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COMPARISONS OF CALCULATED AND MEASURED HELICOPTER NOISE NEAR INSTRUMENT HILL

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SUMMARY

The polar parabolic equation (POPE) method solves for the diffraction of sound by a curved surface including a realistic sound speed profile. POPE is outlined briefly to describe diffraction which propagates the field over a hill. Experimental data are compared with POPE predictions using the measured sound speed profile and ground impedance. Two trial cases are considered for the comparisons: the helicopter located at the base of the hill and far away from the base of the hill, respectively. The physical mechanisms for sound propagation over a hill are examined with and of POPE calculations and experimental data. The shedding of rays from the hillside gives an interference effect with a wave along the flat surface beyond the base of a hill.

INTRODUCTION

The parabolic equation method[1] (PE) is a useful tool for outdoor sound propagation over flat, open, locally reacting ground surface with a realistic sound speed profile. The polar parabolic equation method is an extension of the PE method to solve non-line of sight sound propagation outdoors. POPE[2] introduces new coordinate systems into the PE to explain diffraction over a curved surface such as a hill. The coordinate system in POPE consists of the distance along the ground surface and the height perpendicular to the ground at any point. To introduce this coordinate system, the hill is segmented as shown in Fig. 1. The standard PE marches the field in range along the flat surface. POPE marches the field along the flat and curved surfaces.

COMPARISONS TO DATA

In order to verify POPE, the Terrain Masking experimental data are compared with POPE using a realistic sound speed profile. The Terrain Masking experiment was performed in the vicinity of Instrument Hill at White Sands Missile Range, New Mexico, during the period 27-28 July 1991. To use POPE, a hill shape is required which fits Instrument Hill as closely as possible. Figure 2 shows that the POPE hill and Instrument Hill fit very closely. Two trial cases are selected for the comparisons: Trial 172405 and trial 204405. The reference microphone was mounted 3 m above the top of the hill.

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Trial 172405

The helicopter was hovering 10 m high above the ground surface, 200 m away from the south base of Instrument Hill. Figure 3 shows the comparison at 10 Hz and Fig. 4 shows the comparison at 21 Hz. They show reasonable agreement with each other.

Trial 204405

The helicopter was hovering 17 m above the south base of Instrument Hill. Figure 5 shows the comparison of the POPE prediction and data at 10 Hz. Figure 6 shows the comparison at 53 Hz.

The comparisons with experimental data indicate that POPE is a good tool for predicting non-line of sight sound propagation outdoors where the source is located at the base of a hill or far away from a hill.

DISCUSSIONS AND CONCLUSIONS

Generally, the data and POPE show that the sound level along the masked side of the hill decreases linearly and the sound level along the flat surface beyond the base of the hill stays approximately constant or decreases slowly. At some frequencies along the flat surface, the sound level fluctuates with distance. In the following, consider two different sections of the hill: the hillside and the flat surface beyond the base of the hill.

A creeping wave was introduced in the residue series solution[3] for propagation over a curved surface. The creeping wave propagates over a curved surface within the shadow region corresponding to the hidden side over the top of a convex curved surface. The ground impedance mode was introduced for a wave propagating along the ground in the normal mode solution[4] in a downward refracting atmosphere which corresponds to the concave surface along the hillside. Therefore, the creeping wave propagates and couples into a ground impedance mode along the hidden side of a hill.

The shedding of rays from the creeping wave can reach the ground surface beyond the base of the hill, but the ground impedance mode propagates parallel to the flat surface. Therefore, the total field along this surface is determined by the superposition of rays which have been shed from the creeping wave and a wave along the ground beyond the base of the hill. If the shedding rays and the wave along the flat surface are in phase, the field level is increased at around 100 m beyond the north base of the hill as shown in Figs. 3 through 6. The POPE calculation in Fig. 7 shows a deep interference minimum resulting from the shedding rays and the wave along the surface at around 570 m.

