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Elevation Scaling of Rain Attenuation Time Series

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In satellite links, the variations in the elevation angle have a strong impact on the magnitude of the attenuation induced by rain because the path-length across precipitation increases with the decrease in the elevation. In particular, it is definitely challenging to identify of a proper way to scale the instantaneous values of rain attenuation with the elevation as it is needed for the development of a time series generator suitable for non-geostationary satellites systems.

In this contribution we propose a methodology to scale up the time series of rain attenuation from low elevations angles – generated with the procedure described in [1] – to higher ones. The model relies on simulations carried out on the synthetic rain fields generated by the MultiEXCELL model [2], as well as on direct measurements from the ITALSAT experiment. By analysing the attenuation time series obtained from the MultiEXCELL synthetic rain field maps for a large range of elevations, we studied the variations occurring from one elevation to another. Obviously, the simple scaling law that multiplies each single value of attenuation by the ratio between the path lengths ($[\sin(\theta_{ref})/\sin(\theta)]$) is not valid because:

a) The path-length-ratio law applies reasonably well on statistical basis only for angles above 20°.
b) At lower elevations a correction to the path length ratio must be applied even on statistical basis [1].
c) Because the number of rain structures crossed by the radio link is likely to increase at lower elevations.
d) We are interested in reproducing, although statistically, the actual instantaneous variation in $A(\theta)$.

The synthetic attenuation time series obtained from MultiEXCELL were subdivided into rain events and a percentage error dependent on the initial θ_{REF} and the final θ, as well as on the peak attenuation, is derived for each of them. Then the error functions are duly modelled. As the time series generator is for non-geostationary satellites applications, the analysis is done from a minimum elevation ($\geq$ 5°) up to the maximum one (90°) in 1° step.

The generator will receive in input a proper set of measured (ITALSAT experiment) attenuation time series selected in order to reproduce the CCDF at the initial elevation angle according to the procedure outlined in [1] and in [3]. The scaling method applied to this set of time series consists in a combination between the scaling with the path lengths ratio and the error functions mentioned above. In this way we are able to generate correspondent time series for all the angles, which, once summed up, reproduce quite accurately the long-term statistics (CCDFs) of rain attenuation for each elevation angle (as predicted by the MultiEXCELL synthetic rain field maps, which is here assumed as the reference).

Once we have the time series of rain attenuation for all the elevations of a LEO or MEO satellite, we derive the non-geostationary one by selecting and combining pieces from the different elevations and applying the azimuthal weighting function.

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2. L. Luini and C. Capsoni, "MultiEXCELL: A new rain field model for propagation applications," IEEE Transactions on Antennas and Propagation, November 2011.
3. L. Resteghini and C. Capsoni, "A time series synthesizer of tropospheric impairments affecting satellite links developed in the framework of the Alphasat experiment (PhD. Dissertation)," Politecnico di Milano, Milan, 2014.