RADIO BROADCAST

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Linking Continents with Twenty Kilowatts

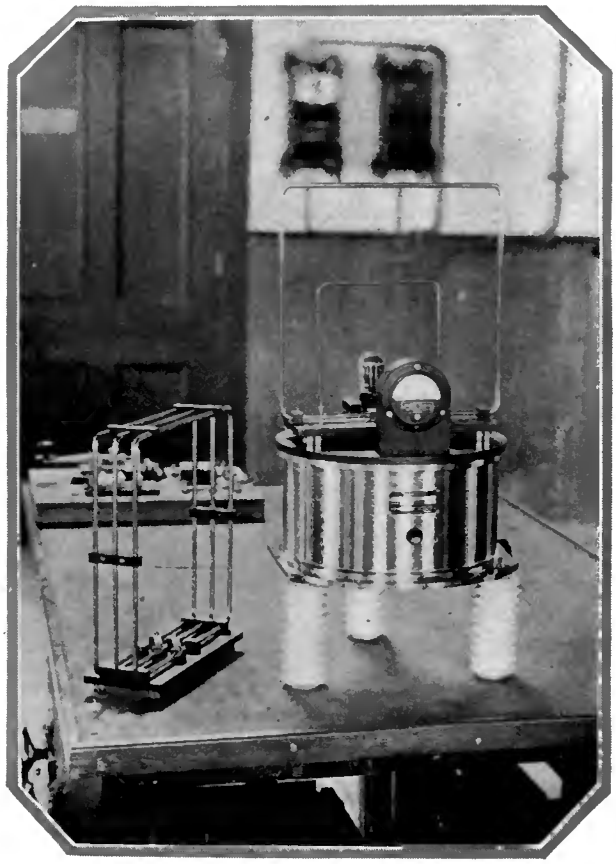
How Britain Is Linking Up with Her Colonies by Means of the Short-Wave Beam System—New Stations Can Handle Five Times as Much Traffic as Long-Wave Stations and Expense Is Lowered—A Description of a Typical Beam Station and the Principles Involved—What Marconi Thinks of the "Ham's" Share in Short-Wave Development

By KENNETH B. HUMPHREY

"I HAVE always felt," said Senatore Guglielmo Marconi in the "James Forrest" lecture given before the Institute of Civil Engineers in London recently, "that wireless waves are far too valuable to be continuously scattered and broadcast equally in all directions instead of being concentrated as much as possible on the station with which one desires to communicate."

"Ten years ago," he continued, "during the War, I began to consider the possible alternative which might be offered by an exploration of the capabilities for point to point communication of those electric waves which had never yet been used for practical radio telegraphy. I mean waves only a few meters in length, and I was particularly attracted to this line of research because I was well aware that with these waves, and with these waves only, it would be possible to project most of the radiation in a narrow beam in any desired direction, instead of allowing it all to spread in every direction.

"There is no doubt that, generally speaking, radio engineers of four or five years ago thought they knew much more about the subject than we think we know to-day. Laws and formulas were announced and accepted showing which wavelengths were best adapted for various distances, and indicating what amount of power would be necessary in order to be able to communicate any given distance. Unfortunately, it soon became apparent that the logical application of these laws and formulas brought us to the necessity of employing, for long-distance transmission, such enormous and expensive antenna systems, and such large amounts of power as to make the method so costly in capital expenditure and operation, that only a very small margin of profit would remain when the system was worked in competition with modern cables and land lines."



A SHORT–WAVE WAVEMETER

This particular instrument is utilized to keep check on the Bodmin short-wave beam station

As long ago as 1913 efforts were made to design long-wave stations which could be used for long-distance communication. It was not until 1923, however, that the British Government finally decided definitely to proceed with a plan of linking up the Dominions with the mother country by means of wireless telegraph stations. The Dominions had been asking for such a service for many years, and when the decision was finally reached by the British Government, the Dominion governments immediately made arrangements for the construction of corresponding stations in their own territories to complete the service. Even while negotiations were under way to provide long-wave stations, Senatore Marconi became convinced, as a result of his experiments, that a new system could be developed which would prove to be better both from a standpoint of effectiveness and cost.

