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NON RECIPROCAL IONOSPHERIC PROPAGATION IN THE MEDIUM FREQUENCY BROADCASTING BAND

P. Knight
British Broadcasting Corporation
Research Department
Kingswood Warren
Tadworth Surrey KT20 6NP

ABSTRACT

Measurements made in the U.S.A. suggest that east-west ionospheric propagation in the medium-frequncy broadcasting band is non-reciprocal. A possible explanation is put forward in the paper, which draws attention to the fact that the combination of polarisation-coupling loss and ground-reflection loss which occurs between hops on multi-hop paths depends, in general, on the direction of propagation.

A recent paper[1] describes an analysis of measurements made in the U.S.A. which indicates that sky-wave propagation in the m.f. broadcasting band is non-reciprocal on east-west paths. Transmission loss is shown to be greater on paths from east to west.
A possible explanation has been given in a paper[2] which shows theoretically that ionospheric propagation on multi-hop paths is, in general, non-reciprocal in the m.f. broadcasting band. This arises because the gyromagnetic frequency falls within the band and the extraordinary wave is heavily attenuated. Thus, the ordinary wave is the only component which contributes significantly to the received signal. If the polarisation is unchanged when the wave is reflected from the ground between hops, it will re-enter the ionosphere as the ordinary wave. However the upgoing wave will excite the ordinary wave less efficiently, and coupling losses will occur, if the polarisation is changed by ground reflection. Loss will also occur at the ground-reflection point, since the ground is not a perfect reflector. The sum of ground-reflection and polarisation-coupling losses is known as intermediate reflection loss; it is a complicated function of the Fresnel plane-wave reflection coefficients for vertical and horizontal polarisation at the ground reflection point, derived in Reference 3 and reproduced in Reference 2. Under some circumstances the intermediate reflection loss depends on the direction of propagation, and the path will then be non-reciprocal. It can be shown that paths are non-reciprocal if either of the Fresnel reflection coefficients are complex. Consequently the two directions of propagation are likely to differ most when waves are reflected from land at the Brewster angle, because the reflection coefficient for vertical polarisation then has a phase angle of -90°. Little difference is to be expected when waves are reflected from the sea because both reflection coefficients approximate closely to real quantities at all angles of incidence.
Computations show that large differences between the two directions of propagation occur on east-west land paths in temperate latitudes, the greater loss occuring when waves propagate from east to west. Fig. 1 shows computed losses for east-west paths at 65° dip latitude at 0.5 and 1.5 MHz for both land and sea reflection. Fig 2 shows how losses vary with dip latitude when waves are reflected from land of the same conductivity as before. Losses in the northern and southern hemispheres are identical.
The difference between the two directions of propagation is most likely to be observed on paths which are just beyond the range of the one-hop mode; at this distance (2000-2500 km) the two-hop mode is reflected at angles near the Brewster angle. Unfortuantely, most of the U.S.A. measurements which satisfy this condition were made on paths from east to west; there are only two paths in the reverse direction (paths 1-3 and 5-2) where the two-hop mode is likely to predominate. The U.S.A. measurements do not therefore provide conclusive evidence for non-reciprocal propagation on multi-hop paths, although the large transmission losses observed on the east to west paths may well be due to the large intermediate reflection losses predicted for this direction of propagation. A carefully-controlled experiment would be required to prove the existence of non-reciprocal propagation.
The U.S.A. measurements suggest that east-west propagation on single-hop paths may also be non-reciprocal. However, the theory contained in Reference 3 shows that there would be no change in the polarisation coupling losses at the ends of the paths if the direction of propagation were reversed, provided the receiving antenna is either a vertical wire or a correctly-oriented loop. A carefully controlled experiment would again be necessary to determine whether single-hop paths are non-reciprocal.
Intermediate reflection loss is taken into account as one of several factors in the wave-hop method for m.f. sky-wave field-strength prediction.[4] Figure 9 of Reference 4 contains curves which enable intermediation reflection losses to be determined for various directions of propagation, frequencies, ground conductivities and arrival angles. Examination of these curves shows that non-reciprocal propagation is not confined to east-west paths. For example, two-hop paths at 45° to magnetic north, at 45° dip latitude, also show an appreciable non-reciprocal effect when reflection takes place from land at angles near the Brewster angle.
The various field-strength prediction methods which have been proposed for frequency planning take no account of variations of intermediate reflection loss or of the possibility of non-reciprocal propagation. Any method would become very complicated if such a correction were properly applied.

