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BY

Senator GUGLIELMO MARCONI,
G.C.V.O., LL.D., D.Sc.,
A Vice-President of the Society.

Reprinted from the Journal of the Royal Society of Arts.

from Canadian Marconi.

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HASTINGS:
PRINTED BY F. J. PARSONS, LTD.,
415-418, BANK CHAMBERS, 329, HIGH HOLBORN, W.C. 1, AND 14, CLAREMONT, HASTINGS.

Results obtained over very long distances by Short Wave Directional Wireless Telegraphy, more generally referred to as the Beam System.

A Paper read at a Meeting of the Royal Society of Arts, on the 2nd July, 1924.

The study of short electrical waves dates from the time of the discovery of electric waves themselves, that is, from the time of the classical experiments of Hertz and his contemporaries, over thirty-five years ago; for Hertz used short electric waves in all his experiments when he conclusively proved that these waves obeyed the same laws as the waves of light in regard to speed of propagation, reflection, refraction and defraction.

I might also, perhaps, recall the fact that when I first came to England, over 28 years ago, I was able to show to the late Sir William Preece, then Engineer-in-Chief of the Post Office, the transmission and reception of intelligible signals over a distance of $1\frac{3}{4}$ miles of a beam system employing short waves and reflectors, whilst, curiously enough, by means of the antenna or elevated wire system I could only get signals, at that time, over a distance of half a mile.

Many years afterwards, through the courtesy of the Post Office, I was favoured with a copy of the Official Report of those early tests, which, from an historical point of view and in regard also to latest developments, makes now most interesting reading.

The progress subsequently made with the long wave system was, however, so rapid, so comparatively easy and so spectacular that it diverted all research from the short waves, and this, I think, was regrettable, for it has only recently been discovered that these waves, which alone can be in practice confined in beams to definite directions, are capable of results unobtainable by the use of the lower frequency system which up to now has held the field for long distance radio communication.

The late Sir William Preece described my early tests at a meeting of the British Association for the Advancement of Science, in September, 1896, and also at a lecture he delivered before the Royal Institution in London on the 4th of June, 1897.

On the 3rd of March, 1899, I went into the matter more fully in a Paper I read before the Institution of Electrical Engineers, to which Paper I would recall your attention as being of some historical interest.

At that lecture I was able to show that it was possible, by means of short waves and reflectors, to project the rays in a beam in one direction only, instead of allowing them to spread all around, in such a way that they could not affect any receiver which happened to be out of the angle of propagation of the beam, and I described tests carried out before the Post Office Engineers at Salisbury Plain, pointing out the possibilities of such a system if applied to lighthouses and lightships, in enabling vessels in foggy weather to locate dangerous points around the coasts.

I also showed results obtained by a reflected beam of waves projected across the lecture room, and how a telegraphic receiver could be actuated or a bell rung only when the aperture of the sending reflector was directed towards the receiver. (Figs. 1 and 2.)

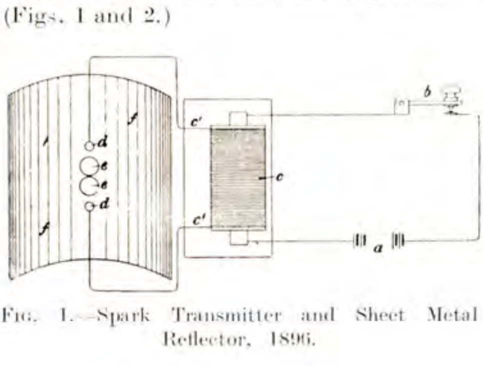

FIG. 1.—Spark Transmitter and Sheet Metal Reflector, 1896.

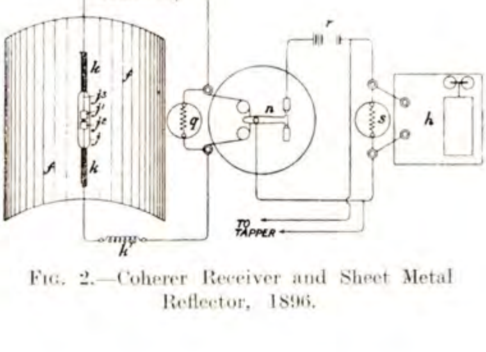

FIG. 2.—Coherer Receiver and Sheet Metal Reflector, 1896.

Since those early tests of over twenty-five years ago, and for a very long period of years afterwards, so far as I can ascertain, practically no research work was carried out, or at least published, in regard to the application of very short waves to radio communication.