Some courage was necessary to propose a system which might easily revolutionize the whole art of long-distance communication. This too, it must be remembered, at a period when larger and larger long-wave stations were being erected in America and at other points, such as the Lafayette station at Bordeaux, France, the station at Nauen, Germany, and others. But in spite of the opinion against him, Senatore Marconi was able to convince the British Government and the Dominions that the beam system of short-wave telegraphy was entirely practical. The early predictions of Marconi have been justified, and the Government has officially accepted the first link in the chain between England and Canada after a rigid seven days' test.

To get some definite conception of what the inauguration of the new beam system will mean, consider the great long-wave stations which have recently been completed, and which may eventually have to give way to the new competitor. Commercial long-distance radio communication has been accomplished previously by stations employing frequencies from 37.48 up to 9.99 kilocycles (8000 to 30,000 meters), and using several hundreds of kilowatts in power at the transmitting station.

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-foot steel towers, and the length of each antenna is in the neighborhood of three 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 wireless station at Rugby (England) has an antenna 800 feet high supported on 12 masts, and uses about 500 kilowatts of power. The frequency used in transmission is 21.3 kilocycles (14,080 meters).

Buenos Aires, in the Argentine, has an antenna about 680 feet 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 operating in Germany, France, Italy, and other countries.

Contrast the above stations with the modern short-wave beam station having five masts 277 feet in height and using a power of only 20 kilowatts, and a transmitting frequency of 11,500 kilocycles (26.09 meters).

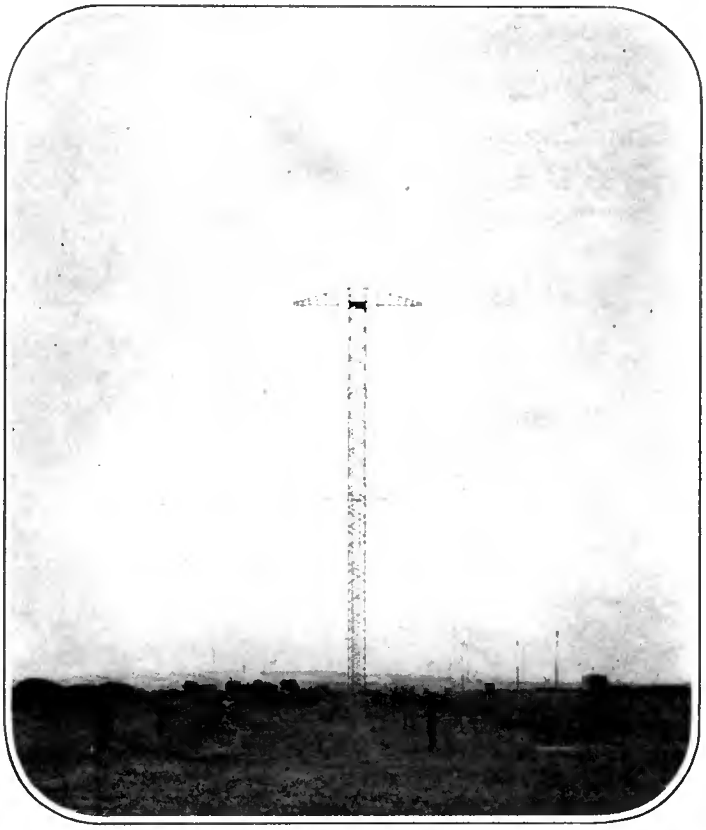
Senatore Marconi said that the *average* speed obtained by the long-wave stations was 20 words a minute for a daily average of 18 hours. The beam stations, during the official tests, averaged at least 100 words a minute for 18 hours a day.

