Radio Direction-Finding by Transmission and Reception.*

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TRANSMISSION OVER SEA AND NIGHT ERROR.

WHEN the transmission is entirely over sea the minimum range for night errors to be experienced is increased to about 100 miles, due to the diminished attenuation of the direct wave resulting from the superior conductivity of sea water. At distances greater than the minimum already mentioned, the errors increase in magnitude for distances up to a few hundred miles. When the distance is very great it is possible for much of the downcoming radiation to arrive at a very large angle of incidence. For example, a section of the earth and the ionised layer drawn to scale is shown in Fig. 4. From this it is evident that, at distances of 1780 and 3560 miles, it is just possible for radiation leaving the transmitter horizontally to return to the earth's surface at grazing incidence. It is likely that the intensity of such waves, after two reflections from the ionised layer and one from the earth's surface, will be much greater than that of waves which have undergone a greater number of reflections, and thus it is the 'downcoming' wave arriving horizontally which will be chiefly responsible for the received signal intensity. It is evident that only small variations in direction-finder bearings will be expected under such conditions.

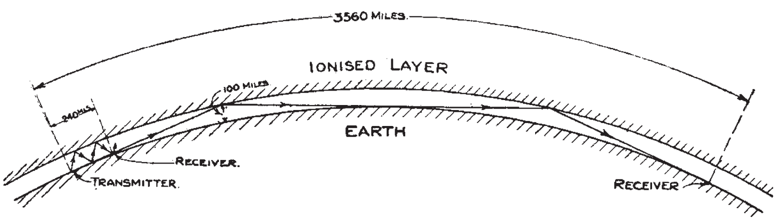

FIG. 4.—Section of earth, radius 4000 miles, and ionised layer at a height of 100 miles, showing the paths of waves from a transmitting station and two receivers at distances of 240 miles and 3560 miles.

Now, the distance of 3500 miles is approximately that between the National Physical Laboratory, Teddington, and some of the high-power transmitting stations in the United States of America. A series of systematic observations carried out on two of these stations operating on wave-lengths of 16·4 km. and 16·8 km. showed that the proportion of bearings correct to within 2° was 100 per cent in one case and 94 per cent in the other, the maximum error in the second instance being 3·4°. Under similar conditions, observations made on several European transmitting stations, using wave-lengths between 14 km. and 19 km. at distances of 75—760 miles, showed maximum errors in bearings of 12° to 28°, while the proportion of bearings correct to within 2° was only 16—63 per cent. Reference to Fig. 4 shows that this result is to be expected, since at a range of 240 miles, for example, the angle of incidence of waves arriving at the receiver after two deflections from the ionised layer is of the order of 35°.

ELIMINATION OF NIGHT ERRORS IN DIRECTION-FINDING.

It will be evident that any receiving system which is unaffected by horizontal components of electric force will be free from night errors, even though the vertically polarised downcoming waves still produce variations in received signal strength. A direction-finding receiving arrangement which fulfils this condition was patented by Adcock in 1919, but it does not appear to have received practical consideration until Mr. Barfield and I experimented with it in 1926. The simplest form of the Adcock aerial system is a pair of spaced vertical aerials, arranged to rotate about a central vertical axis, thus forming the equivalent of the single closed coil direction-finder. By making all connexions to the centres of the aerials, the horizontal members of the system are compensated so that no electromotive force is induced in the receiver by a horizontal electric force. Preliminary tests with this direction-finder carried out a few years ago showed that the system was effective in considerably reducing the magnitude of the night variations experienced with the closed loop system. The continued development of the system as a practical form of direction-finder free from night errors is still in progress.

THE ROTATING LOOP BEACON.

As an alternative to the direction-finding schemes outlined above, the directional part of the wireless system may be transferred from the receiving to the transmitting end. This is effected in the rotating loop beacon system developed by the Royal Air Force, which employs a vertical closed loop transmitter arranged to rotate about a vertical axis at a uniform speed of one revolution a minute. As the loop rotates, the field radiated in any given direction varies according to a cosine law, passing through successive maximum and minimum values at intervals of 15 seconds. When the plane of the loop is perpendicular to the geographical meridian, a characteristic signal is emitted by the beacon which may be termed the north point. The observer at a distant receiving station upon hearing this signal starts a chronograph. As the beacon rotates the intensity of the received signal varies and will ultimately pass through a minimum or zero, at which instant it is known that the plane of the transmitting loop is at right angles to the great circle through transmitter and receiver. If the reading of the chronograph is observed at this instant of minimum signal intensity, it is evident that the bearing of the transmitter from the receiver can be obtained from a simple calculation.