Research along these lines did not appear easy or promising; the use of reflectors of reasonable dimensions implied the use of waves of only a few metres in length which with the means then at our disposal were difficult to produce, and up to a comparatively recent time the power that could be radiated by them was small. This, and the supposed high attenuation of the waves over any distance of land or sea, gave results which appeared to be rather disappointing.

Some years ago, during the War, I could not help feeling that we had, perhaps, got into a rut by confining practically all our researches and tests to what may be termed long waves, that is, waves of some thousands of feet in length, especially as I remembered that during my very early experiments, in 1895 and 1896, I had obtained promising results over short distances with waves not more than a few inches long.

The investigation of the subject was therefore again taken up by me in Italy early in 1916 with the idea of utilising beams of reflected waves for certain war purposes, as I was greatly impressed with the advantages which such a system would afford in minimising tapping or interception by the enemy, besides greatly reducing the possibility of interference with our own stations.

At subsequent tests during that year and afterwards I was most valuably assisted by Mr. C. S. Franklin.

The Royal Italian Navy also gave me all possible facilities for the carrying out of my tests in Italy.

Mr. Franklin since then followed up the subject with great thoroughness, and results of his investigations were described by him in an admirable paper read before the Institution of Electrical Engineers on the 3rd of April, 1922.

At a lecture delivered by me before a joint meeting of the American Institute of Electrical Engineers and the Institute of Radio Engineers in New York, on the 20th of June, 1922, in which I described the results obtained up to that time by Mr. Franklin and myself, I felt I could not but express the opinion that it was most regrettable that the study of the characteristics and properties of short waves and their adaptability to directive methods had been so sadly neglected, and pointed out that very many important problems in radio transmission could only be solved by the use of the short wave directional system.

The reflectors now used for this system are not composed of solid sheets of metal, such as those employed in my early tests in 1896, but of a comparatively small number of wires placed parallel to the antenna and spaced around it on a parabolic curve of which the transmitting or receiving antenna constitutes the focal line (Fig. 3), as it was soon ascertained that this was a much more practical arrangement, and that, moreover, much better results could be achieved.

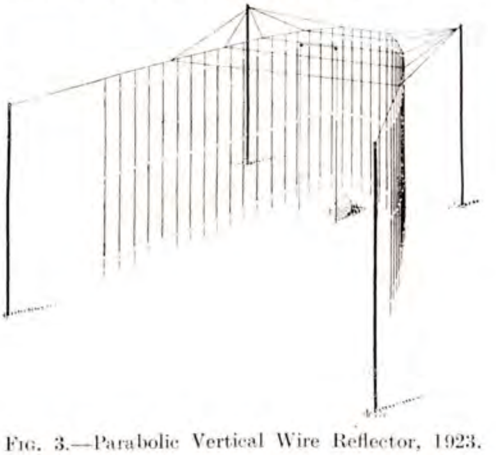

FIG. 3.—Parabolic Vertical Wire Reflector, 1923.

Suggestions for using reflectors of this kind were made by Brown, in 1901, and by De Forest, in 1902, but many essential conditions necessary for efficiency were apparently not realised by these workers at that time, which probably explains why no application of their arrangements was made for practical purposes.

Since 1916 various patents have been taken out by myself and Mr. C. S. Franklin, and in the latest of these Mr. Franklin describes an arrangement in which the antennæ and reflector wires are arranged so as to constitute grids parallel to each other, the aerials or antennæ being energised simultaneously from the transmitter at a number of feeding points through a special feeding system, so as to ensure that the phase of the oscillations in all the wires is the same. It has been proved by calculations confirmed by experiments that the directional effect of such an arrangement is a function of its dimensions relative to the wave length employed. (Fig. 4.)

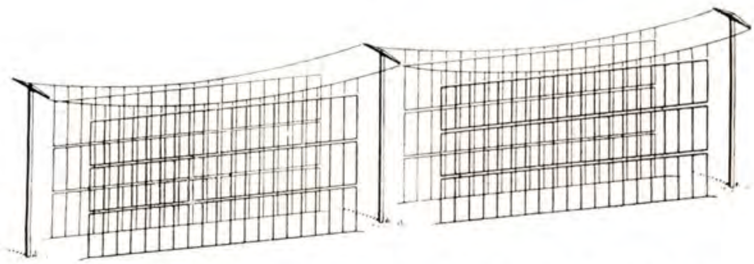

FIG. 4.—Vertical Wire Flat Transmitting Aerial and Reflector, 1924.

During my tests of 1916 I used a coupled spark transmitter and the receiver was a crystal receiver. The reflectors employed were made of a number of wires tuned to the wave used, arranged on a cylindrical parabolic curve with the aerial in the focal line.

