Numerical computation of signal log-amplitude variance in tropospheric turbulence

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Small scale fluctuation of the refractive index leads to the phase and amplitude variation of an electromagnetic (EM) signal passing through the troposphere. This phenomenon is known as the tropospheric scintillation. Though the scintillation effect on the wave magnitude may be minimal, it has a significant cumulative effect on the wavefront at long ranges. Such fast fading becomes a major impediment for low-margin systems, low elevation angle (less than 10 degrees) air-ground links and systems operating at high frequencies (above 10 GHz). Various empirical models exist to characterize such fade depths. However, the models take into account very few atmospheric parameters, almost no location parameter and works mostly at low frequencies (mostly, till 20 GHz). This necessitates the study of the signal log-amplitude variance due to tropospheric turbulence by numerical models. In this work, we use the parabolic wave equation (PWE) along with large eddy simulations (LES) to numerically compute the log-amplitude variance.

Large eddy simulation is a computational fluid dynamics tool, which based on a local numerical weather prediction tool or mesoscale atmospheric measurements, provides thermodynamic parameters from a which a three-dimensional refractive-index profile can be generated. Since LES incorporates the real-time atmospheric parameters of a particular region in the generated refractive-index realization, it improves upon the assumptions used in the empirical models. Usually LES includes turbulence due to eddy sizes extending into the inertial subrange (around 100 m). However, smaller scale turbulence has more impact on the log-amplitude variance at high frequencies. Hence, the power spectral density (PSD) of the refractive index extracted from the LES are extended so that they cover the entire inertial subrange (till mm scale length). The refractive index PSDs are used to define phase PSDs, which in turn leads to random phase realization to be used in the PWE. Two different phase screen realizations can be generated out of the refractive index PSD, one assuming the random media is uncorrelated in the propagation direction, which is termed as the uncorrelated phase screen method, and the other without this assumption, termed as the correlated phase screen method. Both the techniques have been used in the numerical computation of variance of a spherical wave propagating in a turbulent atmosphere and the results obtained have been compared to analytical result. It has been shown that the correlated phase screen method is advantageous over the uncorrelated one, especially at higher frequencies (above 10 GHz).