The velocity of the clouds was 75 metres a second on December 30, 1926, towards the south-east, but on the other occasions rather small, 10–20 metres a second in the same direction. The astronomer Sigurd Einbu has written to me that he observed mother of pearl clouds from Dombaas on February 16, 1934, which moved towards the south-east with a velocity of 90 metres a second, the height being supposed to be 25 km.

A series of forty-one successive pictures of a cloud on January 29, 1932, showed rapid changes probably due to turbulence with successive evaporations and condensations in the layer from 26 km. to 28 km.

As already remarked in my former letter in NATURE[2], measurement of a corona round the moon in the night of February 19–20, 1932, led to a diameter of the particles of the cloud not exceeding 0·0025 mm.

Series of observations of mother of pearl clouds were also received from northern Scandinavia and from Finland.

As to the accompanying meteorological conditions, they were the same as those described by H. Mohn in a paper in 1893[3].

CARL STÖRMER.
Institute of Theoretical Astrophysics,
Blindern, V.Aker.

[1] NATURE, **123**, 260 (1929).
[2] NATURE, **129**, 941 (1932).
[3] Mohn, H., "Irisierende Wolken", *Meteor. Z.* (March 1893).

Wireless Propagation and the Reciprocity Law

THE theorem of reciprocity has been expressed in several different forms, notably by Rayleigh[1] and by Sommerfeld and Pfrang[2]. The form most directly related to wireless wave propagation has been given by Carson[3], as follows:

If an E.M.F. is inserted in the transmitting branch of antenna A_1 and the current measured in the receiving branch of antenna A_2, then an equal current (both as regards amplitude and phase) will be received in the transmitting branch of A_1 if the same E.M.F. is inserted in the receiving branch of A_2.

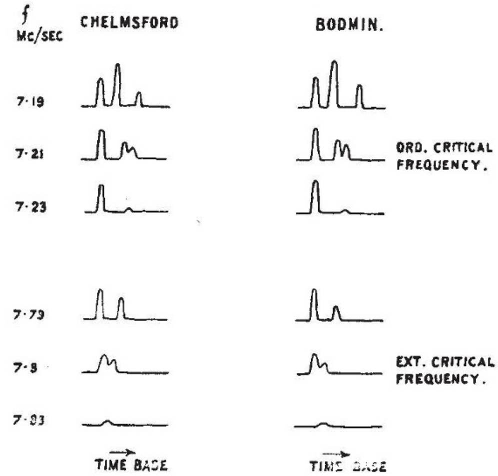
The extent to which this theorem applies to waves propagated in the ionosphere has been much discussed. The presence of the earth's magnetic field renders the medium anisotropic, so that the arguments on which the theory is based are no longer applicable. In practice, the theory is of importance in deciding whether transmission from one station to a distant one is as 'good' as that in the reverse direction. Measurements made in 1922 on long waves[4] suggested that this was not always the case; but much more data would be required to provide a complete check.

Recently we have made tests on two-way transmission between Chelmsford and Bodmin (distance 393 km.), using pulses in each direction. Provision was made for varying the frequency of both transmitters, and for observing at each station on a cathode ray tube the 'echo pattern' due to the distant transmitter. Some interesting results concerning the reversibility of the waves have been obtained by this means.

Experiments were made in which the frequencies of the two transmitters were varied together in small steps over a range embracing the critical frequency of the F layer (for oblique reflection).

On each frequency the echo pattern was observed at the two stations, and the exact point of disappearance of the signal was thus determined. The results at the two ends were then compared. The experiment was repeated a large number of times, and was carried out covering the critical frequencies of both the ordinary and extraordinary waves.

The results obtained were of the type shown in the accompanying figure. Each critical frequency is marked by the convergence of two rays, a high and a low angle[5], and the final point of disappearance of each could be estimated to an accuracy of about 0·02 Mc./sec. They show a remarkable agreement between the critical frequencies for propagation in the two opposite directions, this being equally true for either magneto ionic component: the frequencies can be said to be within 0·03 Mc./sec. for the two directions in either case.



The results are thus consistent with reciprocity and prove that in this particular case the observed effects are what, indeed, would be deduced from this principle. They do not prove that this is true in the general case; but it is notable that the critical trajectory we have observed is one which is highly sensitive to the properties of the refracting medium, and the exact agreement found suggests that in other conditions too the behaviour of waves propagated in the ionosphere is the same for one direction of transmission as for the other. The practical importance is perhaps the greater, for in long-distance communication between two stations one limiting condition for reception of a signal is that the receiver shall be outside the skip zone. This condition is identical with that referred to above, as applied to the extraordinary wave, this wave being the last to escape through any ionospheric layer. Thus it is clear that, so far as electron limitation is concerned, if transmission is possible for one direction of travel between two stations, it is necessarily possible in the opposite direction.

T. L. ECKERSLEY.
S. FALLOON.
F. T. FARMER.
W. O. AGAR.
Research and Development Dept.,
Marconi's Wireless Telegraph Co., Ltd.,
Chelmsford. Jan. 9.

[1] Rayleigh, "Theory of Sound".
[2] *Z. hochfreq. Tech.*, **26**, 93 (1925).
[3] *Proc. Inst. Rad. Eng.*, **17**, 952 (1929).
[4] *J. Inst. Elec. Eng.*, **63**, 953 (1925).
[5] *Proc. Phys. Soc.*, **50**, 956 (1938).