Reflectors with apertures up to 3½ wave lengths were tested, and the measured polar curves agreed very well indeed with the calculated values.

The Italian experiments showed that good directional working could always be obtained with reflectors properly proportioned in respect to the wave length employed, and with the apparatus then available the range obtained was six miles.

The tests were continued in Wales at Carnarvon during 1917, and through the introduction of further improvements, with a wave length of three metres, a range of over 20 miles was readily obtained when using a reflector at the transmitting end only.

In 1919 further experiments were commenced in which Mr. Franklin succeeded in using electron tubes or valves for the generation of very short waves, the object then being to evolve a directional radio-telephonic system.

During further tests, and by utilising a 15 metre wave, clear and strong speech was received in Kingston Harbour, at a distance of 78 miles from Carnarvon.

At a later date these tests were repeated over a land range of 97 miles between Hendon and Birmingham. The power supplied to the valves was approximately 700 watts, and the speech received was strong and of good quality.

The great value of the reflectors was demonstrated by average measurements made, which showed that the value of the energy received when both reflectors were used was 200 times that of the energy that could be received without reflectors.

In April, May and June of last year a eries of long distance tests was carried out under my direction between a small experimental transmitting station at Poldhu in Cornwall and a receiver installed on the S.Y. "Elettra."

Mr. C. S. Franklin was responsible for most of the design and operation of the transmitting arrangements at Poldhu, and Mr. G. A. Mathieu was in charge of the receiving apparatus on the yacht, where I also was present during the whole of these tests. Mr. Mathieu was able to make some valuable calculations based on the observed results, especially in regard to the absorption or attenuation of the waves brought about by sunlight.

The principal objectives of these tests were :—

(1) To ascertain the reliability of signals transmitted on approximately a 100 metre wave over considerable distances with or without the use of a transmitting reflector.

(2) To investigate the conditions which affect the propagation of short waves, and to ascertain the maximum reliable ranges obtainable by day and by night in respect to the power and wave length employed at the sending station.

(3) To investigate and determine the angle or spread of the beam of radiation when employing a transmitting reflector, especially with regard to the possibility of establishing long distance directional wireless services.

During the tests carried out on the S.Y. "Elettra" no receiving reflector could be employed, and it will therefore appear obvious that the strength of the received signals and the ranges covered must have been considerably less than could have been obtained had it been possible to use a fixed receiving station equipped with a suitable reflector.

Up to the present time the general impression prevailing amongst most technical experts in regard to the behaviour of short waves is :—

(1) That their range during day time is variable and short.

(2) That the night ranges are exceedingly variable and freaky, and altogether too unreliable to allow of the carrying out of commercial work.

(3) That any considerable amount of intervening land or mountains very seriously reduces the distance at which it is possible to communicate.

The tests carried out between Poldhu and the "Elettra" proved by the definite results obtained that the above mentioned impressions or conclusions must be erroneous, at least in so far as they may concern waves of about 100 metres long, for we observed :—

(1) That the day ranges proved to be reliable and not inconsiderable.

(2) That the night ranges were much greater than anyone, myself included, had anticipated, and no doubt very considerably exceeded the maximum distance to which I was able to proceed with the "Elettra."

(3) That intervening land and large portions of continents do not present any serious obstacle to the propagation of these waves.

In carrying out these tests we discovered that it is by no means correct in dealing with these waves to refer to distances covered during daylight as day-ranges, as the strength of the signals which can be received during the hours of daylight varies definitely and regularly in accordance with the mean altitude of the sun over the space or region intervening between the two stations.

This discovery, based on the observed results makes it safe to infer that our tests, which took place mainly during the months of May and June, and partly within the tropics, were carried out at the most unfavourable time of the year for daylight transmission (as the sun reaches its maximum altitudes during June in the Northern Hemisphere) and over what is a most difficult region.

Perhaps one of the most remarkable scientific results of the experimental work carried out on my yacht was to ascertain quite definitively that the coefficient of the well known Austin Formula for the propagation of the waves was defective when applied to short wave phenomena.

It will be remembered that this absorption factor is an exponential of the form e^{-x}, where -x the negative index is given by Austin as the product of a constant multiplied by the ratio of the distance between the stations and the square root of the wave length used.

Slightly modified values for that constant have been suggested by several scientists during recent years, and a different value has also been suggested for daylight and night communication.*

The results of our measurements and observations are that for short waves of the order of 100 metres this constant must be replaced by a variable, which is approximately a linear function of the mean altitude of the sun calculated on the great circle track between the two stations.

