lies the fundamental principle upon which this type of antenna functions.

The system of wires which constitutes the connecting link between the transmitter and the antenna is known as the

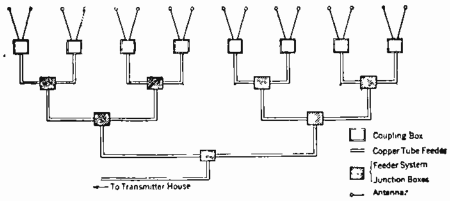

Fig. 10. Courtesy of Radio Broadcast.

feeder system. This system consists of two concentric copper tubes, air insulated from each other to avoid loss. The outer tube is grounded and carried on metal standards a short distance above the ground, while the inner tube carries the current to the antenna. In order to insure an equal amount of current for each of the separate antenna wires, the feeder system is so arranged that the distance which the current has to travel through the feeders is exactly the same for each individual wire in the entire antenna system. In order to prevent the presence of reflected waves in the feeder system which would cause trouble, equalization may be obtained by means of the coupling transformers located in each junction box. (See Figure 10.)

Figure 11 shows a view of part of the feeder system. The copper tubing which constitutes the line between the transmitter and the antenna system, together with one of the junction boxes, is shown in this picture. To the left, may be seen one of the antenna coupling boxes to which two of the antenna down leads are taken. The wooden structures seen dotted about the field in the background are the automatic counterweights which provide a certain amount of slack to the antenna wires when necessary.

The receiving aerial and reflector system have the same general construction as the transmitter. If required, either may be arranged to serve as the transmitter or receiver.

The calculated directional effect of aerials of different widths is indicated below:

Width of aerial in wave-lengths	1	4	20
Approximate horizontal angle within which practically all the energy is confined	180°	30°	6°

The approximate energy magnification, due to the concentration of the energy by the directional effect when using this type of antenna is shown in the table below, which gives the comparative energy available on the receivers, compared with what would be available from an ordinary vertical antenna radiating the same amount of energy.

Type of Aerial.	Approximate Magnification with Similar Aerials at Transmitter and Receiver.
Simple vertical aerial one-eighth wave-length high or less	1
Beam aerial half wave-length high, three wave-lengths wide, plus reflector	350
Beam aerial one wave-length high, three wave-lengths wide, plus reflector	900
Beam aerial one wave-length high, five wave-lengths wide, plus reflector	2500
Beam aerial one wave-length high, twelve wave-lengths wide, plus reflector	14000

There are some general laws governing the beam antenna system just described, which may be stated as follows:

(1) The ratio of the loss by radiation to the loss by ohmic resistance and, therefore, the efficiency, remains constant for all sizes of the aerial at the same frequency. The efficiency of the Marconi System is very high and can be easily of the order of 80 per cent.

(2) The natural decrement of the aerial is very high and remains constant whatever the extension, as the ratio of the inductance to the resistance of the aerial remains the same.

(3) The greatest magnification for a given area of aerial and, therefore, for a given cost, is obtained by having equal areas at the transmitter and receiver. Thus, an aerial of 20 square wave-lengths at the transmitter or the receiver gives a magnification of 200, but if divided into two aerials at the transmitter and receiver, each of 10 square wave-lengths, it gives a magnification of 10,000.

A SHORT WAVE BEAM STATION

The first beam service to be open for commercial purposes was between England and Canada. This recalls the fact that Senatore Marconi's earliest long distance experiments were conducted between these two countries in December, 1901,

