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THE APPLICATION OF NUMERICAL SIMULATIONS IN BEACON SCINTILLATION ANALYSIS AND MODELING

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Abstract. This document describes a talk to be given in the 2010 Beacon Satellite Symposium Session 5 Scintillation Measurements and Model'

1 INTRODUCTION

Modeling beacon satellite scintillation presents unique challenges. The propagation distances are large and the geometry changes continuously. The ionospheric structure is anisotropic and varies along the changing propagation paths. As a consequence, it is difficult to organize scintillation measurements with respect to driving-point conditions and to map local scintillation structure to other regions in the propagation space. Most scintillation models use a mix of theory and empirically derived structure inputs. However, numerical simulations have evolved significantly, particularly in their application to the physical processes that generate the structure. This paper presents some recent applications of numerical simulations to propagation in structured plasma.

Numerical simulations have made important contributions to strong-scatter, the physics of beacon scintillation, and its systems effects. However, most of beacon applications have been limited to one-dimensional structure-models. The results to be presented are fully three dimensional, and build on a reformulation of scintillation theory.

To briefly review the theory, consider the coordinate system shown in Figure 1. Let $\Psi(x,\rho)$ represent a scalar field measurement in the xy plane. The following equation forms the basis of the simulations: $\partial\Psi\_k(x,\rho)\partial s = ik\Theta\_k\Psi(x,\rho) + ik\delta n(x,\rho)\Psi\_k(x,\rho)$ The term $\Psi\_k(x,\rho)$ represents the field in the continuously displaced coordinate system. The term $\Theta\_k\Psi\_k(x,\rho)$ is a diffraction operator akin to the corresponding term in the parabolic wave equation. The term $\delta n(x,\rho)\Psi\_k(x,\rho)$ represents the media interaction, essentially a phase perturbation. The split-step method is used in a continuously displaced coordinate system that remains centered on the central ray in Figure 1. The structure is constrained only by the requirement that gradients over wavelength scales must be small. Propagation can be simulated at any aspect relative to the magnetic field.

Structure is generated with appropriate geometric transformations to accommodate oblique propagation in the continuously displaced coordinate system. The simulations produce a realization of the instantaneous field structure mapped onto the measurement plane centered on the receiving antenna. The apparent velocity of the structure is determined by the source, receiver, and drift motion of the structure. A point measurement is simulated by interpolating the two-dimensional field along the effective scan direction.

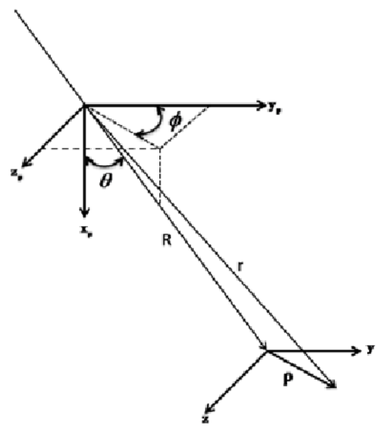

Figure 1: Propagation geometry.

2 RESULTS TO BE PRESENTED

Figure 2 shows the simulated intensity field for an equatorial high-elevation pass. The white line show the effective scan direction. The anisotropy reflects the projection of the magnetic field direction mapped onto the measurement plane. A uniform power-law structure distribution in the scale-free regime produced the large-scale variation of the intensity structure. Figure 3 shows the intensity structure that would be observed by a receiving station (upper frame). The lower frame shows the scintillation index computed over segments spanning $\sim 500m$.

The presentation will discuss the phase structure and robust spectral-domain measures that can be used to interpret the power-law characteristics of the structure. The analysis emphasizes the large scale phase structure that can be extracted from total electron content measurements. This structure is transitional between statistically homogeneous structures that can be modeled by conventional correlation measures and larger-scale trend-like structures.

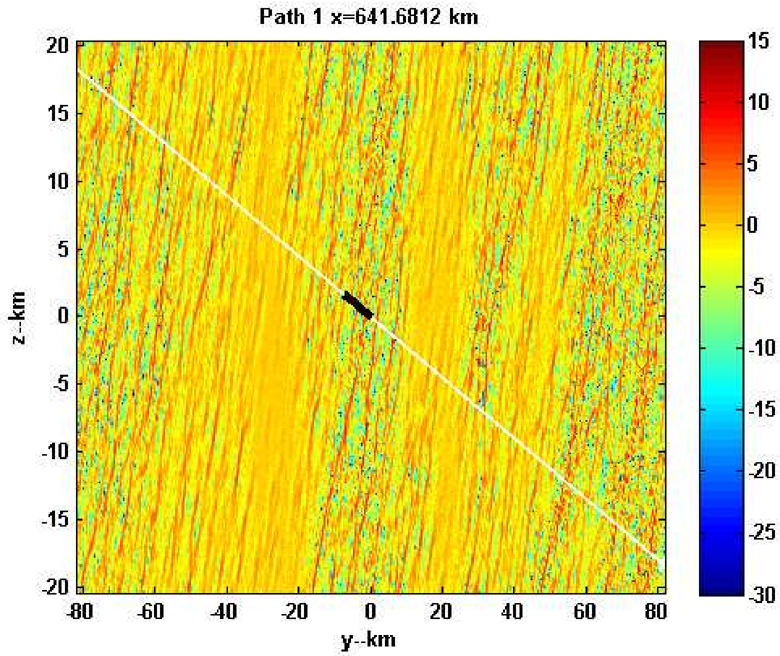

Figure 2: Simulated measurement-plane intensity field.

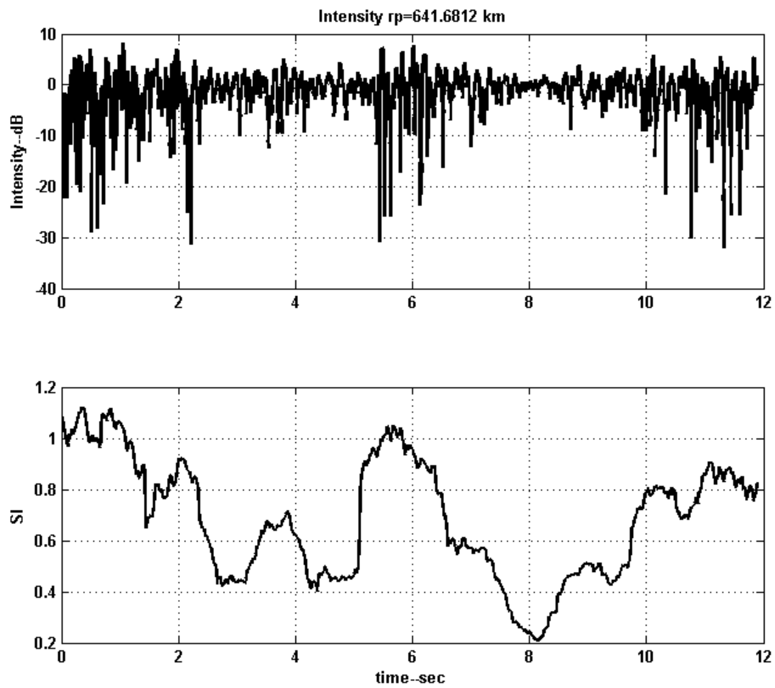

Figure 3: Intensity structure along scan direction.