In other words, the coefficient of absorption is a function of the time, the seasons and the relative geographical situation of the stations, and can now easily be ascertained for wave lengths of the order of 100 metres.

Our tests obviously show that short waves behave quite differently in their propagation from long waves, and that the weak period at sunset and sunrise followed by a recovery in signal intensity observed with the long waves over great distances, is not true in the case of short waves.

It also appears that there is probably no sharp limit between short and long waves, and that the change in the behaviour of short waves, of say 100 metres, to that of long waves of, say 10,000 metres, may follow a slow process of transformation.

Very likely over very long distances as the wave length increases there may be a tendency for the signals to recover progressively during the period of no signal, for short waves, and this may form the object of further very interesting investigation.

In regard to the X's and atmospheric disturbances generally, these usually appeared to be, during day time, less severe than those experienced when working with the longer waves up to now employed for practical radio telegraphy.

During night-time, even when receiving at St. Vincent, which is situated at 2,230 nautical miles from Poldhu, and well within the tropics, the strength of received signals was so great that absolutely none of the X's or atmospherics which we there experienced ever approached being able to interfere in any way with the reception of signals or messages from Poldhu.

*Based on the so-called night effect, which I discovered early in 1902. (See Proceedings of the Royal Society, Vol. LXX., by G. Marconi, June 12th, 1902.

During the tests to the "Elettra" on 97 metres wave the Poldhu transmitter consisted of 8 glass valves (standard M.T.2) worked in parallel, the input to the valves being 12 kwtts. The radiation from the aerial was approximately 9 kwtts. The parabolic reflector concentrated the energy towards Cape Verde and gave a strength of field in that direction which would have required a radiation of approximately 120 kwtts. from the aerial without a reflector to produce.

For the purpose of the experiment a special receiver with independent aerial was installed and added to the wireless gear of the "Elettra."

The receiving aerial was a vertical wire, the top of which was at a height of 20 metres above sea level.

The receiver consisted of an aerial circuit, a closed condenser intermediate circuit, a frequency changer circuit, two high frequency tuned amplifications and an auto-heterodyne detecting valve to which could be added two stages of low frequency amplification.

After carrying out a few preliminary tests in Falmouth Harbour on the 11th April, the "Elettra" sailed for Cape Finisterre (Spain).

A first series of tests was carried out without the transmitting reflector.

After rounding Cape Finisterre it was anticipated that the intervening land would have cut off signals during daytime and also would have considerably weakened them during the night.

These expectations were not verified.

Signals during the day weakened according to the distance and the altitude of the sun, but were received right up to Seville (780 miles from Poldhu) although practically the whole of Spain, consisting of over 300 miles of high and mountainous land, intervened between the sending and receiving stations.

The night signals were always so strong as to appear almost as powerful as those received when the yacht was at her anchorage in Falmouth Harbour at only 12 miles from Poldhu.

It should be stated that the yacht, when at Seville, was moored in the Guadalquivir River, in a situation particularly unfavourable for the reception of signals, as the adjacent banks of the river were high and surrounded by trees and buildings.

At Gibraltar (820 miles), notwithstanding the greater distance, a better strength of signals was noticed during the hours of daylight, probably in consequence of the fact that the yacht was anchored in a more open space, and therefore in a more favourable position.

Similar results were also obtained at Tangiers (840 miles) and at Casablanca (970 miles).

I find it almost unnecessary to refer to the night signals, as these were always, and in all places throughout the whole of the cruise, extraordinarily strong and capable of being received at all times without using an amplifier, with the aerial out of tune, or disconnected, or without using the heterodyne.

At Casablanca I telegraphed instructions to hoist the reflector aerials at Poldhu.

The "Elettra" then proceeded to Madeira, but at Funchal was obliged to anchor in a very unfavourable position for the reception of wireless signals from England, being at the far end of the island and immediately under the mountains of Madeira, some of which rise to heights of over 6,000 feet.

On the 17th of May tests were recommenced between Poldhu and the "Elettra," but although the night signals were, as always, extremely strong, I considered it desirable to carry out daylight tests in positions not so completely screened by the immediate vicinity of mountains.

Thus it was ascertained that signals could be received from Poldhu by day up to 1,250 nautical miles when that station was using 12 kwtts. of energy.

On the 21st of May we sailed for St. Vincent, Cape Verde Islands, and although at St. Vincent our anchorage was at a position partly screened by mountains, daylight reception was still possible for a few hours after sunrise and for some time before sunset.

The night signals continued to arrive from Poldhu at all times with apparently unabated strength, notwithstanding that our distance had increased to about double what it was at Madeira, that is, to 2,230 nautical miles.