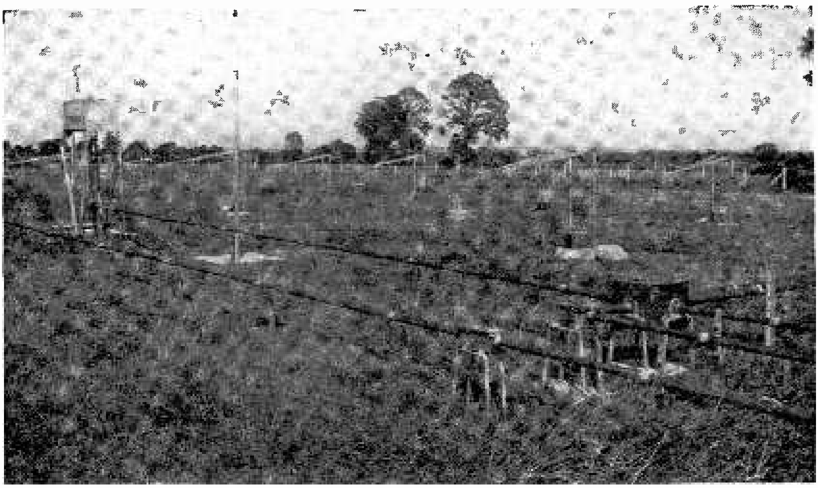

Fig. 11.

and the establishment of the first trans-Atlantic wireless service was between Clifden, Ireland, and Glace Bay, Canada, in the year 1907.

During the preliminary tests, before the stations were open for public service, speeds of 1,250 letters per minute in each direction, equal to 2,500 letters per minute over the whole circuit, were accomplished and the stations were worked without an error for hours on end. Counting every hour of a 7 day test, the average speed of signalling was 650 letters per minute in each direction, or 1,300 letters per minute over the complete circuit.

The Canadian transmitting station is situated about 2 miles south of the city of Drummondville, Quebec, and the receiving station at Yamachiche, about 30 miles north of Drummondville. Figure 12 shows an interior view of the power apparatus room, showing some of the motor-generators used and the main switchboard for controlling the output from the various motor-generators. These furnish the various D. C. voltages for the transmitter, and the A. C. voltages and frequencies required by the rectifiers. Power is obtained from the hydro-electric system of a local power company at 48,000 volts, three phase, and is stepped down to 550 volts, three

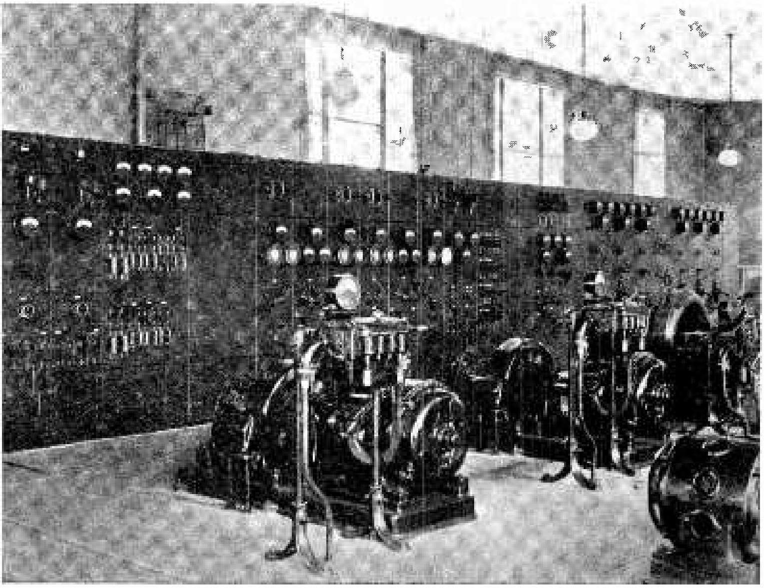

Fig. 12.—View of the Drummondville Transmitting Station, showing Motor, Generators and Switchboard.

phase, at an outdoor substation just outside the transmitting building. This 550 volts, three phase supply, operates the motors of the various motor-generator sets, the generators of these motor-generator sets furnishing low voltage D. C. for the filament lighting of the transmitter, D. C. for charging the master oscillator storage battery, 110 volts D. C. for the exciter and control circuit, 300 cycle single phase A. C. for the main rectifier and 1,000 cycle single phase A. C. for the master oscillator rectifier.

Figure 13 shows a rectifier for furnishing the main 10,000 volts anode D. C. supply to the transmitter and also a separate small rectifier for furnishing anode supply to the master oscillator. Two sets of each of the aforementioned rectifiers are shown. These rectifiers are situated in the apparatus room and furnish D. C. for the filament, 1,000 cycle A. C. single phase for the master oscillator rectifier, and 300 cycle A. C. single phase for the main rectifier.

