GROUND-WAVE PROPAGATION ACROSS A LAND/SEA BOUNDARY

100-m. Waves

In a previous letter[1], I described an experiment on a wave-length of 4 m. in which a predicted recovery on crossing a land/sea boundary was obtained. As there indicated, this phenomenon may be of great practical importance on longer waves, and since the theory is not completely rigid, it was felt desirable to make an experiment on a wave-length of about 100 m. where the land curve in the diffraction region is twice as steep as the sea curve.

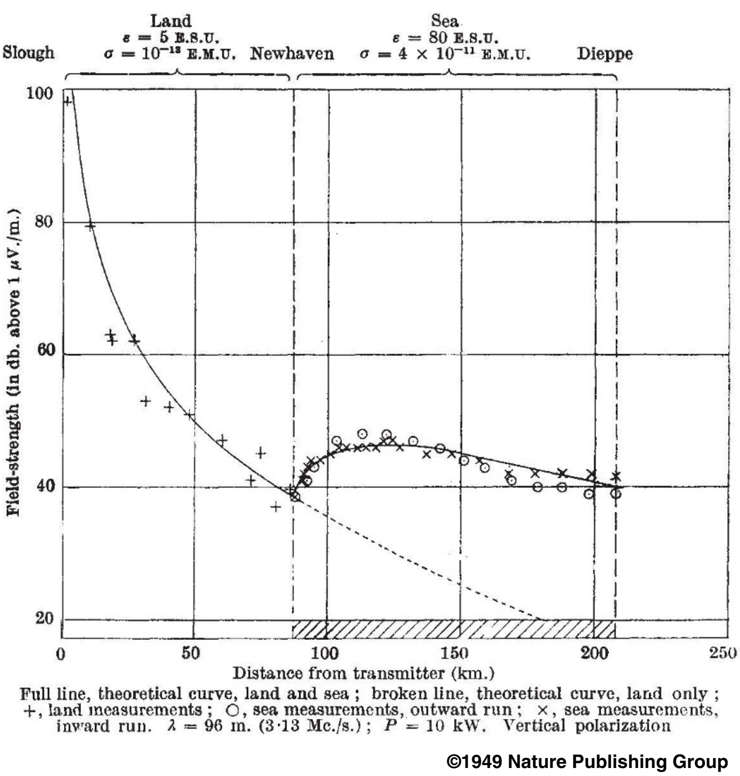
This has now been done at my suggestion by Mr. G. A. Isted, of Marconi's Wireless Telegraph Co., Ltd. The theory suggests that the recovery should be fully developed, and of the order of 10 db., when the boundary is 100 km. from the transmitter, and that the maximum should then occur at about 25 km. beyond the boundary. Of the possible regular sea routes, the most suitable was the Newhaven–Dieppe crossing of 120 km.; for the line of this route produced backwards passes reasonably near the Radio Research Station at Slough, 87·5 km. inland. Here, through the kindness of Dr. R. L. Smith-Rose, of the Department of Scientific and Industrial Research, we were able to use a pulse transmitter which radiated 10 kW. from a specially erected quarter-wave vertical aerial on a frequency of 3·13 Mc./s. ($\lambda = 96$ m.), giving a field-strength at Newhaven of about 80 μV./m., which was ample for our purpose. Pulses were necessary to isolate the ground-wave signal from the first-order E-layer reflexion, which even in the day-time would be of comparable strength at a distance of 100 km.

A Marconi TME.18 field-strength measuring set with a loop aerial, and fitted with a miniature cathode ray oscilloscope, was used along the land path. Permission was then kindly granted to install it in the wheelhouse of the paquebot *Londres*, where a vertical aerial from the masthead was coupled into the set by a special unit in place of the loop. This was essential, as the local disturbance in the field was too great for the reliable use of the loop. It was, in fact, impossible to calibrate the vertical aerial against the loop on board, so that the land value at Newhaven had to be used as a reference.

