In Figures 25 and 26, we show propagation in both directions at frequencies of 2 MHz and 5 MHz. Since the results are in close agreement at the ends of the paths, reciprocity is well satisfied and the accuracy is probably quite good. We did not run WAGSLAB for higher frequencies over such a long path because of the large computer time which would have been required.

7. CONCLUSIONS AND RECOMMENDATIONS

The main purpose of this report is to describe a theoretical method for predicting HF ground wave propagation over irregular terrain with forest, building, or snow cover. The only method that appears to be general enough for detailed predictions over arbitrary paths is the integral equation method (Ott, 1971a). The approach which was adopted and described in Section 3 was to generalize Ott's program WAGNER (Ott et al., 1979) to allow for the effect of a lossy, anisotropic slab over the earth. The slab parameters can be chosen to match those of forest, snow, or buildings as discussed in Section 5. Although the approach was applied to the HF band (3 MHz - 30 MHz), it actually becomes more efficient as the frequency is decreased. For frequencies above HF, it is probably only useful for short, relatively smooth paths. The new computer code is called WAGSLAB and a user's guide, listing, and sample output are given in Appendix C.

Numerous special cases were considered in this report because they are good checks for WAGSLAB and because they are amenable to analytical solution. For uniform paths which are short enough to neglect earth curvature, the uniform slab model (Tamir, 1967; Wait, 1967a) is adequate. This model is described in Section 2, and the results are cast into a form convenient for ground wave propagation. When the path has two sections as in a forest-to-clearing case, an approximate analytical solution can be derived. This solution is derived and compared with the integral equation solution in Section 4. When the path is uniform, but is long enough for curvature to be important, then spherical earth theory (Hill and Wait, 1981b) can be used. It is compared with the integral equation solution in Section 6.1.

Two long, rough paths were analyzed by program WAGSLAB in Section 6.2. No experimental results were available, but some comparisons were made with multiple knife edge diffraction (Vogler, 1981). Also, reciprocity was checked by running the terrain profiles in each direction. This appears to provide an excellent check for asymmetric paths.

This report represents only a first attempt at ground wave prediction over irregular, forested, and built-up terrain. Numerous improvements and extensions are probably possible, but we recommend the following: (1) detailed comparisons

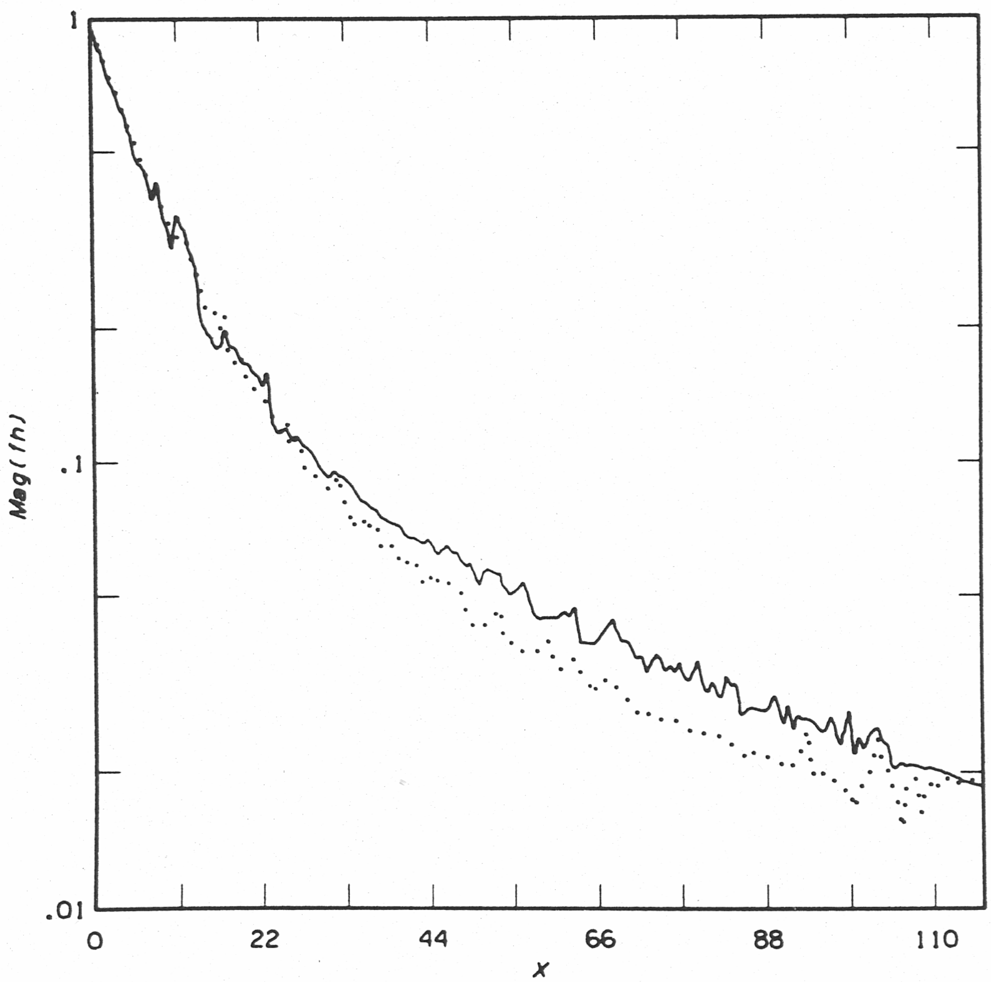

Figure 25. Propagation from Inneringen to Lechfeld (solid) and in the reverse direction (dotted). Both curves are for bare ground, and the frequency is 2 MHz.