The D. C. for filament, controls, etc., direct from the switchboard and the high tension direct current from the rectifiers are carried by cables to the transmitter in the transmitting room, shown in Figure 14.

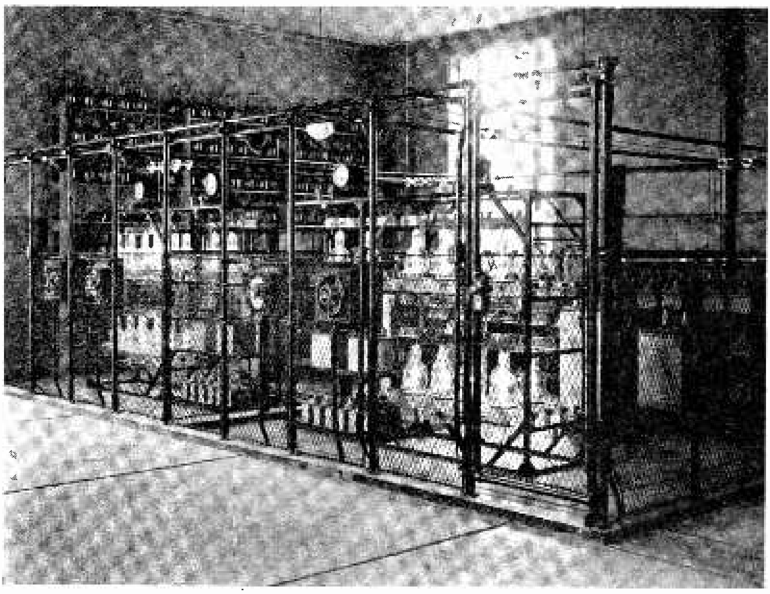

Fig. 13.—View of Rectifiers.

The transmitter consists of the four panels shown in the background and the local controls are contained on and under the tables in the foreground. The panel on the extreme right carries two oil cooled tubes which are so connected and operated by the keying system that they act as absorbers of energy during the period of no signals. This panel operates in the same manner as the modulator panel on a Radiotelephone set, and its inclusion in this installation enables a steady load to be maintained upon the power supply apparatus whether signalling is going on or not, thus avoiding any fluctuations which might arise from varying loads.

