XIV. SURFACE WAVES*

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Some initial experimental results have been obtained in an attempt to determine whether or not a surface wave of the Zenneck type can be excited and propagated. For cylindrical symmetry in the flat-earth case this type of wave may be described by the z component of the Hertz vector.

$$\Pi = \begin{cases} A\, e^{-\mu z}\, H_o^{(2)}(\lambda r) & z \geq 0 \\ A_e\, e^{\mu_e z}\, H_o^{(2)}(\lambda r) & z \leq 0 \end{cases}$$

with appropriate restrictions on the coefficients μ, μ_e, and λ. The upper half-space, $z \geq 0$, is taken to be loss-free (air); the lower half-space is occupied by a lossy dielectric.

Calculations indicate that in order to obtain a small radial attenuation factor, attention should be focused on frequencies of the order of a few megacycles per second, with sea water as the lossy dielectric. However, as far as the excitation of the wave is concerned, it is desirable to have the source as large as possible with respect to a wavelength, so that a physically large antenna is necessary. Furthermore, since the attenuation of this type of wave over land is much greater than over the sea, any considered source must not be far removed from the water's edge. These requirements severely limit the number of existing transmitters available for use; so far only two have been considered. With one of these, using a horizontal rhombic of the old WBOS station at Hull, Massachusetts, it was possible to make only one test before the station was taken out of service. The other station considered is the Loran transmitter at Cape Hatteras, North Carolina, which is in continuous operation, radiating pulse signals at 1.95 Mc/sec, 800 kw peak power, from a 300-foot tower located close to the water.

The method of detection of the surface wave is based upon the different attenuation rates of this type of wave and the normal diffraction field (assuming that the flat-earth guided-wave theory is at least roughly applicable to the actual spherical earth case). Calculations for the Loran station indicated that the guided-wave component should become observable at distances greater than about 320 miles from the transmitter. This is a convenient figure, since an over-sea path from Cape Hatteras to the Cape Cod region covers approximately 500 miles and makes the interesting end of the path fairly accessible.

A navy blimp was available for use in this region, and in cooperation with the Navy, field-strength measuring equipment was installed in the blimp, and a number of flights

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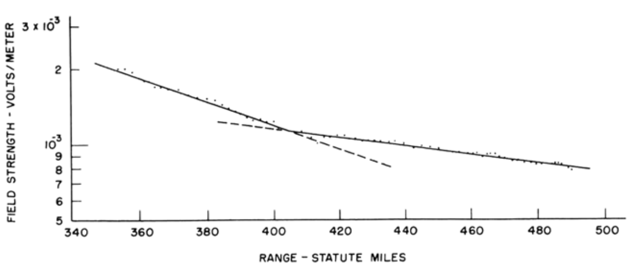

Fig. XIV-1

Measured signal strengths from Cape Hatteras Loran Station (1H4, 1.95 Mc/sec, 800 kw) over sea path, using TS-318/UP test set, August 27, 1953. Height, 500 feet; speed, approximately 60 mph.

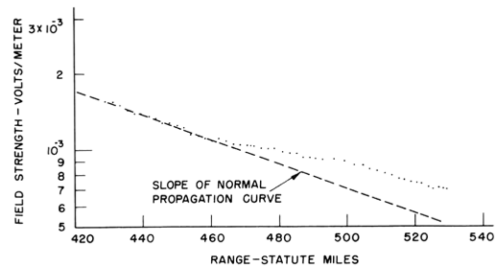

Fig. XIV-2

Measured signal strengths from Cape Hatteras Loran Station (1H4, 1.95 Mc/sec, 800 kw) over sea path, using TS-318/UP test set, October 9, 1953. Height, 500 feet; speed, approximately 60 mph.

