on the calculation of absolute magnitudes of stars as determined from the apparent magnitudes (which are known) and from the trigonometrical parallaxes (also known) obtained from one or other of the methods previously described. The equation for this computation is as follows:

$$\text{Absolute Mag.} = \text{Apparent Mag.} + 5 + 5 \log (\text{Parallax}).$$

Stars of the same type of spectrum but of different absolute magnitudes are then compared with one another and the relative intensities of selected pairs of lines carefully measured. Curves are then drawn showing as ordinates the observed differences of intensities for each selected pair of lines, and as abscissæ the absolute magnitudes.

With these data it is a simple matter to determine the parallax of any star. Thus, it is only necessary to (1) determine first its type of spectrum, (2) measure the differences of intensities of certain lines in it and refer these values to the curves for that type; the next step is to (3) note from the curve the corresponding absolute magnitude, and lastly (4) determine the parallax from this absolute magnitude by means of the same formula as given above but arranged in a different order, thus:

$$5 \log (\text{parallax}) = \text{Absolute Mag.} - \text{Apparent Mag.} - 5,$$

in which all the members on the right-hand side of the equation are now known quantities.

Thus a single photograph of the spectrum of a star is sufficient for the determination of the star's distance. Naturally greater accuracy is obtained when more than one photograph is examined and several pairs of lines in them are used, but this involves very little extra labour.

The rapidity with which the determinations of parallax can be secured, when once the fundamental curves are formed, is far in excess of that of the older methods. The large powerful instruments of the present day are capable of photographing the spectra of very faint stars, so that a rapid survey of the whole heavens, at any rate to stars of about magnitude 6·5, will be accomplished in the near future.

At the recent meeting of the International Astronomical Union in Rome, great attention was paid to organising this work on an international basis. The Parallax Commission pointed out that there is a large amount of latent information regarding stellar distances in the long series of spectrograms obtained for other purposes at many observatories, and it is to be hoped that these data would be utilised.

A year ago the spectroscopic determinations of parallax were confined entirely to the United States at the Observatories of Mount Wilson and Harvard College. The Astrophysical Observatory at Victoria, B.C., now proposes to examine their slit spectrograms for this purpose.

In this country the only observatory occupied at present with this work is the Norman Lockyer Observatory at Sidmouth. For more than a year the large collection of spectrograms has been undergoing measurements in this connexion, and a large number of new photographs has been taken. An interesting point in this observatory's work is that the measurements of the intensity differences between pairs of lines are being determined by a method originated by the writer, which is different from either of those used at the American observatories. Thus an independent check on the American results is rendered possible.

It is necessary to point out, however, that this research on so large a scale could not have been undertaken had it not been for the opportune assistance rendered by the Department of Scientific and Industrial Research. This Department appointed Mr. W. B. Rimmer, D.I.C., in July 1921 as a research assistant, and his appointment was due to terminate towards the latter end of this year. It is with very great satisfaction that it may now be stated that it has been extended to September of next year. The work is so far advanced that now most of the fundamental curves are completed. It is hoped, therefore, to publish shortly the spectroscopic parallaxes of about 500 stars, followed after a short interval by another 500.

It is satisfactory, therefore, to record that in this new impetus given to the investigation of the distances of the stars, this country is taking a part, and it is hoped that other observatories here which have useful material will join in and discuss it from this point of view.

This line of research should also provide an interesting field of work for the amateur astronomer. The instrumental equipment required need be only on a moderate scale, for a five-inch telescope, fitted with a suitable prism, would meet the case, if a larger one were not available. It is a definite and straightforward piece of research which would be a valuable contribution to astronomy.

Short-wave Directional Wireless Telegraph.[1]

By C. S. FRANKLIN.

DIRECTIONAL wireless telegraphy is by no means a new development, for Hertz made use of reflectors at the transmitting as well as the receiving ends in order to augment the effects, and to prove that the electric waves which he had discovered obeyed, to a considerable degree, the ordinary optical laws of reflection. Senatore Marconi, in his earliest endeavours to develop a telegraph system using electric waves, also employed reflectors to increase the range and get directional working.

The discovery by Marconi of the great increase of range obtained by the use of longer waves, and the earthed 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 wireless telegraphy, namely, working to and between ships, required "all round" working, there was very little call for directional systems.