The average 20-word speed of the long-wave stations referred to above, is considerably less than maximum speed, which is said to be 100 words a minute. The maximum workable speed for ordinary telegraphic work on the new "Permalloy" cables is said to be about 500 words a minute. During the tests of the new beam station, a speed of 250 words a minute was maintained for several hours at a time without difficulty.

ADVANTAGES OF THE BEAM SYSTEM

THERE are several distinct advantages in using the short-wave beam system over the long-wave system for point to point communication over long distances:

1. The cost of equipment is less.
2. It is more economical to operate and maintain.
3. The speed is greater.



AT THE BODMIN BEAM STATION

The antenna system for the transmission of directional signals to Canada is here shown. There are five masts, providing four spans of horizontal supporting wires from which the vertical antenna and reflector wires are dropped. Canada, looking at this picture, is "way over" to the right, hence the reflector wires are at the left. The antenna coupling boxes, one for each pair of antenna wires, are shown in the picture, as also is a part of the copper-tubing feeder system

Concentrating the radio waves in a beam instead of allowing them to wander to every point on the earth makes it possible to use only 20 kilowatts of power instead of 200 kw. or more (as in long-wave telegraphy). In spite of using less power at the transmitting station, more power is received at the receiving station, and that is the goal that all radio engineers strive for.

Economical operation and maintenance costs are in direct proportion to the amount of power used and the size of the antenna, both of which are less in beam transmission than for long-wave stations giving the same kind of service.

Another advantage is that the speed in signalling is increased, due to the utilization of short waves. The larger antenna takes an appreciable time to charge and discharge while the smaller antenna takes much less time.

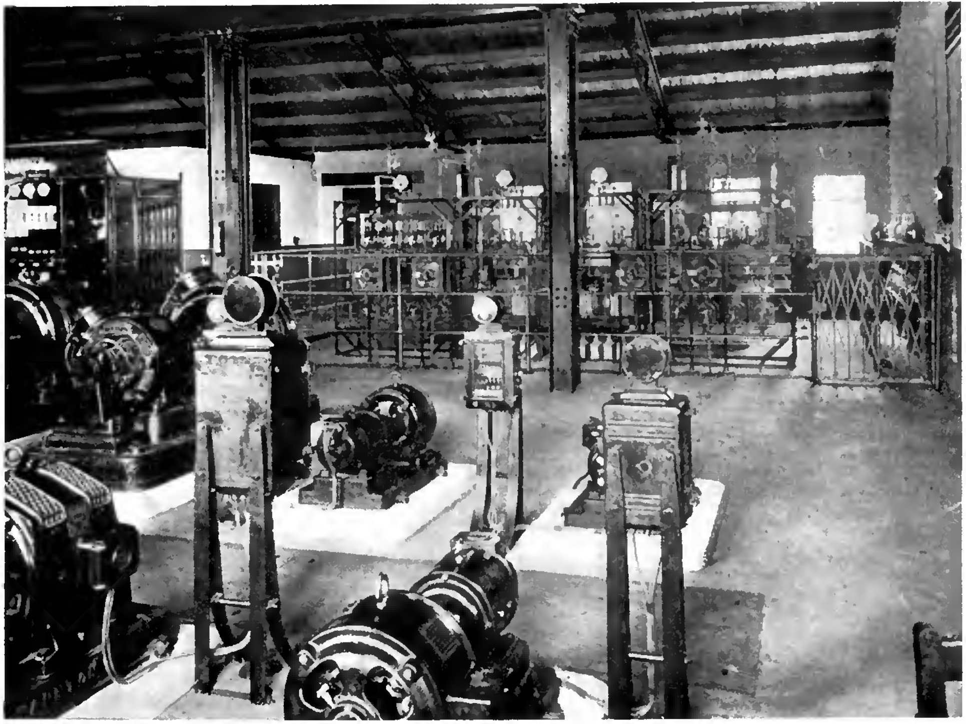
Short waves alone, however, would not accomplish the desired result as far as speed is concerned. It is by the use of reflectors at both sending and receiving ends that the signal is stepped up about a hundred times over that which would be possible with ordinary non-directional sending and receiving. The wave is projected out in a narrow beam and is caught at the receiving station by a similar reflector, and concentrated on the receiving antenna.

