SCINTILLATION PREDICTION USING IMPROVED PRE-PROCESSED RADIOSOUNDING DATA

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Tropospheric scintillation has an impact on earth-space low availability and deep-space systems, but also on fade mitigation techniques that are developed for communications above 20 GHz. The classical prediction models [1] predict the cumulative distribution of scintillation variance using ground measured data, such as temperature and humidity. Scintillation being due to the presence of turbulence in the troposphere, it is realistic to expect that the accuracy of the prediction should be increased if height profiles of those parameters should be used.

A proof of feasibility that radiosoundings are able to adequately predict the cumulative distribution of the variance of the signal received from the satellite ($\sigma_\chi^2$), in the presence of turbulence, has been given by Vasseur [2]. The method however required a manual check of the data and the goal of this work is to improve the accuracy of the prediction method and to avoid manual inspection of the data. Under the classical assumption of log-normally distributed short term scintillation variance $\sigma_\chi^2$, its mean value is expressed as

$$\overline{\sigma_\chi^2} = 42.48 \frac{k^{7/6}}{(\sin \alpha)^{1/6}} \sum_z \overline{C_n^2(z)} \Delta z$$

where $k$ is the free-space wavenumber, $\alpha$ is the elevation angle and $\overline{C_n^2}$ is the mean structure function of the refractive index, at height $z$ above the ground, averaged over one month or one year. The hypotheses and limitations of this method have been presented in [3].

In the early years, routine radiosoundings only contained data at WMO standard and significant levels. Since 1990, the operational radiosoundings at the Royal Meteorological Institute (RMI) record measurements every 10 seconds, leading to a vertical resolution between 50 and 100m. The turbulent layers show a thickness of a few meters, so the small scale structure is not visible in the radiosounding data and a probability of turbulence in the layer is used for the calculation of $C_n^2$. Furthermore, the calculation of $C_n^2$ profiles is very sensitive to the noise present in the measurements of temperature and humidity. The presence of their derivatives in the mathematical expression of $C_n^2$ further enhances the noise in the final values.

A first improvement has been obtained by using a four-point derivative but it is not enough to solve the problem [3]. As the humidity profiles measured with operational radiosondes are known to (i) show a dry bias due to an inaccurate basic calibration model for the temperature dependence of the sensor response at low temperatures, (ii) contain a ground-check error, and (iii) exhibit a time-lag error, the RMI re-processed the vertical humidity profiles, applying the correction algorithms proposed by Leiterer et al. [4]. Their method is based on simultaneous soundings consisting of routine sondes and research reference sondes with their own calibration/calculation method.
Using the new pre-processed data, the 4-point derivative and excluding the \( C_n^2 \) points that do not respect the log-normal distribution of \( C_n^2 \) for each height, the cumulative statistics of scintillation improves drastically, as shown in Figure 1. This figure shows the measured cumulative distribution of the scintillation variance \((\sigma^2)\), the cumulative distribution using the classical radiosonde data from British Atmospheric Data Centre (BADC) without any pre-processing (BADC), the cumulative distribution using the pre-processed RMI data used by H. Vasseur (Vasseur) and the cumulative distribution using the newly pre-processed radiosonde data (RMI).

![Cumulative distribution of the scintillation variance using radiosoundings, for different processing methods.](image)

It can be concluded that the new pre-processing of the humidity proposed by the RMI improves drastically the precision of the prediction of the cumulative distribution of the scintillation variance.

References