We conclude that POPE predicts the helicopter noise propagation over a hill. Further, the POPE calculations and experimental data explain the physical mechanisms for sound propagation over a hill.

REFERENCES

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2. You, C.: Non-Line of Sight Sound Propagation Outdoors. Ph.D. dissertation. University of Mississippi, May 1993.

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4. Raspet, R.; Baird, G.E.; and Wu, W.: Normal Mode Solution for Low-Frequency Sound Propagation in a Downward Refracting Atmosphere above a Complex Impedance Plane. *J. Acoust. Soc. Am*, vol. 81, 1992, pp. 1341-1352.

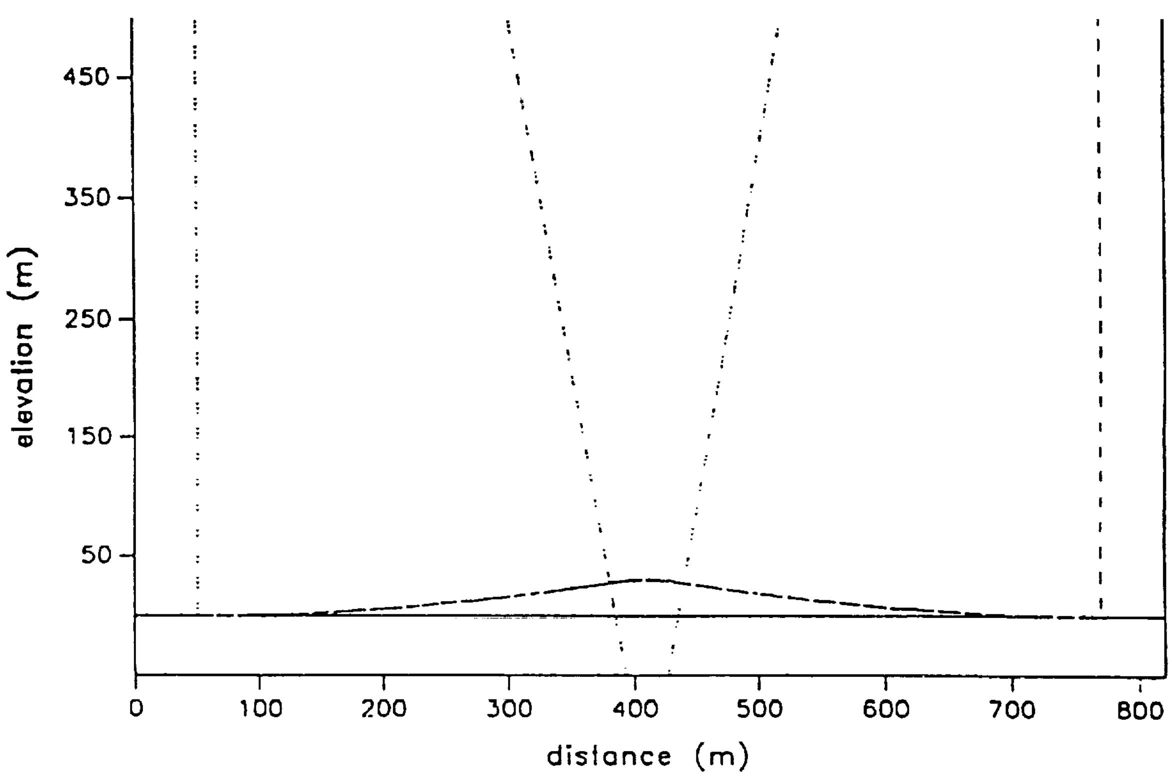

Figure 1. Segmenting a 30 meter hill for comparison with conformal mapping.