To-day the range has arrived at the maximum possible on the earth, and the wave-length has increased to such an extent that the frequencies pro-

[1] From a paper read before the Institution of Electrical Engineers on May 3.

posed are within or near to the limits of audibility. The possible gamut of wave-lengths is becoming very fully occupied, and although the development, during the last four years, of nearly pure continuous-wave transmitters, and of receivers with vastly improved selective powers has eased the problem, the time will soon arrive when the only way of increasing the number of possible services will be by employing systems having good directional characteristics.

There are, broadly, two general classes of directional aerial systems: (*a*) Those having the general characteristic that their directional power or polar curves are nearly independent of their dimensions. The directional result is obtained by opposing the effects of a number of aerials, or parts of an aerial with suitable phasing adjustments, 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 aerial. (*b*) Those having the general characteristic that their directional power or polar curves depend on their dimensions relative to the wave-length employed. In this class the directional result is obtained by adding the effect 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, have small dimensions only when using short waves, and this fact makes their development difficult.

As examples of such systems may be mentioned—

(1) Reflector systems in general.

(2) Systems composed of lines of aerials, at right angles to the working direction, correctly adjusted as regards phase.

(3) The Beverage long, horizontal receiving aerials.

The reflector system was the first tried for wireless telegraphy. The use of reflectors of reasonable dimensions, however, implies very short waves of the order of a few metres, and the very high attenuation of such waves over land or sea, and the difficulty of getting much power into them, tended to make early attempts very discouraging.

The investigation was 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 metres and 3 metres. The only interference experienced with such waves is from motor boats and motor cars, for these machines apparently emit waves from near 0 up to about 40 metres in length. A coupled-circuit spark transmitter was developed, the primary having an air condenser and spark 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 decrement of the waves emitted was judged to be of the order of 0·03. The receiver used was a carefully picked crystal, while the reflectors employed were made of a number of strips or wires tuned to the wave, arranged on a cylindrical parabola with the aerial at the focus. The transmitting system was arranged so that it could be revolved and the effects studied at the receiver.

Reflectors having apertures up to $3\frac{1}{2}$ wave-lengths were tested, and the measured polar curves agreed very well indeed with the theoretical curves. The use of two reflectors with apertures of $3\frac{1}{2}$ wave-lengths, one at the transmitter and one at the receiver, increased the working range about 3 times.

These Italian experiments showed that good directional working could be obtained with reflectors properly proportioned with respect to the wave-length. The attenuation over sea for the wave-length used was found to be very high, and with the apparatus available the maximum range obtained was 6 miles.

The experiments were continued at Carnarvon in 1917. With an improved compressed-air spark transmitter, a 3-metre wave and a reflector having an aperture of 2 wave-lengths, and a height of 1·5 wave-lengths, a range of over 20 miles was obtained to a receiver without a receiving reflector. The experiments at Carnarvon brought into prominence a property of wave propagation which is not generally known, and the extent of which is not realised, namely, the very rapid increase in the strength of the electric field with height above the ground. The rate of increase appears to be a function of the height divided by wave-length, and while not very noticeable with waves of several hundred metres, is very marked with waves of a few metres' length.

It was found that the limiting range at sea level and over sea was 4 miles. When both transmitter and receiver are at a low level the range is very dependent on the nature of the intervening country, and is very restricted even over sea; when, however, both stations are many wave-lengths above the intervening country its nature is of far less importance, and the range is increased many times. These experiments showed that very considerable ranges were possible with very short waves.

In 1919 experiments were commenced at Carnarvon with valve transmitters, with the idea of producing a directional telephone system. A wave of 15 metres was selected, which while well within the capacity of the power valves available, allowed a simple reflector to be used without too large a structure. After some trials a single valve transmitter was arrived at taking about 200 watts with a 15-metre wave, and giving 1 ampere in the centre of a half-wave aerial. A heterodyne receiver with supersonic beat-note was employed. Finally, very strong speech was obtained at Holyhead, 20 miles away. The strength was such that shadows produced by small hills and buildings were scarcely 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 strength. Tests were carried out with the Dublin Steam Packet Company's boats running from Kingston to Dublin in June 1920, and speech was received in Kingstown Harbour, 70 nautical miles from Carnarvon, and the point was proved that there was no rapid diminution of strength after passing the horizon line from Carnarvon.

The range of the system was also tested wholly over land. A site was chosen at Hendon, and a reflector and transmitter for 15-metre waves erected with the reflector pointing towards Birmingham. Tests were commenced in February 1921 from Hendon to a portable receiver on a motor car. Very good speech was received up to 66 miles, and fair speech in the neighbourhood of Birmingham. A reflector station was then erected at Frankley near Birmingham, 97 miles from Hendon, and tests were started there in August 1921.

