PhD Position:
PEMTIM: Electromagnetic Propagation through Turbulent Media: Multiscale modelling Investigation

ENAC: French National University of Civil Aviation
ISAE:

General Information

Location: French National University of Civil Aviation (ENAC), Toulouse, France
Supervision: Rémi Douvenot, Hélène Galiègue (ENAC) and Stéphane Jamme (ISAE)
Starting Date: between Septembre and Decembre 2021
Duration: 3 years
Funding: **CNES** and Research Federation (ONERA, ISAE, ENAC)
Candidate Profile: Engineering student / Master 2. Skills in radiowave propagation, mathematics, signal processing

Context

Atmospheric turbulence has an important impact on RF and optical signal propagation, on both their phase and amplitude: for example, ionospheric scintillation impacting GNSS L-band signals or tropospheric turbulence impairing SAR imaging and link-budget of wireless optical links.

Propagation tools have been already developed to estimate the phase and amplitude of electromagnetic signals through a turbulent atmospheric layer. They mainly use a spectral Kolmogorov representation to model the turbulence, both for the troposphere and the ionosphere. However, turbulent structures exhibit multiscale anisotropy features that are not correctly modeled by the Kolmogorov spectrum [1, 2]. Moreover, the error made using Kolmogorov's representation in propagation tools has not been assessed yet.

Objectives

The main objective of this PhD is to propose a multiscale model for the atmospheric turbulence (ionosphere and troposphere), based on multi-fractal developments, scattering moments and hydro-dynamic models of the atmosphere, in order to better fit the physical characteritics of traversed media. For this purpose, three main steps are then followed:

- to assess the error of Kolmogorov representation vs multiscale developments;
- to model an accurate and fast atmospheric model based on a multiscale representation (wavelets and scattering moments [3]);

- to implement multi-scale schemes in the propagation tools using SSW formalism, without increasing the computation time;
- to retrieve medium physical parameters from real data.

This thesis project will follow the following steps:

- state-of-the-art on multi-scale solutions and SSW propagation formalism;
- state-of-the-art on tropospheric and ionospheric turbulence and scintillation;
- assessment of the error between physic-based models, multi-scale modelling and Kolmogorov spectrum for the estimation of propagation parameters (amplitude and phase);
- data processing to characterize tropospheric and ionospheric medium physics using the parameters of the multiscale representation.

Applying

Candidates should demonstrate skills in one or more of the following fields: mathematics, signal processing, numerical simulations, electromagnetic propagation. A good English level and good writing skills are also requested.
Interested candidates should apply to the CNES website.

Contact

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References

[1] V. Malkin and N. Fisch, "Transition between inverse and direct energy cascades in multiscale optical turbulence," *Physical Review E*, vol. 97, no. 3, p. 032202, 2018.

[2] S. Mallat, S. Zhong *et al.*, "Characterization of signals from multiscale edges," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 14, no. 7, pp. 710–732, 1992.

[3] M. Andreux, T. Angles, G. Exarchakis, R. Leonarduzzi, G. Rochette, L. Thiry, J. Zarka, S. Mallat, J. Andén, E. Belilovsky *et al.*, "Kymatio: Scattering transforms in Python." *Journal of Machine Learning Research*, vol. 21, no. 60, pp. 1–6, 2020.