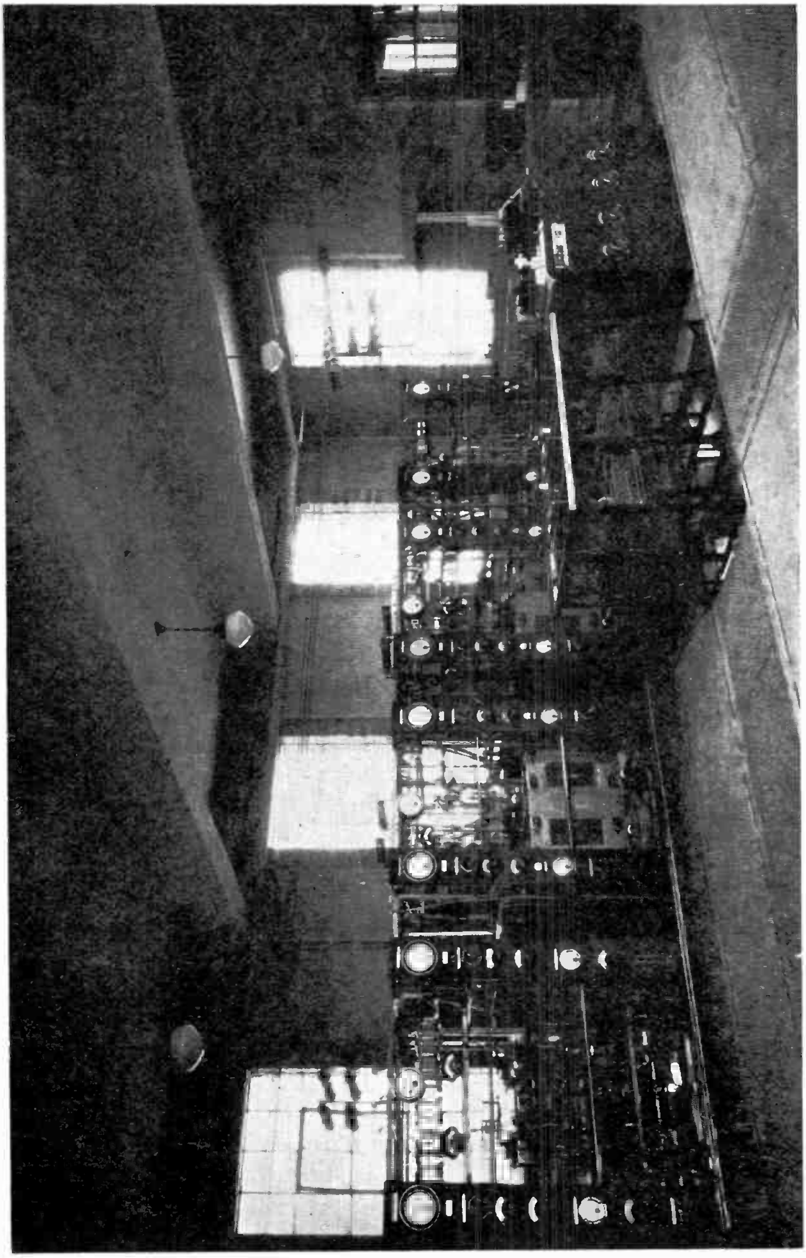

Fig. 14.—Transmitter Room at the Drummondville Station.

The second panel from the right contains the master oscillator and first amplifier in the screened compartment in the lower portion, and the second amplifier on exposed circuit immediately above it. The third panel from the right is simi-

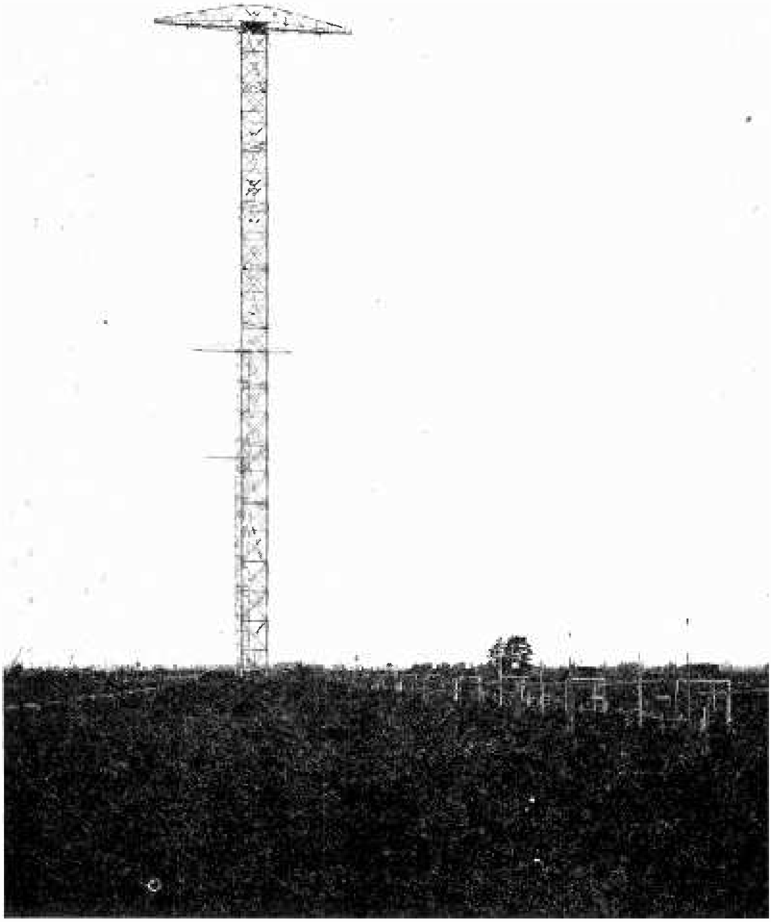

Fig. 15.—View of Antenna and Reflector System.

lar to the second from the right excepting that it is tuned to a different wave-length. The panel fourth from the right, or extreme left, is the third amplifier which operates directly on the aerial through the feeder system. This panel is arranged so that it may be tuned to the wave-length of either of the middle two panels, depending upon which wave-length is being used. When in operation, one of these center panels is not in use.

