Simulation of tropospheric total attenuation based on numerical weather forecast simulations

Keywords : Tropospheric attenuation; Numerical weather forecast; Earth observation data downlink.

Laurent Quibus, Carlos Pereira, Danielle Vanhoenacker-Janvier

Abstract – Tropospheric total attenuation is well modelled for Earth to satellite communication in clear air and rainy conditions. Time series simulators have been developed for geostationary links but are not valid for spatial applications involving Low Earth Orbit (LEO) satellites such as Earth Observation Satellites. A new simulator is developed in order to take into account both the dynamic behaviour of the troposphere and the movement of the LEO satellite. This model takes advantages of the outputs generated by Weather Research and Forecasting software which simulates the space-time behaviour of the turbulent troposphere.

The necessity of increasing the data rate for new spatial applications forces the utilization of higher frequencies, such as Ka-band (26.5-40 GHz) and W band (76 GHz). At these frequencies however, the signal transmitted becomes more sensitive to the tropospheric impairments. Even in the absence of rain, the scintillation generated by tropospheric turbulences in the lower part of the atmosphere impacts significantly the performances of the systems for low elevation links.

The WRF simulator

The WRF simulator [1] provides high resolution reanalysis and weather forecast simulating the space-time variation of the troposphere, with as output vertical profiles of pressure, temperature, humidity, rain, wind speed, etc. These parameters obtained with a kilometric space resolution enable the evaluation of propagation effects as attenuations due to gases, cloud and rain [2]. The outputs of this simulator are also used to compute the refractive index and its constant structure parameter for the assessment of the turbulent intensity and the calculation of its effects on radio wave propagation. Figure 1 shows a vertical cut of the evolution of the specific content of water vapour from WRF.

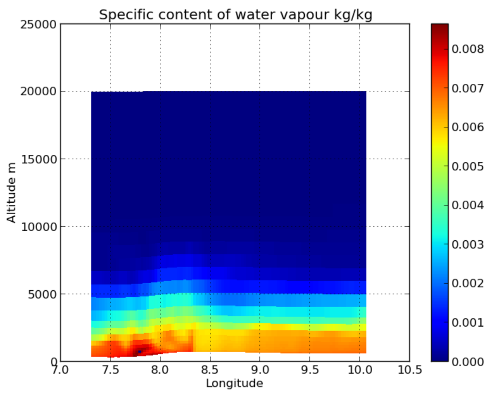

Figure 1: Vertical profile of specific water vapor content from WRF simulator.

The tropospheric scintillation modeling

The model for tropospheric scintillation has been developed; it is based on a space-time varying meteorological environment simulated by a Numerical Weather Research and Forecasting simulator (WRF). The atmospheric data are used to quantify the turbulence intensity (proportional to the structure constant of the refractive index of the medium C_{n^2}) and predict the scintillation properties. Figure 2 shows C_{n^2} at 2000m, where its intensity is maximum for this time of the day.

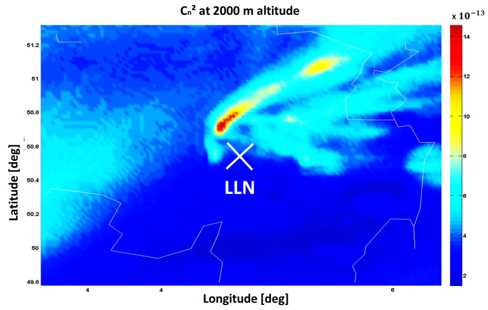

Figure 2: Intensity of refractive index structure constant C_{n^2} above Louvain-la-Neuve on 7/7/90 10 am from WRF simulator.

The azimuth and elevation of the satellite during its passage above the station is then calculated from its orbital parameters and the time evolution of the signal received by the ground station is simulated taking into account the movement of the satellite and the movement of the air masses, clouds and rain simulated by WRF. An example of time series of scintillation due to turbulence is shown in Figure 3.

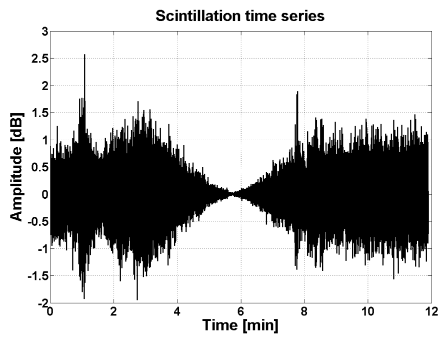

Figure 3: Time series of scintillation simulated using WRF meteorological parameters.

The full attenuation model is under development for Earth-LEO links simulation and tropospheric degradation nowcasting.

References

[1] Michalakes, J., et al., "The Weather Research and Forecast Model: software architecture and performance". 11th Workshop on the Use of High Performance Computing in Meteorology, United Kingdom, ECMRWF, 2004.

[2] Jeannin N., Outeiral M., Castanet L., Pereira C., Vanhoenacker-Janvier D., Riva C., Capsoni C., Luini L., Cossu M., Martellucci A., "Atmospheric channel simulator for the simulation of propagation impairments for Ka band data downlink", 8th European Conference on Antennas and Propagation, EUCAP2014, April 2014.