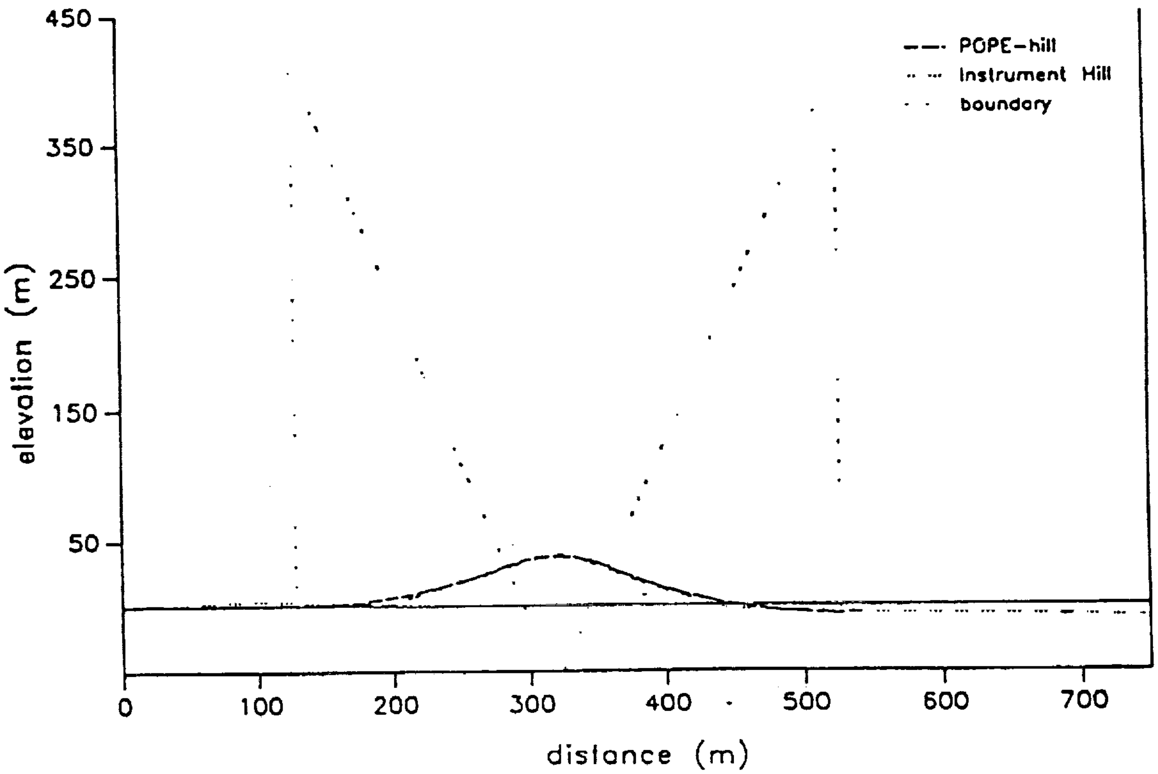

Figure 2. Elevation versus range for POPE-hill and Instrument Hill.