Air-cooled vacuum tubes are used for the master oscillator and the No. 1 and No. 2 amplifiers. Oil-cooled tubes are used in the main amplifier No. 3. The circuits of No. 2 and No. 3 amplifiers each use two tubes in a balanced circuit arrangement.

The keying relays on the absorber panel are operated direct from Montreal by wired radio.

The high-frequency output from the transmitter is conveyed through the back of the building to a feeder system or special transmission line supported close to the ground. The feeder system consists of concentric copper tubing, the inner tube being insulated from the outer throughout the whole of its length by means of porcelain insulators. The outer tube is directly supported by angle irons and straps and is always directly grounded.

The feeder system is continued for over 1,000 ft. to a point near the aerial system and on the center line of it, and is there branched and sub-divided by special distribution boxes so as to obtain the required number of outlets for the various aerial wires. All these branches are symmetrical and balanced so that the actual physical length of conductor between any aerial wire and the first junction box of the feeder is exactly the same. At each point where the feeder is sub-divided, impedances are introduced so that the load impedance at any junction point is always equal to the surge impedance of the feeder. These precautions insure that all the aerial wires are radiating energy in phase and that loss by reflection on the feeder system is at a minimum.

The aerial and reflector system is shown in Figure 15. The complete aerial consists of a number of independent wires supported in a flat vertical plane by means of horizontal stays or cross-arms. There are sixteen antenna wires and thirty-two reflector wires between each tower. The antenna wires are shown to the right of the towers in Figure 15, and the reflector wires are to the left. Each aerial wire consists of a long single wire with several special inductance coils in series, these coils being used for phasing purposes. Their action is such that the several exposed lengths of aerial wire are radiating energy in phase one with the other.

The vertical plane of aerial and reflector wires extends horizontally a distance of two spaces of the mast line. Provision is made for the use of two wave-lengths on the trans-Atlantic circuit and there are, therefore, five masts which allow two spaces to be utilized on each wave-length. On the Australian circuit, one wave-length is provided for and there are, therefore, three masts. The distance between the masts, which also constitutes the width of each space is 650 feet. The height of the mast on the trans-Atlantic circuit is approximately 300 feet to the cross-arm, and on the Australian circuit, approxi-

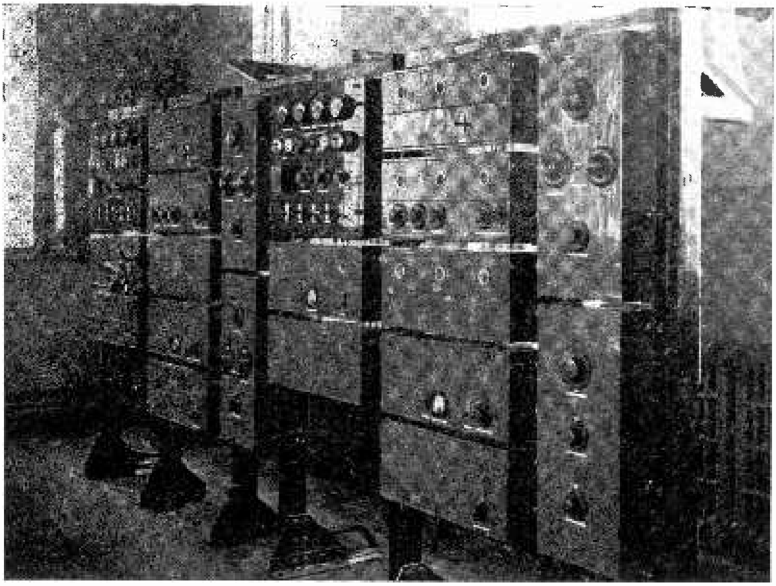

Fig. 16.—Panel Arrangement of Receiving Equipment.

mately 250 feet to the cross-arm. The mast line is laid out perpendicular to the great circle (shortest distance between two points on the surface of a sphere) between the transmitting and receiving stations.