ACKNOWLEDGEMENT

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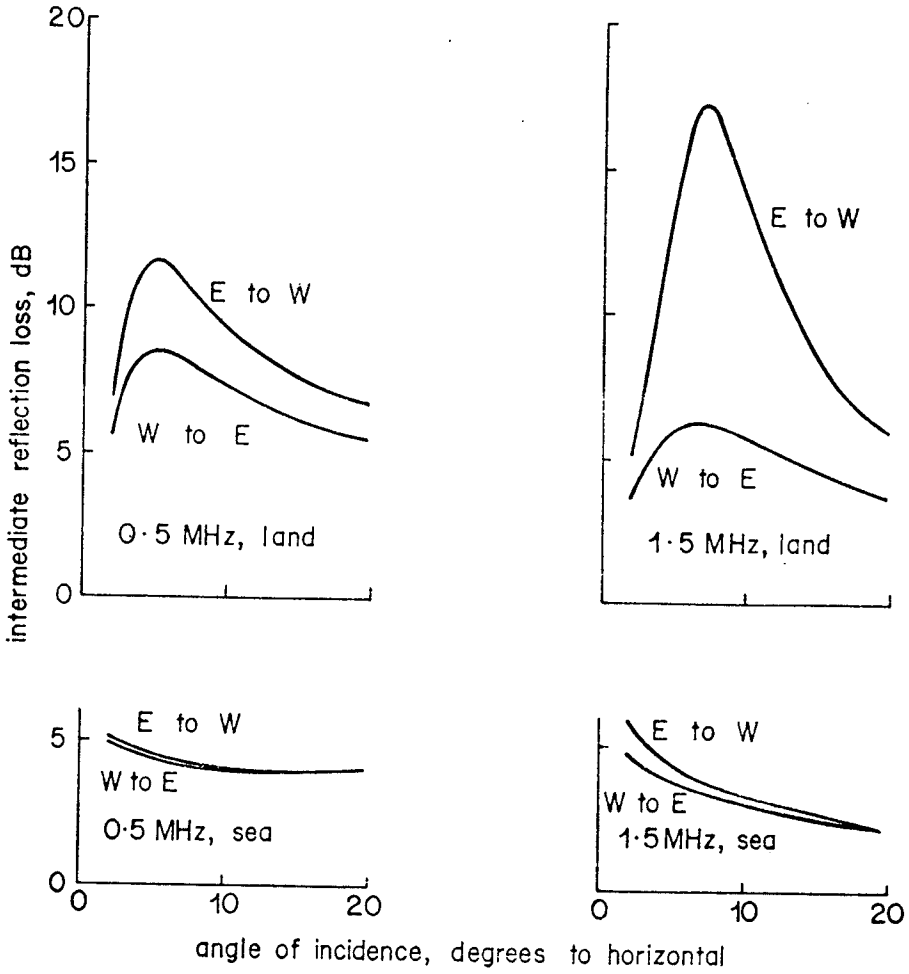

Fig. 1

Intermediate reflection loss on east-west paths at 65° dip latitude
Gyromagnetic frequency 1.25 MHz
Ground constants assumed for land paths: dielectric constant, 4 conductivity, 10 mS/m

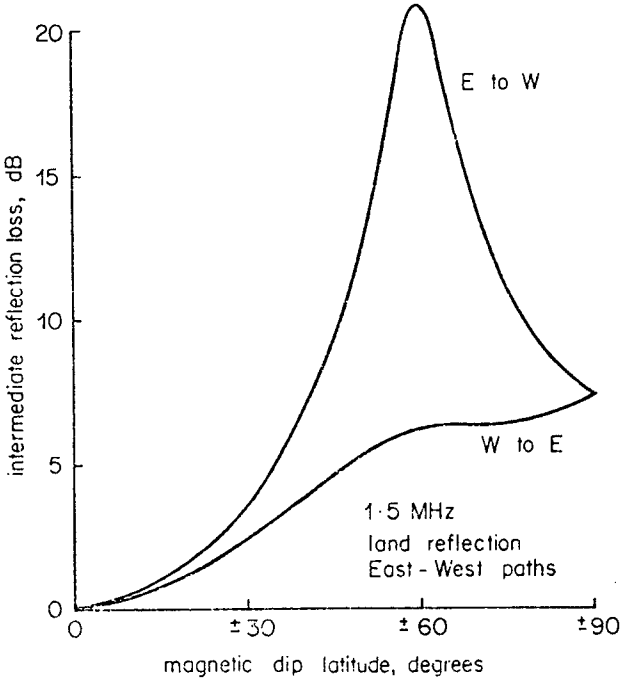

Fig. 2 Variation of intermediate reflection loss with magnetic-dip latitude