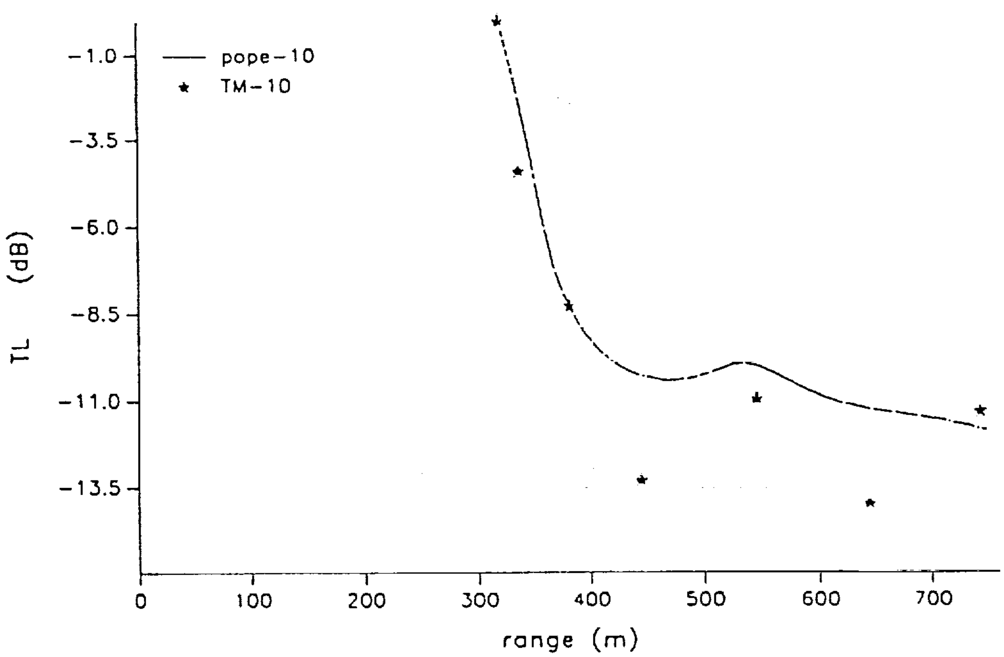

Figure 3. Comparison of Terrain Masking experimental data with POPE calculation at 10 Hz when helicopter hovers 10 m above the ground surface 200 m from the south base of Instrument Hill.

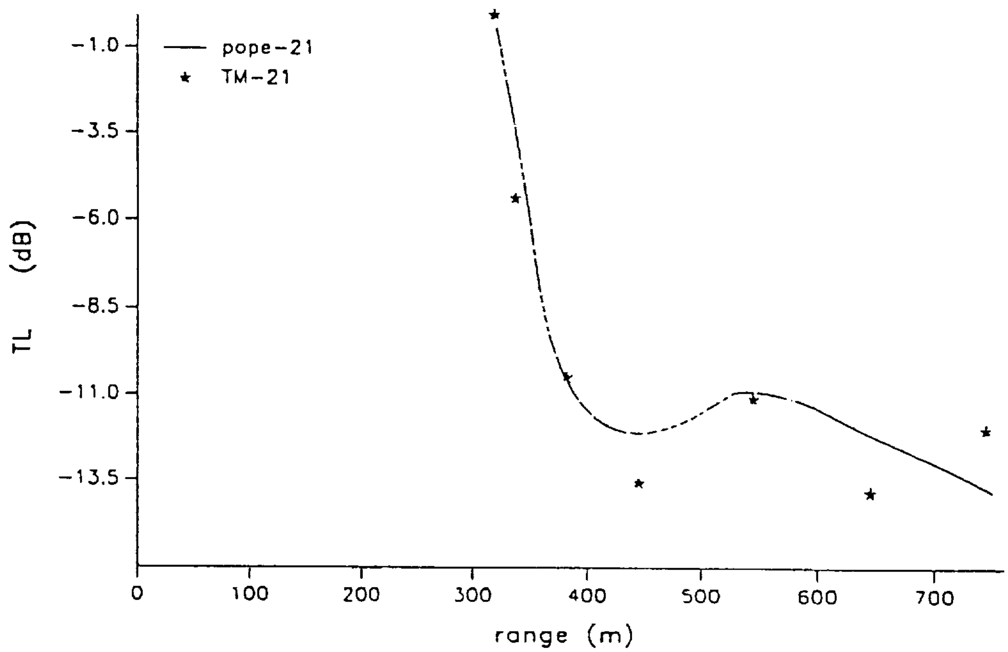

Figure 4. Comparison of Terrain Masking experimental data with POPE calculation at 21 Hz when helicopter hovers 10 m above the ground surface 200 m from the south base of Instrument Hill.