The reflector wires shown on the left of the figure are suspended from the left-hand end of the cross-arm of the masts. The plane of the reflector wires is one-quarter wave-length behind the plane of the aerial wires and it is on that side of the aerial remote from the direction it is desired to transmit. These reflector wires consist of independent lengths insulated from each other and from the ground, and have no physical connection with the aerial or feeder system, acting simply as radiators in space. Energy transmitted backwards from the aerial wires excites the reflector wires and the combination of this excitation and the one-quarter wave-length spacing produces polarization of energy in a forward direction. The foot of each aerial and reflector wire is steadied by a balanced weight and a lever arrangement which permits the aerial to rise or fall with changes in wind pressure and temperature but which anchors the lower point in the horizontal plane. This anchoring arrangement is shown in Figure 15 at the lower end of each of the aerial and reflector wires.

At the Yamachiche receiving station, the aerial system, consisting of reflector wires, aerial wires and feeder system, is identical with that of the transmitting station. Two wave-lengths, occupying two spaces, each on a mast line, are provided for the trans-Atlantic service and one wave-length occupying two spaces on a mast line is provided for the Australian circuit. As in the case of the transmitting station, the mast line is laid out perpendicular to the great circle between the transmitting and receiving stations, the reflector being on that side of the aerial remote from the transmitting station. Received energy at several million cycles per second is collected in phase by all the aerial wires, each of which delivers the energy so collected to the feeder system, and the total carried by the main feeder to the receiving station and equipment.

The panel arrangement of the receiving equipment is shown in Figure 16. There are two separate receiving systems shown, each receiver comprising 3 vertical panels, one unit being for use on the Australian circuit and the other on the trans-Atlantic circuit.

The copper tubes comprising the feeder can be seen just above the panel and behind the right-hand upper corner where they make the right angle bend into the receiver. Each unit embodies special circuits, amplifiers, and filters, whereby the energy is received from the feeder at several million cycles per second and is delivered to the land line through the switch on one of the lower panels at a much lower frequency. The signals are conveyed to Montreal by wired radio at this frequency, where they are rectified, amplified and made to operate automatic recording devices. The system of heterodyning employed at the receiving station is quite unique in that it employs two heterodyning systems, or what is practically the equivalent of two Superheterodynes in series. The energy from the feeder system is fed to the first detector through a very loosely coupled tuned unit. The loose coupling is resorted to in order to cut out interference and reduce the pick-up of static and other noises. The first detector is coupled with an oscillator which changes the wave of approximately 26 meters wave-length over to a wave-length of about 1,600 meters. The signal then goes through a three stage amplifier at this frequency and is again detected. At this point, another heterodyne oscillator is provided and the wave-length changed from 1,600 meters to approximately 10,000 meters. Again, it is amplified through 3 stages and again detected. This second heterodyne may be tuned to an audible note so that the operator may listen in and tune the signals as received through the first part of the receiver. Each stage of amplification is of the push-pull type in order to provide distortionless amplification throughout. The output works through a bridge system which insures the signal strength to be practically the same, no matter what the strength of the incoming signal.

TEST QUESTIONS

Number Your Answers 44 and add your **Student Number**

1. Name two advantages of short wave beam transmission over long wave omni-directional transmission.
2. What is the approximate power used by the omni-directional long wave transmitting stations?
3. What wave-lengths were used by Marconi in his experiments with beam transmission in the year 1916?
4. Draw a diagram of a 10 meter Hartley beam transmitter.
5. Describe the antenna used with the transmitter whose diagram is shown in Fig. 3.
6. Give a brief description of the reflector shown in Fig. 4.
7. Draw a diagram of a 10 meter receiver used for receiving signals from a beam transmitter.
8. What is the size of coil La, Fig. 6?
9. What is the approximate efficiency of the Marconi beam antenna described in this lesson?
10. How are the tubes in the main amplifier of the set shown in Fig. 14 cooled?

RADIO BY MAIL

National Radio Institute

STUDENTS ALL OVER THE WORLD