It may be calculated, that, to obtain a signal strength of a hundred times that of another signal, the power required would be ten thousand times as large. Considering the ordinary method of signalling without reflectors, the power applied would have to be 20,000 kilowatts instead of the 20 kilowatts actually used in the beam system!

Atmospherics, which have always limited high speed radio sending, do not exist as a serious factor in the new system. Fading is reported to be considerably less in the directional system than in the non-directional system. True, there is still some fading, but because of the increased signal strength, the margin of reliability is increased. During the test week there were only two bad periods where fading was enough to hamper the service. These were during the appearance of very large sun spots, and during an intense display of the aurora borealis in Canada. No interference was experienced on the long waves, but the cables and land lines were seriously affected. It was also noticed that, by changing the wavelength slightly, a path could be found which was practically free from interference.

In the first beam experiments carried out in Italy and in England, the reflectors consisted of a number of vertical wires parallel to the antenna and spaced around it on a parabolic curve of which the transmitting or receiving antenna constituted the focal line, but in the more modern stations an arrangement devised and patented by Mr. C. S. Franklin has been more advantageously employed.

In this arrangement, the antenna and the reflector wires are disposed so as to constitute grids parallel to each other, the antenna wires being energized simultaneously from the transmitter at a number of feeding-points, through a special feeding-



THE MACHINERY HALL IN THE BODMIN STATION
Built by the Marconi Company for the British General Post Office. In the background may be seen the rectifying panels for the Canadian and South African transmitters

system, so as to insure that the phase of the oscillations in all the wires is the same. It has been proved by calculations, and confirmed by experiments, that the directional effect of such an arrangement is a function of its dimensions relative to the wavelengths utilized.

A similar system of antennas and reflecting wires is used at the receiving stations.

THE BEAM ANTENNA SYSTEM

IN A typical short-wave beam station, the Bodmin station, for example, there are five steel lattice masts, each 277 feet high, erected in a straight line at right angles to a line passing through both sending and receiving station. These five masts provide four spans of wire (one between each pair of masts) the sole purpose of which is to support the vertical antenna and reflecting wires. Except as supports, the horizontal spans serve no useful purpose in the actual transmission. At each station there are two distinct transmitters for each point it is intended to communicate with, operating on different frequencies. but whether the second one is to be used as a standby or as a supplementary channel has not as yet been definitely decided. Of the two transmitters, one operates on 11,500 kc. (26.09 meters), while the second will operate on a slightly higher frequency.

Cross-arms at the top of the masts extend for forty-five feet on either side of the vertical, forming a support for the horizontal sustaining wires. For the 11,500-kc. band, there are thirty-two vertical antenna wires, grouped in fours, in a parallel row with which are the reflector wires. There are twice as many reflector wires as antenna wires. The horizontal wire spans between the first second and third masts (two spans) support the antenna-reflector system for the 11,500-kc. transmitter.