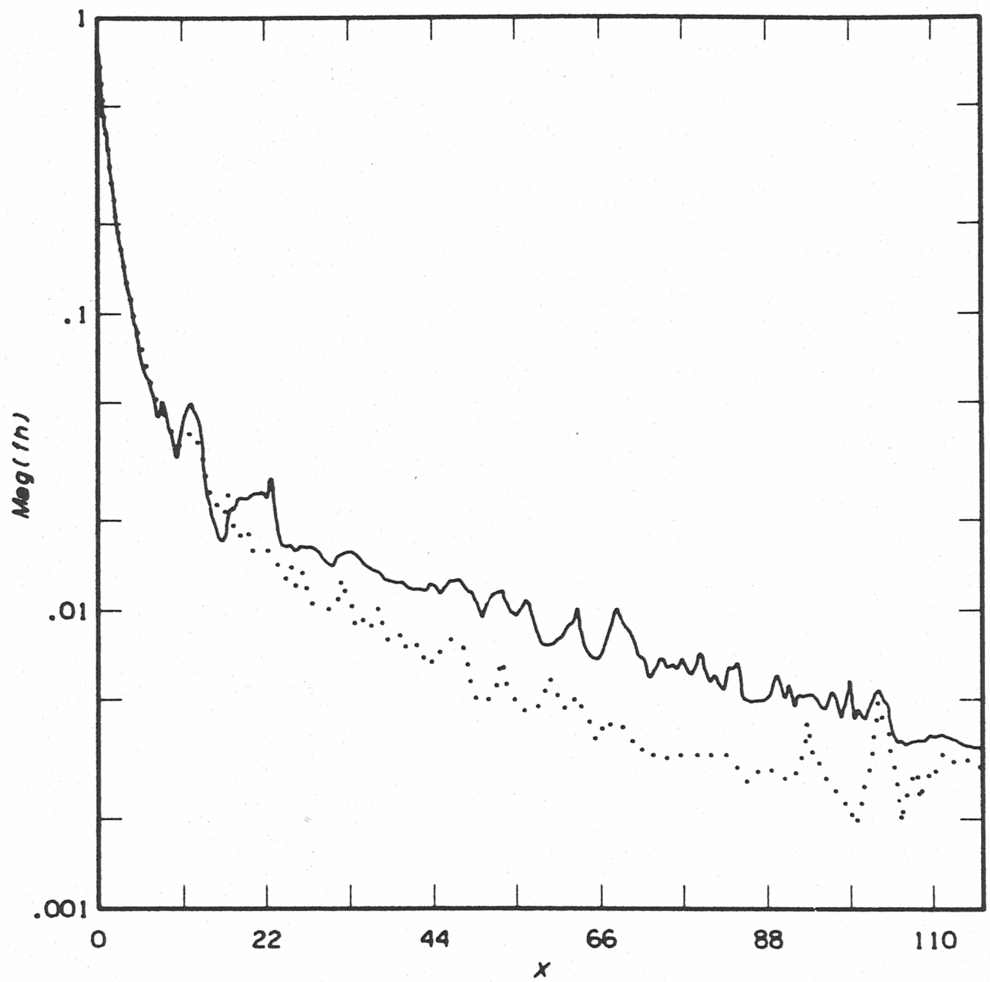

Figure 26. Propagation from Inneringen to Lechfeld (solid) and in the reverse direction (dotted). Both curves are for bare ground, and the frequency is 5 MHz.

with measurements over a variety of radial paths containing forest, building, and snow cover (NTIA Technical Memorandum 82-80 by Kissick and Adams, limited distribution); (2) a complete study of the limits of WAGSLAB for long paths and high frequencies; (3) consideration of a switch from the integral equation approach to multiple knife-edge diffraction for long, rough paths; and (4) the addition of an additional height-gain function for the magnetic field which would be applicable to reception with loop antennas. The height-gain functions for the vertical electric field and the horizontal magnetic field are equal in free space, but are different within the slab medium. This difference has been observed experimentally in cities and forests at MF by Causebrook (1978b). In addition it might be possible after a comparison with measurements to improve the theory for the equivalent slab parameters for cities or to infer the equivalent parameters directly from measurements.

8. ACKNOWLEDGMENTS

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