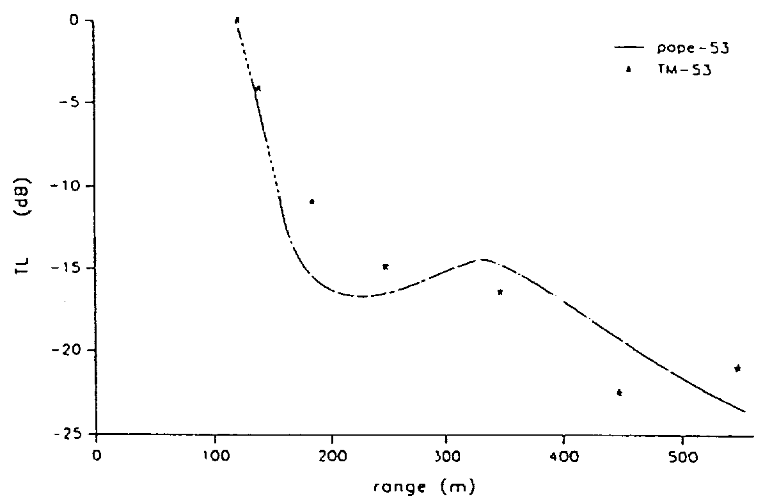

Figure 5. Comparison of Terrain Masking experimental data with POPE calculation at 10 Hz when helicopter hovers 17 m above the south base of Instrument Hill.

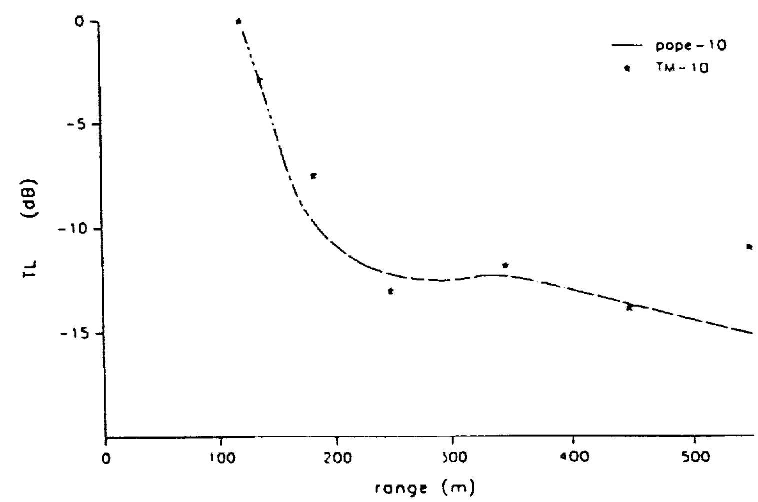

Figure 6. Comparison of Terrain Masking experimental data with POPE calculation at 53 Hz when helicopter hovers 17 m above the south base of Instrument Hill.

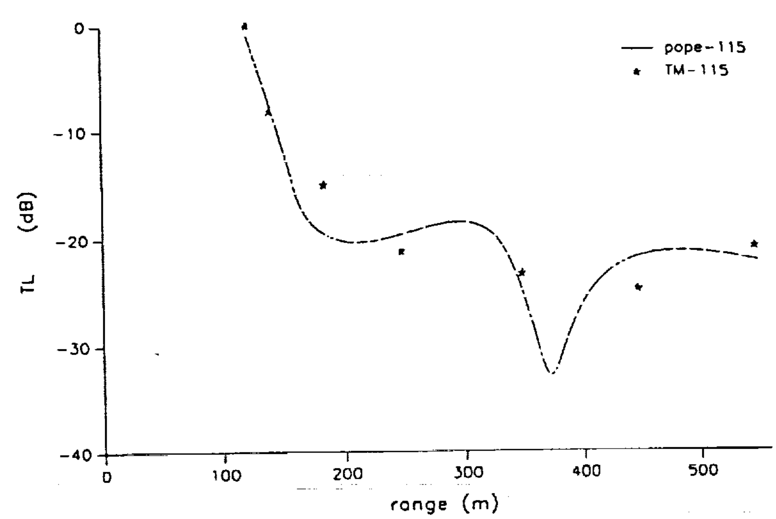

Figure 7. Comparison of Terrain Masking experimental data with POPE calculation at 115.7 Hz.