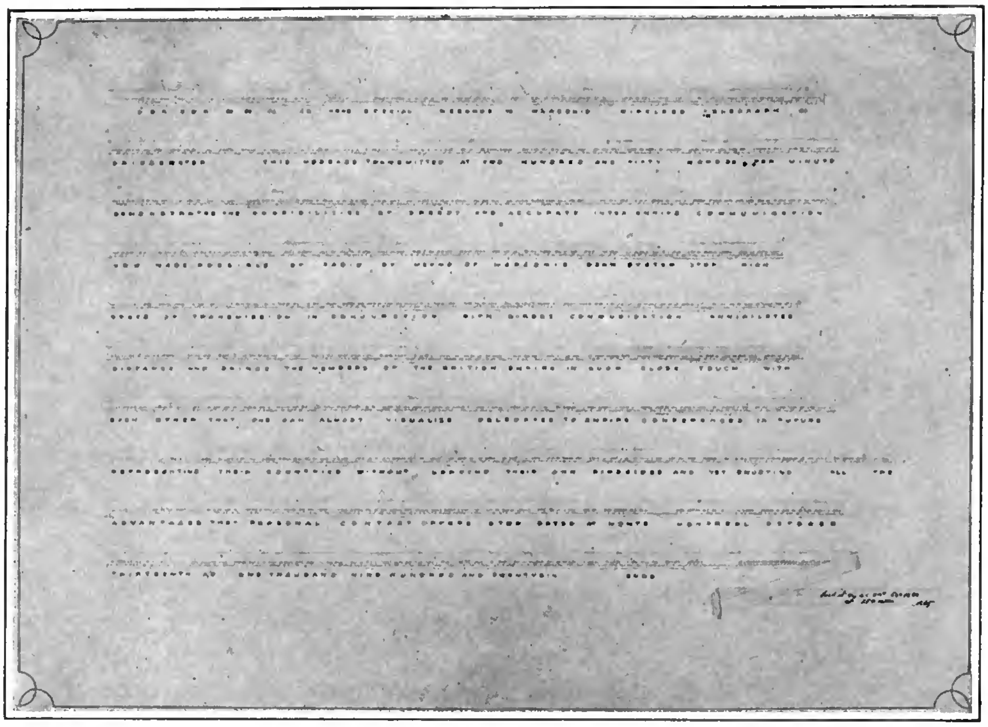
Each of the reflector wires is divided into five complete sections by means of insulators. The reflector wires are placed on that side of the actual antenna wires which is remote from the distant receiving station. Counterweights are attached to the lower ends of both antenna and reflector wires, the object of these being to keep an equal tension on each wire irrespective of changes in wind pressure.

The system of wires which constitutes the connecting link between the transmitter and the antenna is known as the "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 arranged so 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 coupling transformers located at each junction box. A check against any reflected wave in the feeder system is provided by three high-frequency thermo-ammeters wired at three different points 32 feet apart. Actually the three meters are located at one point for ease in reading. With no reflected waves in the system, the meters will all register alike.

Each antenna coupling box is grounded by means of metal plates three feet square, arranged in a circle of 50 feet in diameter. This is for the short-wave antenna. For the long-wave antenna the diameter of the circle is 100 feet. Each transmitter is grounded near the building with a galvanized iron plate six feet by three feet connected to a copper tray placed under the transmitter proper by means of heavy copper bars. All masts and guy wires are grounded, as is the support for the feeder system.

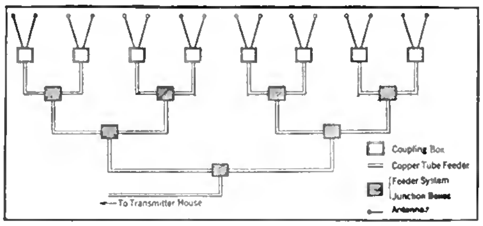
The transmitting apparatus follows closely that used in standard practice.

RECEIVING EQUIPMENT AT THE BRIDGEWATER STATION
There are two distinct receivers shown here. That on the left is for South African signals while the right-hand one is for Canadian signals. As two wavelengths may be used for each transmitting station, each receiver may be tuned to receive either of the two wavelengths



