Ray Propagation in Inhomogeneous Atmospheres Over High Resolution 3D Terrains

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Ground surveillance radars and terrestrial communication systems are strongly influenced by atmospheric propagation phenomena and terrain structure. Parabolic wave equation methods are most often used for modeling the propagation and scattering phenomena, but the methodology is restricted to two dimensions. Three-dimensional ray tracing has been used effectively to analyze propagation in inhomogeneous media; moreover "shooting-and-bouncing" techniques have been used successfully to calculate scattering from large complex objects. A marriage of ray tracing and "shooting-and-bouncing" methods is attractive here, but the atmosphere-terrain interface presents a challenge. Terrain elevation data are typically processed to extract the height of the earth's surface, which leaves artificial structure behind and eliminates critical scattering structures. Surface models that preserve structure on the earth's surface typically have not been readily translated into tractable boundary specification for scatter computation.

This dilemma was resolved coincidentally. Terrain elevation maps derived from high-resolution interferometer synthetic aperture radar data have been made available prior to extracting "bald-earth" digital terrain maps. Because the terrain elevation data are derived from surface backscatter, the results are intrinsically smooth on a scale suited for ray bouncing. Although terrain dielectric properties are highly inhomogeneous, surface reflectivity is mirror-like at the small grazing angles associated with the dominant reflections that support long-range propagation; moreover, neglected backscatter glints, although easily detected, represent a small fraction of the incident energy. An efficient computer code has been developed and tested for X-band and Ku-Band ray tracing over high resolution (5-m by 5-m by 1-m elevation) digital surface maps. Results will be presented for highly variable terrain areas approaching 10 Km by 10 Km.

Within visible regions points above the surface may or may not be affected by multipath. We have observed that where reflected rays coincide with the direct path there is a finite probability of interference with more than one ray. Because of the long paths involved, the bounce rays are all largely out of phase with the single in-phase direct path. The net result is multipath speckle that presents an opportunity for detection at ranges that would otherwise suffer large propagation losses.