At St. Vincent, as at Madeira, the Poldhu signals could always be received with the heterodyne or l.f. amplifier switched off.

Mr. Mathieu estimated the strength of the night signals at St. Vincent from 400 to 500 microvolts per metre in the aerial, and with such a strength on the wave length we were using, no trouble was ever experienced in consequence of atmospherics or X's. In fact, for greater convenience, all messages from Poldhu were read with the aerial out of tune or disconnected from the receiver.

At St. Vincent the signals received from the Post Office at Leafield were weak and often unreadable. I therefore gave instructions that all wireless messages addressed to me should be transmitted by our short wave experimental station at Poldhu. No difficulty was ever experienced in the accurate reception of these messages.

As, in consequence of my having to return to England, it was decided not to carry on these tests to still greater distances, I instructed Poldhu to gradually reduce the transmitting power from 12 kwtts. down to 1 kw., but even with this small amount of energy the signals received at St. Vincent were still stronger than would have been necessary for the carrying out of commercial work over that distance.

Mr. Mathieu calculated that the signals would still have been readable at St. Vincent, even should the power at Poldhu have been reduced to 1-10th of a kilowatt.

I might add that the night signals received at St. Vincent, even when Poldhu was using only 1 kilowatt, were much stronger than those received from Carnarvon, or than those which could be received at either St. Vincent or Madeira from any of the other European or American high-power stations.

The signals by night or by day did not appear to be subjected to lengthy fluctuations in strength, nor inclined to give what have been termed freak results. The results obtained could always be repeated over the same distances under similar conditions in respect to the sun's altitude.

Short periodical fluctuations of strength, lasting less than a minute, were constantly observed, but I believe that these variations were mainly caused by slight changes of the wave length determined by imperfections of the arrangements in use at Poldhu, and also by the movements and rolling of the ship at the receiving end.

Although sunrise at St. Vincent occurred about three hours later than at Poldhu, during the period of the tests nothing was observed which would indicate the existence of the weak period so noticeable under similar circumstances in radio reception between Europe and North America.

The results of these tests were sufficient to convince me that it would be possible to carry out reliable commercial services for a large portion of hours out of the 24 over distances of at least 2,300 nautica miles by utilising only about 1 kilowatt of energy at the transmitting stations, and that the practical range of the system, when using 12 kilowatts had not even been approached.

These results were obviously so encouraging that I decided to give the new system very careful study and consideration.

The station at Poldhu was somewhat improved, and the energy employed was increased to about 20 kilowatts.

Since February of this year further series of tests have been carried out over ranges which included the greatest possible distances separating any two places on earth.

A special short wave receiver was installed on the S.S. "Cedric," and reception tests were carried out with Poldhu by Mr. Mathieu during a journey of this vessel to New York and back. No reflectors of any kind were employed at either end.

For the tests to the "Cedric" the wave-length was 92 metres and the transmitter comprised two oil-cooled valves of special design controlled by an independent drive circuit to ensure steadiness of wave-length. The power supplied to the main valves was 21 k.w. giving a radiation of approximately 17 k.w.

These experiments were conducted with the object of supplementing our information on the general behaviour of short waves over long distances.

The results showed that on the "Cedric" signals could be received during daytime up to a distance of 1,400 nautical miles, and it was confirmed that the signals' intensity is symmetrical to the mean altitude of the sun at all times. As a consequence of this, the day limit of the signals on the "Cedric" was greater than what was observed during the cruise of the "Elettra" because the average height of the sun was much less at that time of the year on the particular track of the "Cedric" compared to what it was on the far more southernly track followed by the "Elettra" during the months of May and June.

Signals of great intensity were received at Long Island, New York, during the hours when darkness extended over the whole distance separating the stations, and of less intensity when the sun was above the horizon at either end, the intensity of the signals varying inversely in proportion to the mean altitude of the sun when above the horizon.

According to the measurements carried out Mr. H. H. Beverage, Research Engineer of the Radio Corporation of America, the average strength of the signals at New York was 90 microvolts per metre.

I might mention that a few days prior to the commencement of these tests between Poldhu and the "Cedric," the Chief Engineers of the Amalgamated Wireless (Australasia) Ltd., of the Marconi Wireless Telegraph Company of Canada, Limited, and of the Radio Corporation of America, had been requested by telegraph to attempt to receive the transmissions radiated from Poldhu in their respective countries.