A MESSAGE SENT AT 250 WORDS PER MINUTE

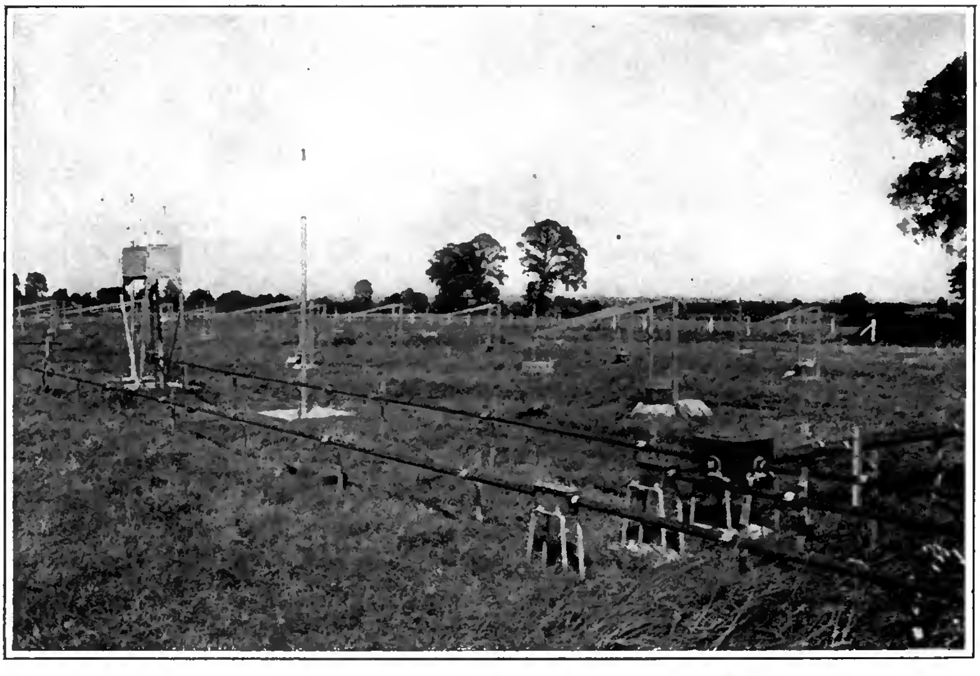
This is an actual record of a message received at a speed of 250 words per minute during official tests of the beam wireless circuit between England and Canada



THE FEEDER SYSTEM

This may be studied in conjunction with the pictures on page 352 and at the foot of this page. The antenna wires are taken in pairs to the coupling boxes and thence to the copper-tubing feeder system. The distance from the transmitter to each antenna wire is the same

Many parts, however, had to be designed especially for the work in hand. Vacuum tubes are used throughout for generating the high frequency current. The main power oscillators are cooled by means of oil and are designed particularly to reduce tube capacity and resistance losses. A master oscillator tube is provided which determines the frequency or wavelength at which the main transmitter tubes will oscillate. The voltage used on the tubes has an approximate range of from 8000 to 10,000 volts, which is supplied by special rectifier tubes.



THE FEEDER AND COUNTERWEIGHT SYSTEMS

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 weird wooden structures, which in windy weather are apt to cultivate bobbing propensities, and which may be seen dotted about the field, are the automatic counterweights which provide a certain amount of slack to the antennas when necessary

The method used in keying, or interrupting the circuit in order to transmit the dots and dashes of the signals, is of interest. When a signal is being sent, the high frequency current is allowed to go out into the antenna, while, when no signal is being sent, the power is absorbed by an equivalent load made up of resistances placed in a small house near the transmitter. This makes it possible to keep the load on the transmitting tubes the same at all times.

The absorption system is controlled by means of vacuum tubes the grids of which are thrown positive or negative by the keying relay through other amplifying tubes.

By using vacuum tubes in place of mechanical relays it is possible to speed up the system to a remarkable degree. Only one small mechanical relay is used to tie up the land line with the transmitter.

Everyone who has followed radio to any extent in the last few years knows something about the super-heterodyne system of receiving signals. The English engineers use this idea in a new way. It will be remembered that the super-heterodyne changes over the incoming signal from a short wavelength (high frequency) to a longer wavelength (low frequency) in order that it may be more easily amplified. It is again detected and operates an audio amplifier.