* Continued from p. 532.

It is to be noted that since the radiation from the coil is symmetrical about its plane, a second minimum will be obtained after a rotation of 180° from the first. With the beacon making one revolution per minute, therefore, a line bearing is obtainable in the above manner every half-minute. To fix the position of a receiving station it is necessary to obtain line bearings from two or more beacons. Since the timing process mentioned above is but an intermediate step in taking a bearing, it is convenient to provide a stop-watch or chronograph for the purpose, with a dial specially engraved in degrees and points of the compass.

An application of the principle of reversibility in direction-finding makes it evident that the performance of a rotating loop beacon transmitter can be largely predicted from the results and experience obtained with receiving loop direction-finders. Thus, a rotating loop beacon when erected on the same site as the direction-finder will give observations at a distant receiver which will be subject to the same type of local error and night variations, for example, as the bearings observed on the direction-finder when the distant receiving aerial is used for transmission. I have confirmed these deductions in the investigation during the past two or three years, of the performance of a rotating beacon erected at Fort Monckton, near Gosport. In order to ascertain the trustworthiness of this type of rotating beacon as an aid to marine navigation, a number of tests were carried out in ships crossing the English Channel between Southampton and Havre, and Southampton and Jersey. Using the ship's ordinary wireless receiver, observations of the bearing of the beacon were made at intervals during each trip and compared with the bearing as given by the captain of the ship.

As a result of tests conducted on these lines, it was found that in the majority of cases the estimated and observed bearings agreed to within from 2° to 4°. Signs of night effects in the shape of indistinct signal minima and wandering bearings were observed at ranges exceeding 60 miles. In many cases at night and during misty weather when visibility was very poor, the ship was navigated by dead reckoning, and in these circumstances it was frequently considered that the bearing obtained from the rotating beacon was the more accurate. Some of the test runs made between Southampton and Jersey were carried out in a ship fitted with a direction-finder of the Marconi Bellini-Tosi type, and the opportunity was thus provided of comparing the two systems of obtaining wireless bearings under actual sea-going conditions. The observations carried out in this manner showed that in the majority of cases the bearings obtained with the direction-finder and from the rotating beacon agreed to within 5°. In some cases, however, due probably to the pitching and rolling of the ship, the accuracy of the direction-finding bearing was inferior to that obtained from the rotating beacon.

As a result of the success of the experiments carried out with the Gosport station, a more permanent type of rotating loop beacon transmitter was installed at Orfordness and put into operation in June 1929. During the few months that this station has been working, a considerable number of reports have been received from various ships giving the results of observations made on transmissions from the beacon. These reports show that the inauguration of this beacon service has been very well received by the mercantile marine. With the ordinary type of ship's receiver adjusted for continuous wave reception, accurate wireless bearings are obtainable at distances of 50–100 miles. Ships fitted with a more elaborate receiver have reported good and consistent bearing observations up to ranges of 250 miles. At such long ranges, however, it is possible that the observed bearings may be subject to night errors in a manner similar to that observed in wireless direction-finding under the same conditions.

From the similarity of performance of the two systems of direction-finding, it would be expected that the elimination of the horizontal components of the transmitting loop would be of advantage in eliminating or reducing the magnitude of night errors or effects observed when using the rotating beacon. A theoretical analysis of the case has shown this deduction to be justified, and experiments are now in progress towards the development of a rotating beacon transmitter with an aerial system of which only the vertical members are active in producing radiation of electromagnetic waves. If these experiments lead to successful results, it is probable that rotating beacons can be erected with a trustworthy working range of the order of 500 miles, supplying wireless bearings at any time or season with an accuracy which is adequate for both aerial and marine navigation.

Obituary.

Sir William McCormick, G.B.E., F.R.S.

Few if any of the men interested in education since the days of the War have been better known to the vice-chancellors and treasurers of the universities of Great Britain than the late Sir William McCormick. None has had so complete a knowledge of their financial difficulties and of the disastrous effects on educational efficiency of their want of means, and no one has done more to help than he, by his sympathetic treatment of the problems placed before him, his wise advice based on his long experience, and his cordial appreciation of the value of the efforts made to fit the universities for their task, whether it be that of advancing knowledge, or of educating the students that fill their lecture rooms and laboratories. To all, his death on Mar. 22 means a very heavy loss.

McCormick was born on April 29, 1859, and educated at the Universities of Glasgow, Göttingen, and Marburg. For a short time he lectured on mathematics, but the study of the English language and literature soon attracted him, and he became, and continued to the end, a serious student of Chaucer.