Rather to my surprise, I must admit, Mr. Ernest T. Fisk, the Managing Director of the Amalgamated Wireless (Australasia) Ltd. reported to me by cable that he could receive the Poldhu transmissions at his house in Sydney every day perfectly well from 5 to 9 p.m. (Greenwich) and also that he had received them between 6.30 and 8.30 a.m., informing me also that for most of the time the signals were clear, steady and strong on an improvised receiver consisting of a 2-stage high frequency tuned plate and grid with one rectification. He also added that he had read every word that was sent and that the signals were better than those he had yet received from the high power station at Carnarvon.

These experiments with Australia were continued during the month of May, consistently good results being obtained at two receiving stations situated in the vicinity of Sydney.

It seems obvious, if we consider the position and altitude of the sun, that during the morning period the waves travelled from England to Australia starting in a westerly direction, across the Atlantic and Pacific Oceans, along the longest route, which is approximately 12,219 nautical miles, whilst during the evening period they travelled in an easterly direction over Europe and Asia, along the shortest route, which is about 9,381 nautical miles.

In Canada, at Montreal, reception was found to be possible for 16 hours out of the 24.

These results were so encouraging that I was tempted to try a wireless telephony test to Australia.

With rather experimental arrangements at Poldhu, intelligible speech was transmitted for the first time in history from England to Sydney on Friday, the 30th day of May, of this year.

For the telephone test to Australia, oil-cooled valves were employed for the main valve and for modulating valves. The wave length was 92 metres and an independent drive was employed for controlling the main valves. The total power supplied to the valves was approximately 28 k.w. divided up as follows: 18 to the main valves, 8 to the modulating valves and 2 to the drive valves. No reflector was employed.

A continuous development of the short

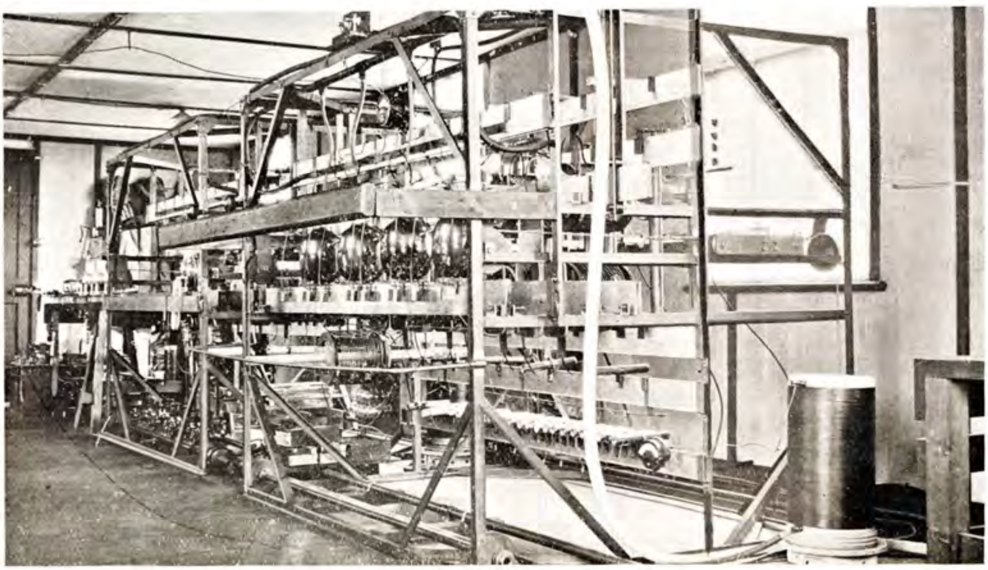

Fig. 5.—Experimental Poldhu Transmitting Plant, 1924.

wave transmitter has been taking place at Poldhu. To utilise considerable power, required the study and development of circuits for paralleling valves satisfactorily, and also the design of special valves. To maintain the wave length steady has necessitated the application and development of an independent drive. These problems have been solved satisfactorily and the production of commercial transmitters dealing with powers up to the order of 50 k.w. now presents no difficulties. Figs. 5 and 6 show the interior and exterior of the small experimental station at Poldhu.

FIG. 6.—Experimental Transmitting Hut, Poldhu, 1924.

It was gratifying to all concerned that the experiment succeeded the very first time it was tried, Mr. C. S. Franklin being in charge of the transmitting apparatus at Poldhu and Mr. Ernest T. Fisk of the receivers at Sydney.

It is also interesting to observe that these extreme distances were obtained without the use of any reflector at either end.

The results obtained between England and Australia easily constitute a record for ratio of distance to wave length, for Sydney, by the shortest route, is approximately 189,000 wave lengths from Poldhu.