The results are shown in the accompanying graph. The land values agree well with the assumption that the average conductivity is 10^{-13} E.M.U., the discrepancies being attributable to the unevenness of the ground, and to local disturbances revealed by very poor bearings. The sea-values show the expected recovery, and it will be seen that the field-strength at Dieppe is actually greater than at Newhaven. The values on the return journey are the more reliable as it was possible to overcome some calibration difficulties that caused small uncertainties on the outward run. The readings throughout were taken to the nearest decibel.

In computing the oversea curve, allowance has been made for the fact that the transmitter was somewhat to the side of the Newhaven–Dieppe line, so that the land path changed during the sea passage, causing a total increase of about 10 km. due to the interposition of the Beachy Head promontory. This had the effect of reducing the recovery by 2 db.

The results confirm that, within the limits of such experimental conditions, the method given in my paper[2] is also correct on this longer wave, and hence probably at all wave-lengths. Only by very specially controlled experiments would it be possible to investigate any standing waves before the boundary that might be indicated by a complete theory.



Full line, theoretical curve, land and sea; broken line, theoretical curve, land only; +, land measurements; ○, sea measurements, outward run; ×, sea measurements, inward run. $\lambda = 96$ m. (3·13 Mc./s.); $P = 10$ kW. Vertical polarization

It is intended to publish these results and those of the previous 4-m. experiment in more detail at a later date, with full acknowledgments to all who helped to make them possible.

G. MILLINGTON

Research Division,
Marconi's Wireless Telegraph Co., Ltd.,
Gt. Baddow, Essex.
May 17.

[1] *Nature*, **163**, 128 (1949).
[2] *Proc. Inst. Elect. Eng.*, **96**, Pt. III, 53 (1949).

300-m. Waves

In a recent letter[1], Millington has published the results of an experiment designed to test his theory[2] of the propagation of radio waves over a 'mixed path' consisting partly of land and partly of sea. Using a wave-length of about 4 metres, he obtained excellent confirmation of the occurrence of a recovery of field-strength after leaving land and passing over sea. This remarkable phenomenon, predicted by his theory, owes its existence to a vertical redistribution of energy near the coastline. Such redistribution is inevitable, because the field must vary with height in a different way on the two sides of the boundary.

The height-gain function depends on the complex Brewster angle for reflexion at the air-ground interface, and is of a different general form, depending on whether the ground is primarily a conductor or primarily a dielectric. For a wave-length of 4 metres, the land is approaching its dielectric characteristics, while for the greater part of the range of wave-lengths used in communications and broadcasting ($\lambda > 25$ m.) the land behaves mainly as an imperfect conductor. The sea is a quasi-conductor except at microwave-lengths and less. It is therefore desirable to attempt to verify Millington's prediction of the recovery effect at a wave-length for which both land and sea are essentially conducting.

Such an experiment was made on March 3 of this year. The transmitter used was at Crowborough, operating on a frequency of 1,122 kc./s., and a special transmission of a tone-modulated continuous-wave signal was provided. Relative field-strengths were measured at quarter-minute intervals by means of a calibrated gain-stabilized receiver operated in a York aircraft, fitted with a 9-ft. high vertical whip antenna. The aircraft was flown at a height of 1,000 ft. above mean sea-level along the mixed path shown in Fig. 1, navigational data being provided by frequent visual fixes or Gee readings.