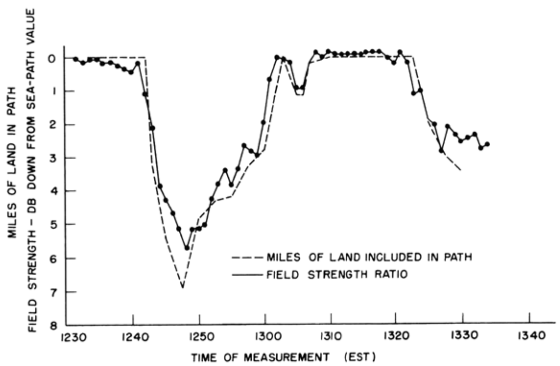

Fig. XIV-3

Variation of field strength with amount of land included in path, using Cape Hatteras Loran Station (1H4, 1.95 Mc/sec, 800 kw); October 9, 1953. Path running between Nantucket and Cape Cod.

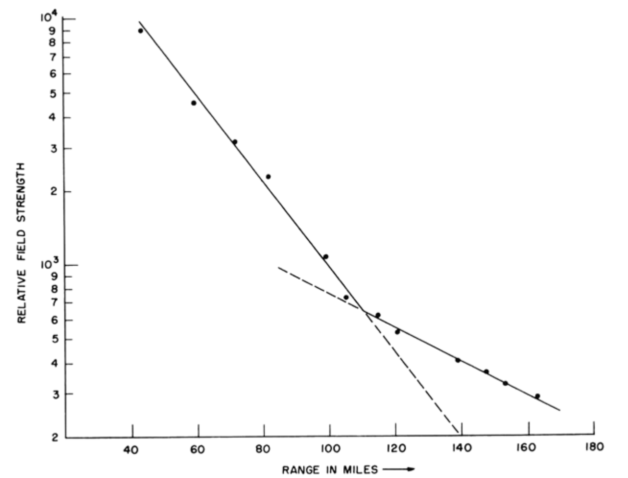

Fig. XIV-4

Measured signal strengths from WBOS, Hull, Massachusetts (6.140 Mc/sec, 50 kw) over sea path; course 085° true, September 28, 1953. Height, 800 feet; speed, approximately 60 mph.

carried out in the Cape Cod region. The first results were extremely promising. As shown in Fig. XIV-1 the measured points fall on a curve with a distinct change of slope at a range of approximately 410 miles. The initial portion of the curve has a slope corresponding to the normal diffraction field; the latter part has a slope which although greater than that computed from the flat-earth theory is still much less than can be accounted for on the normal propagation basis. Attempts to repeat and extend this curve have not met with great success. Successive curves have all shown irregular behavior in the 400-500 mile region. In the one instance in which measurements were obtained out to a range of 630 miles, the latter part of the curve had a slope corresponding to normal propagation. Figure XIV-2 shows one of these later curves, and hardly appears to be indicative of the presence of the surface wave. However, this flight included a short run over a path between Nantucket and the south side of Cape Cod, approximately at a constant range of 530 miles from Cape Hatteras. With this flight path a radial from the transmitter passes over the Nantucket region, thus including a few miles of land near the end of the transmission path. Figure XIV-3 shows a comparison of the measured field strength and the approximate land mileage included in the path. The agreement is quite striking, and the additional attenuation is much greater than would be predicted from the normal propagation curves.

The one run for which station WBOS was used was conducted under slightly different conditions. Although the antenna is a horizontal rhombic, it was hoped that by locating a null of the horizontal component of the field there would be sufficient vertical polarization to provide a useful signal. This appeared to be the case, and the curve shown in Fig. XIV-4 was obtained by flying almost due east of Hull. In this instance the transmission was continuous-wave at 6.14 Mc/sec, with 50,000 watts radiated. A definite break in the curve is observable; the slope of the latter portion of the curve is again somewhat greater than that given by the flat-earth surface-wave theory.

From these results it is apparent that some phenomenon is disturbing the results that would be expected from the normal propagation theory. If we try to explain this phenomenon by means of a surface wave, the Loran results further indicate that something peculiar is happening in the Cape Cod area. It may be that the mass of land and shallow water represented by this region is having an adverse effect upon the surface wave. In this case it would appear advantageous to make measurements further out at sea. Since the position and length of such a new path preclude the use of the blimp, the equipment is now being installed in a navy P2V patrol plane for further measurements.

Theoretical work on this problem is also in progress.

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