In my opinion it appears to have been proved conclusively that adequately designed reflectors, even if of comparatively moderate size, will enormously increase the effective strength of the signals.

This cannot but augment the efficiency of communication, besides increasing the number of hours during which it will be possible to work with very distant countries.

Moreover, the use of receiving reflectors will be of the greatest advantage to practical working, because whilst magnifying the strength of the received waves they reduce all interference whether caused by atmospheric electricity or other stations, unless, of course, the direction from which the interference may be coming happens to coincide exactly with that of the corresponding station.

The energy magnification, due to the concentration of the energy by the directional effect, has been carefully calculated by Mr. Franklin, and tests carried out at Poldhu have fully confirmed his figures.

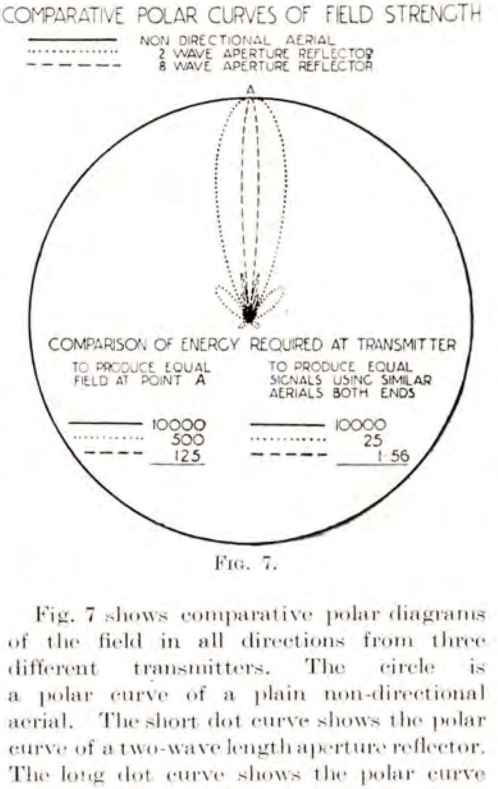

FIG. 7.

Fig. 7 shows comparative polar diagrams of the field in all directions from three different transmitters. The circle is a polar curve of a plain non-directional aerial. The short dot curve shows the polar curve of a two-wave length aperture reflector. The long dot curve shows the polar curve of an 8-wave aperture reflector, such as we propose to use for practical purposes.

The case which was tried experimentally at Poldhu was an aerial and reflector ½ wave high 3 waves wide, the aerial being fed at four points with a cable feeder system. The horizontal polar magnification figure of about 30 was found.

Mr. Franklin has formulated some general laws regarding these aerials, 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. This efficiency figure is very high and can easily be of the order of 80%.

(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, 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 transmitter and receiver gives a magnification of 200, but if divided into two aerials at transmitter and receiver, each of 10 square wave lengths, gives a magnification of 10,000.

(4) For a given area of aerial at the transmitter and receiver, the magnification goes up as the fourth power of the wave frequency used. Thus, assuming aerials 1 kilometre wide and one hundred metres high at transmitter and receiver, these would each be 10 square wave lengths for 100 metre wave and would give a combined magnification of 10,000. For half this wave length (50 metres) each aerial would be 40 square wave lengths and would give a combined magnification of 160,000.

Up to what ranges this fourth power law can be effective in compensating for the greater attenuation of the shorter wave has yet to be ascertained.

The energy capacity of these aerials is enormous and they could never conceivably be worked to their limit. It would be quite possible practically to superimpose several waves and thus several services on the same aerial.

It should not be lost sight of that very high speeds of working appear to be possible only if short waves are employed, whilst speeds of the same order are quite unattainable with the long waves now in general use for long distance radio communication.

I might, in other words, state that there exists no theoretical reason why with a frequency of 3,000,000, such as is the frequency of oscillation of a 100 metre wave, the speed should not be one hundred times as great as the speed attainable with a frequency of 30,000, which represents the frequency of a wave length of the order of those which it is proposed to use for the Imperial Stations.

Between the 12th and the 14th of June (both inclusive) of this year, some further important tests were carried out between Poldhu and a small receiving station at Buenos Aires in the Argentine, the distance between the two points being 5,820 nautical miles (10,780 kilometres).

For this radio-telegraphic test the wave length was 92 metres and the power to main valves was 21 k.w. This gave a radiation of 17 k.w. The parabolic reflector was employed to concentrate the energy towards South America, and gave a strength of field in that direction which would otherwise have required a radiation of approximately 300 k.w. from the aerial without reflector to produce the same effect.

Although many of the arrangements employed were far from perfect, very strong signals were received for over ten hours each day at Buenos Aires.