Measurements with and without the reflectors indicate that the energy received when both reflectors are up is about 200 times the energy received when not using the reflectors. Local measurements of the polar curves taken round the station show that the electric field in front of the station is increased approximately 4 times by the use of the reflector, and that the same order of increase is obtained during reception; the increase of energy received due to the use of the two reflectors should therefore be $4^2 \times 4^2 = 256$ times.

During the continuous-wave tests at Carnarvon it was found that reception was quite possible on the transmitting aerial while the transmitter was operating. The heterodyne may be either the transmitter, or an independent small heterodyne in the receiver. Both the transmission and the reception utilise the same aerial and reflector, and the transmitter is left going and can be operated while receiving.

There is no reduction in strength while the transmitter is on, but a practical trouble has appeared. Owing to the comparatively large power, strong currents are induced in all conducting structures and circuits close to the reflector and transmitter, such as the supporting towers and buildings, and every variable contact produces a noise. The elimination of all variable contacts in the neighbourhood of the transmitter has proved a work of some magnitude.

Reflectors besides giving directional working, and economising power, are showing another unexpected advantage, which is probably common to all sharply directional systems. It has been noted that practically no distortion of speech occurs, such as is sometimes found with non-directional transmitters and receivers.

Although the results between Hendon and Birmingham constitute a record for telephony for ratio of range to wave-length—for such results were believed to be impossible two years ago—they are only a first attempt and do not represent the best that can now be done after the experience gained. But it has been demonstrated that wave-lengths of the order of 20 metres are capable of providing point-to-point directional commercial service over very considerable ranges. Such services will be comparatively secret as compared with the usual non-directional type of transmission.

The directional effect obtained with reflectors which are large compared with the wave-length is so good that it was suggested that it would prove very useful for position finding for ships near dangerous points. The general idea is that a transmitter and reflector revolving will act as a kind of wireless lighthouse. It is not intended at present for long ranges, but rather that revolving reflectors should be erected in position, similar to those at present occupied by fog signals, and be capable of similar ranges, so as to give the position to ships during fog when within about 10 miles of the danger point.

An experimental revolving reflector was erected on Inchkeith, and tests were made to s.s. *Pharos*, the lighthouse tender of the Northern Lights Commissioners during the autumn of 1920. With a 4-metre wave, spark transmitter, a reflector of 8 metres' aperture, and a single valve receiver on the ship, a working range of 7 nautical miles was obtained. The reflector made a complete revolution once every 2 minutes, and a distinctive signal was sent every half-point of the compass. The bearing of the transmitter could then be determined within ¼ point of the compass, or within 2·8 degrees.

The best method of giving the direction to a ship by means of such a revolving beam requires consideration. When listening in a receiver to a moderately sharp revolving beam the signals are heard only for a very short time. The exact time of maximum signals is not easy to determine by ear, but the times of starting and vanishing are easy to determine, as the rate of rise and fall of the signals is extremely rapid. The time half-way between these two times gives with great exactness the moment when the beam is pointing to the ship.

It would be quite possible to arrange to send a general broadcast signal when the beam passes through true north; then by arranging for the beam to revolve at a perfectly uniform rate, the bearing on the ship could easily be determined by means of a stop-watch. This method is probably the most accurate, but has some disadvantages. It entails accurate timing mechanism at the transmitter, the use of two waves, and three, or perhaps four receivers on the ship, as well as the use of a stop-watch.

For the short wave two receivers are required, one at each end of the bridge, or one fore and one aft. This is necessary to avoid screening by the ship itself. If the broadcast wave for giving the time when the beam passes true north is another short wave, then two more receivers would be required.

The method provisionally adopted avoids accurate timing mechanism at the transmitter and the use of a broadcast wave. On the base of the revolving reflector contact-segments are arranged so that a definite signal is transmitted every half- or quarter-point of the compass.

The apparatus proposed is of a very sturdy nature. The spark transmitters are robust, and last for years without attention. The receivers are simple valve rectifiers with fixed adjustments except for a "backing off" potentiometer for dealing with powerful signals at close range. The attenuation of these waves over sea is so strong that a little experience enables distance to be judged by strength of signals, and this can be measured by means of the potentiometer. The only qualification necessary for a person determining the bearing is the ability to read a few Morse signs.

The success of the present experiments indicates a wide sphere of usefulness for the new short-wave directional wireless system.