Radio Communications.[1]

By Senatore G. MARCONI.

I HAVE always attached considerable importance to the problem of a practical directive system of radio communication. During my earliest experiments carried out in England more than twenty-eight years ago, I was able to show the transmission and reception of intelligible signals over a distance of 1¾ miles by means of an elementary beam system employing very short waves and reflectors, whilst, curiously enough, by means of the antenna or elevated wire system, utilising much longer waves, I could only at that time get results over a distance of half a mile.

The progress made with the non-directional long wave system was, however, so rapid and the results so immediately applicable to practical purposes, that it very soon became, and still remains, what might be called the standard system. It is regrettable that the study of short waves was neglected for a long period of years, for these waves, which, so far, are the only ones that can be confined to narrow beams, are also capable of being employed to give practical results unobtainable by the lower frequency system, which, up to now, has held the field for long-distance communication.

When during the War in 1916 I took up the systematic study of short waves, considerable doubt existed in my mind, and in that of other workers, as to whether the range of these waves might not prove to be too small for practical and useful purposes, particularly during daytime, if they might not be altogether too untrustworthy, and also as to whether large stretches of land, and particularly mountains, would not present absolute obstacles to their transmission over long distances.

In 1920 experiments were carried out by Capt. H. J. Round with duplex telephony on a 100-metre wave between Chelmsford and Southend, and the experiments were so successful that early in 1921 two stations which had been erected at Southwold and Zandvoord on the Dutch coast were put into commission experimentally, Southwold station utilising about 1 kilowatt to the aerial. Experiments were carried out, transmitting from these two stations to Norway in August 1921, and at Christiansund day and night telephony was easily received from both stations. At Christiania, about 700 English miles distant, very loud and constant signals were received during the hours of darkness and in the daytime on certain days, apparently when the barometer was low.

During these experiments the curious night distortion of telephone signals was discovered, particularly when transmission was overland, the major cause of which has more recently been discovered by Capt. Round in his work on broadcasting. Later, the results of these tests were merged into the general short-wave beam experiments.

During the tests carried out on the steam yacht *Elettra* in the spring and summer of 1923, I was able to discover that the short wave I was then using could not only cover great distances by day, and much greater distances by night, but that it was also quite trustworthy and that, moreover, large parts of continents and ranges of mountains did not materially reduce their working distance.

A series of tests was for the first time carried out with short waves over what might be termed world-wide distances during the winter, spring, and summer of this year, between Poldhu in Cornwall and receiving stations situated on ships at sea and also at such places as Montreal, New York, Rio de Janeiro, Buenos Ayres, and Sydney (New South Wales, Australia). All these tests proved to be successful, including the first telephonic communication with Australia ever realised, although the amount of power utilised at the sending station never exceeded 20 kilowatts. Very strong signals were obtained at all these places during the hours when darkness extended over the whole distance separating each of them from Poldhu, and weaker signals for a few hours when the sun was about 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. Although the signals were received with great strength at New York, Rio, and Buenos Ayres during the time when darkness spread over the whole or at least the major part of the great circle track separating these places from Poldhu, no signals at all were ever received, during these tests, when the same track or part of space was all, or substantially all, illuminated by the light of the sun.

While this limitation of the period of working to practically the hours of darkness constituted an undoubted disadvantage, still the economical advantages, together with the trustworthiness and possibility of working this system at far greater speeds than would have been feasible with the well-known high-powered long-wave installations, went far to convince me that the short-wave beam system would be capable of transmitting a far greater number of words per 24 hours between England and far-distant countries, such as Australia, than would be possible by the comparatively powerful, cumbersome, and expensive stations actually in use, or which were planned to be used, for Imperial commercial communications. It is a satisfaction to me to be able to state that the stations intended for this purpose in England and others to be installed in the principal Dominions and far-distant countries will all be on the beam system.

Commencing in August of this year, a further series of investigations was carried out between Poldhu and the yacht *Elettra*, the object being to endeavour, if possible, to find means of overcoming the limitation of working hours brought about by daylight, and also to test whether the effect of the reflectors would give the expected increase of signal strength over long distances. The yacht proceeded to Spain, then to Madeira, and afterwards to Italy. From Naples we sailed for Beyruth in Syria, touching at Messina and Crete, returning to Naples via Athens.

At Madeira it was ascertained that a reflector at the transmitting station increased the strength of the received signals in accordance with our calculations, but that, notwithstanding this increase of strength, when using a 92-metre wave, the daylight range was

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only very slightly augmented. Comparative tests were carefully carried out with waves of 92, 60, 47, and 32 metres also at other places in the Atlantic and Mediterranean.