Messages were sent by the Argentine Minister of Agriculture, Dr. Le Breton, who happened to be in London, to the Minister of War, General Justo, in the Argentine, and every message transmitted was correctly received in one transmission.

At the conclusion of the tests we received a communication from the Argentine Committee, representing the wireless interests in the Argentine, who are conducting the wireless telegraph services through their super-power station with Europe and the United States of America, to the effect that the signals from Poldhu transmitted by this new system were received at Buenos Aires with such regularity and extraordinary strength as to permit a service being conducted at any speed, and expressing the opinion that the Argentine station should be immediately equipped with the new system, which, they are confident, will handle more than double the traffic in six hours than they are now able to handle in twenty hours with their present super-power station. Excellent results were also obtained at Rio in Brazil. (Fig. 8.)

All these results, many of which have greatly exceeded my expectations, convince me that by means of this system economical and efficient low power stations can be established which will maintain direct high speed services with the most distant parts of the globe during a considerable number of fixed hours per day.

I am further of the opinion that by means of these comparatively small stations a far greater number of words per 24 hours could be transmitted between England India and her distant Dominions than would be possible by means of the previously planned powerful and expensive stations.

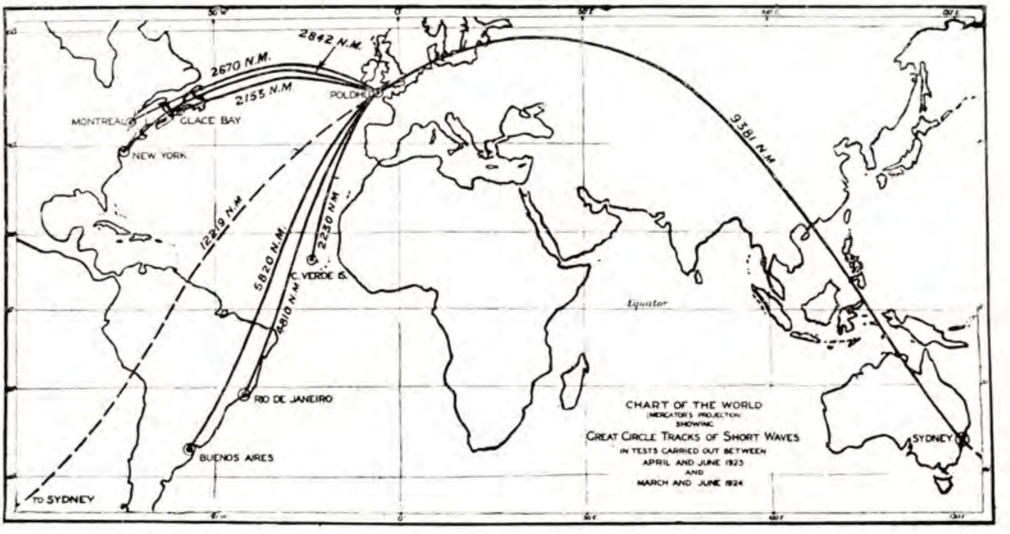

Fig. 8.

Another particular advantage of this system should not be overlooked. As distant stations situated only within a certain angle or sector of the beam are enabled to receive, this condition brings about a comparative privacy or secrecy of communication unobtainable with any other system of radio communication, and this may prove to be of the greatest value in war time, besides considerably increasing the number of stations it will be possible to work, by reducing the possibilities of mutual interference between them.

The comparative economy in capital cost of these stations, the small amount of electrical power which need be employed, together with the capability of working at very high speeds, should make it possible to bring about a substantial reduction in telegraphic rates. The importance of this to the Empire must be obvious.

I wish to take this opportunity of expressing my high appreciation to Mr. C. S. Franklin for all the valuable work he has carried out in order to make this system a practical success, and also to Mr. G. A. Mathieu for his practical and theoretical assistance.

I also wish to thank Mr. Ernest T. Fisk, the Managing Director of the Amalgamated Wireless (Australasia) Ltd., Mr. H. H. Beverage, Research Engineer of the Radio Corporation of America, Mr. J. H. Thompson, Chief Engineer of the Marconi Wireless Telegraph Company of Canada, Ltd., Commander J. Lloyd Hirst, Marconi's Wireless Telegraph Company Ltd.'s Representative on the Commercial International Committee in the Argentine and Mr. P. Eisler, Manager of the Cric Construction Co., Ltd., contractors for the High Power Stations of the Commercial Radio International Committee in Brazil, for their most valuable co-operation in arranging at very short notice to successfully receive in their respective countries the signals transmitted from Poldhu.