This system is extended for use in the receivers at the beam stations by using two heterodying systems, or what is practically the equivalent of two super-heterodynes in series. The signal is collected on the antenna, which, being of the reflector type gives a signal of considerable strength, and 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 pickup of static and other noises. This first detector is coupled with an oscillator which changes the short wave of 26 meters (11,538 kc.) over to a wavelength of about 1600 meters (187 kc.). 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 wavelength changed from 1600 meters to 10,000 meters (30 kc.). Again it is amplified through three 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. The output of the receiver operates a high-speed relay which in turn operates the recording mechanism. 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 that the signal strength is practically the same no matter what the strength of the incoming signal.

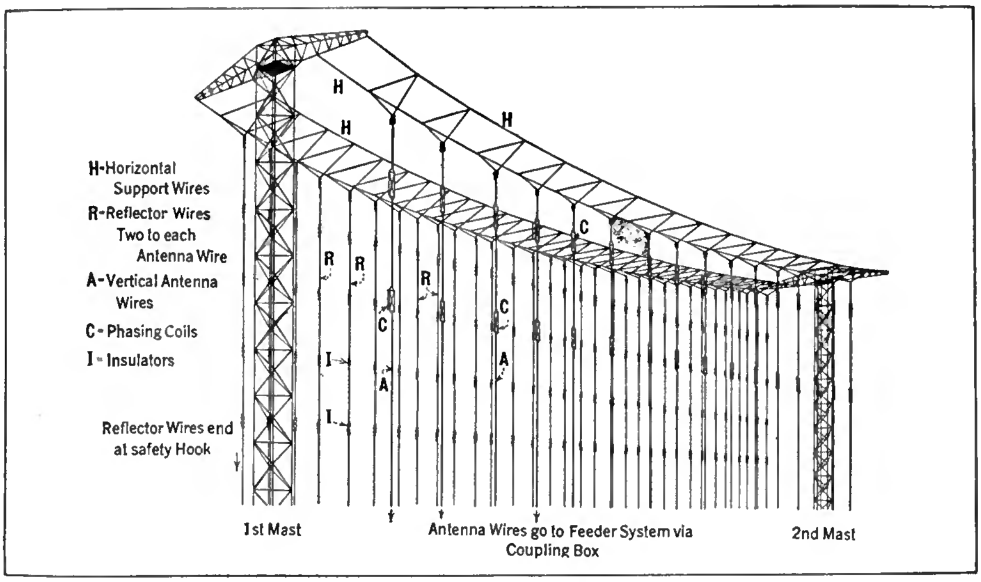
MARCONI PRAISES "HAMS'" EFFORTS

IN THE course of his address on the beam system, Senatore Marconi made some interesting remarks relative to the value of the amateurs' share in short-wave development. "The results obtained by amateurs in the field of short-wave endeavor do great credit to them," he said, "especially if we consider that most amateurs possess only limited facilities for experimental work. It should not be forgotten that amateurs were the first to carry out two-way communication with New Zealand for brief periods. Their observations have often been of value in helping us to arrive at a somewhat better understanding of the very complex phenomena involved, but I think it is sometimes dangerous to attach too much importance to all their observations, especially when they concern what I might term 'negative results.' Only the other day I read a statement by an eminent authority that, according to amateurs' observations, the daylight range of a 100-meter (2998-kc.) wave did not exceed 200 miles, and for a 50-meter (5996-kc.) wave 100 miles. I have carried out tests on a 100-meter wavelength for months on end and have never found its daylight range to be below 1000 miles. With a 47-meter (6379-kc.) wave, which is close to 50 meters, we have never observed any skip distance commencing at 100 miles or at anything like so short a distance. It may well be that some of the observers were not particularly skilled, or were using insensitive receivers or that their stations happened to be situated near buildings or structures which unfavorably affected receiving. I therefore think it would be unfortunate if, in consequence of some reports, the theory of skip-distances should become unduly generalized and extended.

