Electromagnetic Propagation Model in a Turbulent Medium : Comparison between direct stochastic approach results and real data measurements

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We have previously developed a direct stochastic method to generate the response statistics of the electromagnetic field in a random turbulent medium [1][2]. We study in this work the extension of this approach to the propagation over a randomly distributed surface.

First of all, we recall the main steps of the method : the effects of atmospheric turbulence on electromagnetic wave propagation are simulated by adding appropriate random fluctuations to the main deterministic refractive index profile. Introducing this random component in a standard parabolic equation model, we derive a stochastic partial differential equation (SPDE). From this SPDE, using stochastic calculus rules, and more precisely Ito Formalism, we can derive directly the (deterministic) partial differential equations of ALL the moments.

The mean electromagnetic field (first moment) is then proved to be the solution of a modified parabolic equation (MPE) very closely related to the initial PE. A slight modification in any existing code thus allows a direct computation of the first moment of the system response. Results are compared with those derived from a Monte Carlo method and with the analytical solution obtained by V.A. Tatarski using an other formalism, and show very good agreements between each other.

Moreover, this approach allows us to describe accurately turbulence index fluctuations along the vertical coordinate, particularly through the structure constant $C_n^2(z)$ of the turbulence process. We thus use this model in real data analysis, obtained during a RCS measurement campaign during which both meteorological and electromagnetic measures were made simultaneously. Pressure, temperature and humidity measurements, from an instrumented buoy, allow us to compute $C_n^2(z)$ profile in the lower atmospheric surface layer, using the accurate PIRAM model (developed by the CELAR). Moreover, the mean refractive profile is given either by radiosonde data, or by the meteorological mesoscale Meso-NH model outputs, developed by Meteo France : we can thus compare the different model results directly with electromagnetic data obtained by the experimental radar on a calibrated sphere.

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[2]Mandine E. “Modélisation de la propagation des ondes électromagnétiques en milieu aléatoire – Application au couplage entre un modèle de prévision météorologique et un modèle de propagation de type parabolique”
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