These tests enabled us to discover that the daylight range of practical communication over long distances increased very rapidly as the wave-length was reduced, the 32-metre wave being regularly received all day at Beyruth, whilst the 92-metre wave failed to reveal itself for many hours each day even at Madeira, notwithstanding the fact that the distance between Poldhu and Madeira is 1100 miles, entirely over sea, whilst that between Poldhu and Beyruth is 2100 miles, practically all over mountainous land. Our observations went to confirm the fact that for waves between 100 metres and 32 metres the daylight absorption decreased very rapidly with the shortening of wave-length.

These results were so interesting and satisfactory that I immediately decided to try further tests over much greater distances. In October of this year, transmission experiments were carried out on a 32-metre wave from Poldhu to specially installed receivers at Montreal, New York, Rio, Buenos Ayres, and Sydney (Australia). Although the available power utilised at Poldhu was only 12 kilowatts, it was at once found possible to transmit signals and messages to New York, Rio, and Buenos Ayres when the whole of the great circle track separating these places from Poldhu was exposed to daylight. During a complete day transmission at fixed intervals carried out last October with Sydney, New South Wales, that station received the Poldhu signals for 23½ hours out of the 24, and a 48-hour test which was only completed on December 10 fully confirmed the result.

The tests from England to places situated south of the equator, such as Sydney, Buenos Ayres, Rio de Janeiro, and Cape Town, are particularly interesting for the reason that the waves have always in these cases to traverse what may be called a summer zone. They are therefore subjected to an averaging effect of conditions, which can never possibly exist when the transmissions take place only between stations situated in the northern or southern hemispheres. During November some successful receiving tests were carried out in England, from a low power transmitting station in Australia utilising waves of 87 metres. During the present month of December, trials have been continued with Canada, the United States, Brazil, the Argentine, and Australia, and also, for the first time, with Bombay and Karachi in India and Cape Town in South Africa. The power utilised at the Poldhu station during all these tests was 15 kilowatts.

The results have fully confirmed my expectations in regard to the behaviour of the various wave-lengths over such great distances, and I have no doubt that the information gained will render possible the installation of comparatively low power stations capable of establishing and maintaining commercial services by day and by night between England and the most distant parts of the globe.

The low cost of this system both in capital and running expenses, compared with that of the existing type of stations, must prove to be very great, and should bring about the possibility of a reduction in telegraph rates for all long-distance communications, besides making direct communication with some of the smaller outposts of the Empire commercially remunerative. Already the size and power of some of the most modern long-wave stations was becoming a serious question from a financial point of view. The newly equipped station at Buenos Ayres, for example, which was designed primarily for communicating with Europe over a distance of about 6000 miles, employs 800 kilowatts and an aerial supported by ten towers, each 680 feet high. This station usually works on wave-lengths of about 12,000 and 16,000 metres. Another example is the British Post Office station which is being erected near Rugby, which, when completed, will employ 1000 kilowatts and an aerial supported by 16 towers, each 820 feet high, while the station being erected in the Union of South Africa was designed on a similar gigantic scale.

I am now firmly convinced that the beam stations employing only a small fraction of this power and much lower and fewer masts will be able to communicate at practically any time with any part of the Empire, and I cannot refrain from expressing my strong personal opinion that these powerful long-wave stations will soon be found to be uneconomical and comparatively inefficient in so far as long-distance commercial communications are concerned. Although we have, or believe we have, all the necessary data for the generation, radiation, and reception of electrical waves, as at present utilised for long-distance communications, we are still far from possessing anything approaching an exact knowledge of the conditions governing the propagation of these waves through space. These results indicate quite definitely that the well-known Austin formula is inapplicable to these waves. Another formula will have to be devised, based on the results of further investigations.

Reflectors of practical and economical dimensions are only efficiently applicable when short waves are used, and, although very long distances have been covered by these waves without the use of directional devices, I am convinced that these will be found to be essential for ensuring the carrying out of commercial high speed services. The disadvantageous effect called "fading" is sometimes a source of serious trouble when receiving signals transmitted by means of short waves, although much less serious than when waves of several hundred metres in length are employed. According to our experience, the use of reflectors diminishes fading, and also tends to overcome its effects by enormously increasing the strength and therefore the margin of readability of the received signals.

Increasingly large and expensive reflectors could, of course, be used with longer waves than 100 metres, but the results of all recent tests seem to indicate that the shorter waves present the greatest advantages, one of the most important being that their reception is very much less liable to interference by the effects of atmospheric electrical disturbances, or "X's."

If these waves are destined to carry a considerable part of the most important long-distance telegraphic traffic of the world, it may well be necessary in the near future, by international legislation, to regulate their use and safeguard them from preventable interference.