"I have found that, for reliable observations and deductions in regard to the behavior of transmissions over varying distances, there is nothing so good as a receiving station installed on a suitable ship."

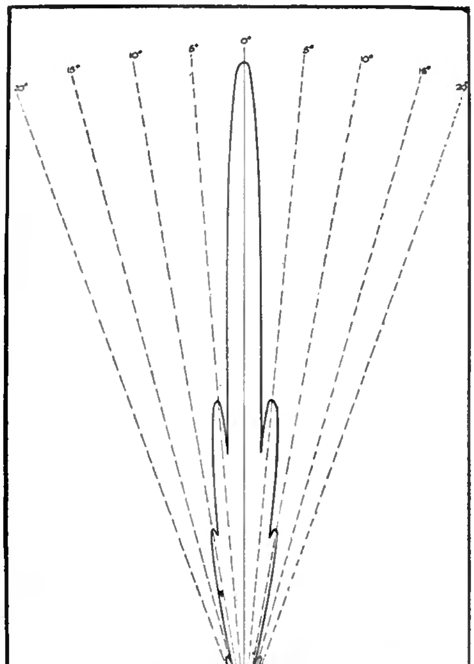
LOCATION OF THE BEAM STATIONS

THE beam transmitting station in Canada is situated at Drummondville, 30 miles east of Montreal, and the receiving station at Yamachiche, 25 miles north of Drummondville. These stations are linked up by land line to the central office of the Canadian Marconi Company in Montreal in the same way that the English stations are linked to the General Post Office, in London. Beam stations are also being erected in Canada for direct communication with Australia, and corresponding beam stations are being built at Melbourne.



THE BEAM ANTENNA SYSTEM

Showing the position of the antenna and reflector wires in relation to each other. The relative location of the insulators, phasing coils, supporting wires, and towers are also shown. There are sixteen antenna wires and thirty-two reflector wires to each span



A POLAR CURVE OF A RADIO BEAM

Showing how the radio wave travels out from the station in a beam instead of being broadcast in all directions

The sites occupied by the beam stations at Bodmin and Bridgwater in England, for communication with Canada, are also utilized for the stations to be used for communication with South Africa. These South African stations are practically complete. Similar stations are being built in England at Tetney, near Grimsby, and at Winthorpe, near Skegness, for communication with Australia and India—the Grimsby stations being transmitting stations and the Skegness stations receiving stations. Corresponding stations are being built in the Dominions near Cape Town, Melbourne, and Bombay. All these stations are in an advanced state of construction, and are expected to be opened within the next few months. This will complete the present Imperial Scheme; but outside of this scheme, the Marconi Company is already engaged on a considerable development of commercial telegraph services on the beam principle. The Company holds a license from the Post Office to conduct wireless telegraph services with certain continental countries and with all other foreign countries outside Europe. In addition to the wireless stations the Company has been operating on these services for some years, it has a beam station nearly completed at Dorchester for communication with North and South America. A corresponding station is also in process of erection at Rio de Janeiro.

Another important development in which beam stations are included—and these are already under construction—is the Portuguese scheme for linking up Portgual and its colonies. Some time ago the Marconi Company obtained a concession from the Portuguese Government for the establishment of wireless telegraph stations in Portugal and its colonies for the purpose of linking them together and establishing wireless communication with other parts of the world. These stations are now being built in Lisbon, in the Cape Verde Islands, in the Azores, and in East and West Africa. When they are completed, wireless services will be established with England, with the principal continental countries, and with South America.

The beam system is not by any means limited to wireless *telegraphy*, according to Senatore Marconi. He feels confident that it can be utilized for placing wireless *telephony* on a much more practical basis than it is on at present, besides helping the systems of picture and facsimile transmission, not to speak of television.

Even for broadcasting he believes it will result in enabling programs and speeches to be transmitted to large portions of the United States, Canada, South Africa, and Australia with much greater strength and accuracy than it is possible to obtain by means of the existing broadcasting systems.