Numerical computation of fading depth for tropospheric scintillation

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For low elevation angle (below 10 degrees) air-ground links, ITU has three different models to calculate the fade depths, namely ITU deep (for fade depths>25 dB), ITU shallow (for fade depths<25 dB and elevation angle<5 degree) and the Karasawa model (for elevation angle>5 degree). The Karasawa model depends on the wet term of the refractivity, N_{wet}, and accounts for the major variability of the fade depth at a particular location. This is because the ITU deep model, which has a latitude factor contributing to the fade depth, does not vary at a given location and the ITU shallow model is a fit between the ITU deep and the Karasawa model. Since the Karasawa model works till 20 GHz, the ITU models cannot be used above this frequency. However, at high frequencies fast fading occurring due to variability of tropospheric refractivity, which is termed as scintillation in this paper, becomes a major impediment, especially for low margin systems.

An alternate approach is to obtain the distribution of propagation loss of an electromagnetic (EM) wave traveling through the troposphere at a particular range and height, from which the fading depth at that location can be found. The Large Eddy simulations (LES), which is initialized by a local numerical weather prediction tool or real mesoscale atmospheric measurements, provides thermodynamic parameters from which a 3D refractivity profile of a region can be generated. Usually LES includes turbulence due to eddy sizes extending into the inertial subrange (around 100 m). A Monte Carlo analysis can be done with several realizations out of this 3D refractivity profiles, using each of them in a parabolic equation (PE) based EM propagation model, like Advanced Propagation Model (APM). The advantages of this technique are that it can be used at any frequency and can also incorporate real-time numerical weather predictions to calculate a real-time expected fading depth.

The power spectral density of turbulence, extracted from LES, has been extended to cover the entire inertial subrange (upto mm). These smaller scale turbulences have a larger impact on fade depths at higher frequencies (more than 20 GHz). Even at 10 GHz, fade depth obtained from the LES-EM simulations has been found to be more than the worst-case prediction of fade depths by ITU models at certain ranges and heights. Future work will try to explain theoretically the discrepancy in fade depth prediction by ITU models and LES-EM simulations. Moreover, roughness of land/sea will also be incorporated into the LES-EM simulation process and experiments will be done to obtain data for scintillation study at low elevation angles.