A FAST RAY OPTICS MODEL FOR PROPAGATION, RADAR, AND COMMUNICATIONS PERFORMANCE ANALYSIS

Raymond P. Wasky*, Jonathan Z. Gehman
The Johns Hopkins University, Applied Physics Laboratory
11100 Johns Hopkins Road
Laurel, Maryland 20723-6099

This paper presents an overview of a fast and versatile ray optics model for accurate calculations of radar elevation, height, and range errors, and lens loss due to tropospheric refraction. The model, Ray Tracing Computer Analysis Program, Version 3 (RAYCAP-3), is a first-principles ray tracing model that can be used to analyze both laterally homogeneous and non-homogeneous refractive atmospheres having a vertically stratified index of refraction. RAYCAP's greatest use has been to correct radar metrics data along target trajectories. Examples are presented to show refraction errors due to surface-based ducts as well as several standard exponential atmospheres with differing surface refractivity values and antenna heights.

Numerous tropospheric ray tracing models have been developed over the years, with some of the most recent reported by Hitney (H.V. Hitney, URSI National Radio Science Meeting, pg. 67, 1996), Bothias (L. Boithias, *Radiowave Propagation*, McGraw-Hill, New York, NY, pp. 111-114, 1987), and Crane (R.K. Crane, *Propagation Handbook for Wireless Communication System Design*, CRC Press, New York, NY, pp. 111-114, 2003). Many such ray optic models are limited to near-horizontal propagation due to their simplifying approximations, or are confined to laterally homogeneous atmospheres. RAYCAP-3 is not restricted by these limitations, and can operate at nearly all elevations and with range-varying refractivity profiles. It calculates the direction of wave front propagation by solving the earth-centered Euler-LaGrange equations of rays normal to incremental wave front surfaces. RAYCAP-3 maximizes its ray density at low elevations, and uses fewer rays at higher elevation angles to improve run time. This paper includes an overview of the capabilities and limitations of the model.

RAYCAP-3 can accept refractivity data in two ways: by specifying the surface refractivity and fitting to an exponential refractivity model; and by inputting multiple vertical refractivity profiles along the propagation path from radiosonde or rocketsonde data. Portions of the code have been incorporated into the Johns Hopkins University Applied Physics Laboratory's Tropospheric Electromagnetic Parabolic Equation Routine (TEMPER) to determine the grazing angle of energy at the earth's surface within an inhomogeneous refractive medium.