The results of the experiment are shown in Fig. 2, in which it is seen that there was a major recovery effect in field-strength at twenty-five miles beyond the coast-line. This was satisfactorily confirmed by a second series of measurements made over the portion *PR* on the return journey. The solid curve in Fig. 2 is the theoretical curve based on Millington's theory for assumed conductivities of 10^{-13} E.M.U. for the land and 4×10^{-11} E.M.U. for the sea. The curve has been adjusted in relative field-strength to provide a fit along the land portion, and a small correction (2·6 db.) has been applied over the land to allow for the height of the aircraft, the corresponding correction over the sea being negligible. The terrain of East Anglia was chosen specially on account of its flatness, so that irregularities in the measured values over land cannot be attributed to the topography. The increased rate of attenuation along the portion of the path extending 30 miles inland from the coast may be attributed to a lower value of ground conductivity (nearer 10^{-14} E.M.U.), as previously noted by Millington (see ref. 2, p. 61, fig. 9). It is intended to make allowance for this in a fuller paper to be published later. Any interference pattern due to sky-wave would have an average spatial period of a mile along the path used and would be effectively smoothed out.

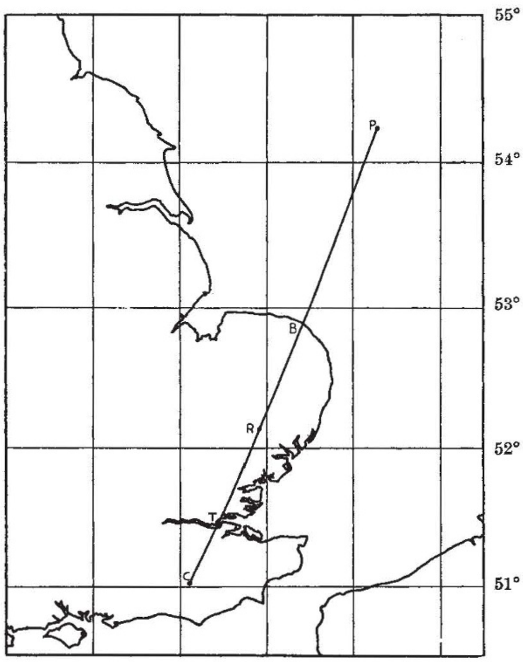


Fig. 1

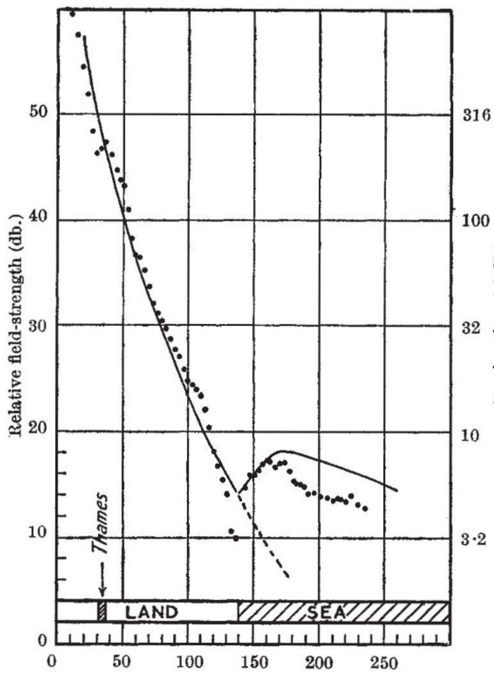


Fig. 2

An interesting feature of the results is the small recovery effect, quite unlooked for, at a distance of about thirty-five miles. The navigational data show that this corresponds to the Thames estuary, which was crossed at Mucking Flats, where the direction of the estuary lies along the course for a distance of about five miles. No allowance has been made for this in the theoretical curve.

The experimental results demonstrate clearly the occurrence of the recovery effect on passing from land to sea at medium wave-lengths, and thus confirm in general outline the prediction of Millington's theory under the conditions in which it is likely to have important consequences in broadcasting practice. Discussion of the details of the phenomenon must await further experimental investigation.

I am indebted to Mr. G. Millington for showing me an early draft of his paper[2], which led to the initiation of this work. Special thanks are due to Mr. C. Williams and the crew of the aircraft for services provided by the Royal Aircraft Establishment, and to the Diplomatic Wireless Service of the Foreign Office for the provision of special transmissions from Crowborough.

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