PEMTIM : Electromagnetic Propagation Through Turbulent Media : a multiscale modelling investigation

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Context

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

Propagation tools have already been 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].

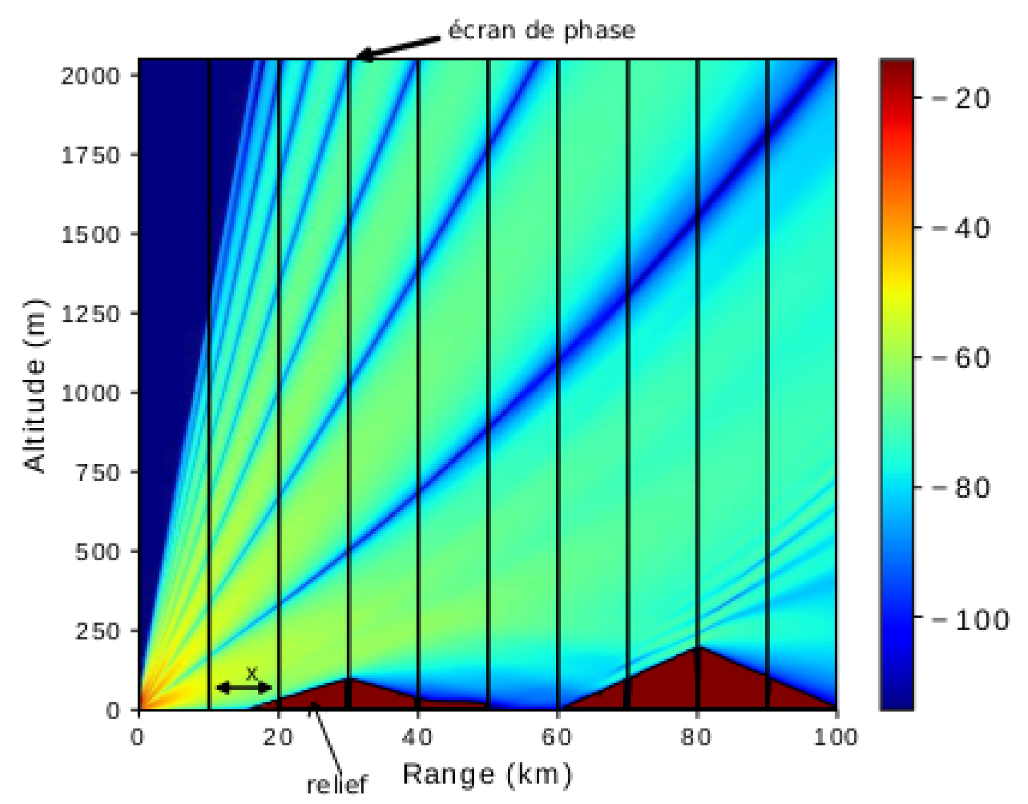

Figure 1: Electric field (dBV/m) obtained with SSW 2D in a non-turbulent atmosphere [2].

Objectives

1. **Propose a multiscale model for atmospheric turbulence based on** :
   - Hydrodynamics models of atmosphere
   - Scattering moments
2. **Implement it in propagation tools** :
   - Split-Step Wavelets (SSW)
   - Without increasing computation time
3. **Application to complex media** :
   - Troposphere
   - Ionosphere

Tools & Methods

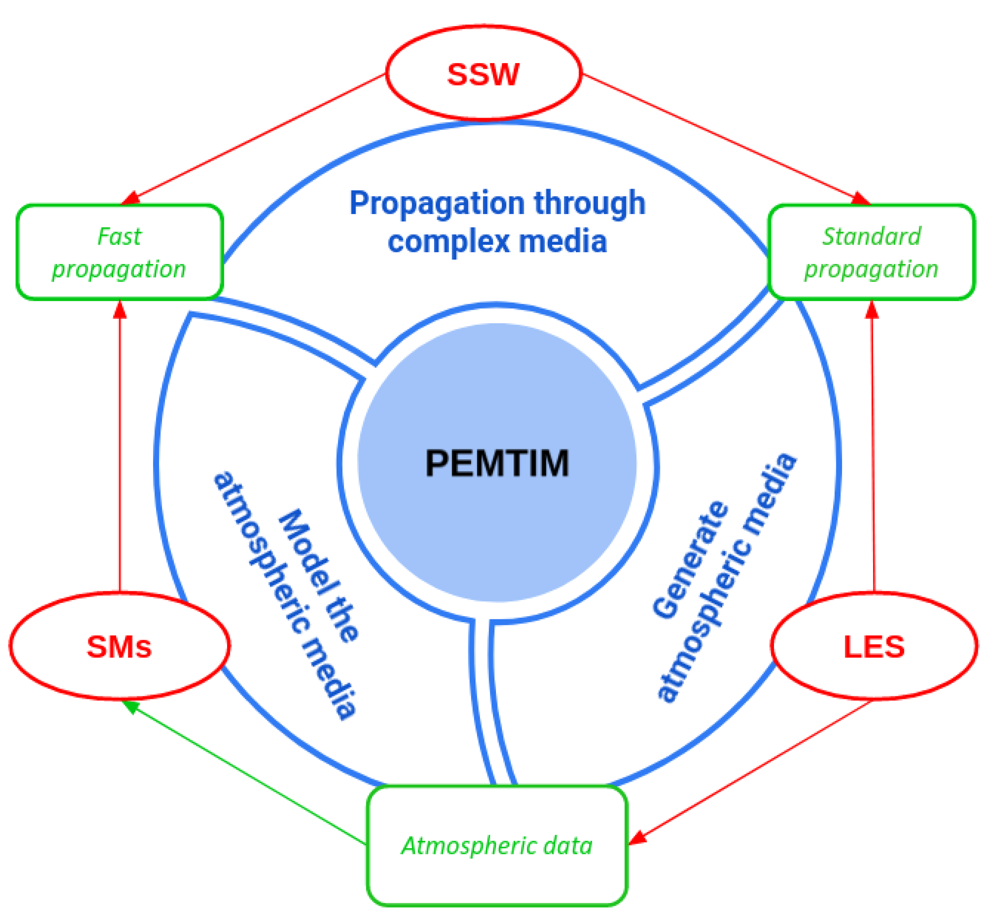

Figure 2: PEMTIM : global scheme

- **Split-Step Wavelets (SSW)**
  - iterative resolution of PWE;
  - propagation made in wavelets' domain;
  - invariance and compression properties;
- **Large Eddy Simulation (LES)**
  - general mathematical model for turbulence;
  - simulates and studies turbulent atmospheric flows;
- **Scattering Moments (SMs)**
  - translation-invariant signal representations
  - implemented as convolutional networks whose filters are fixed

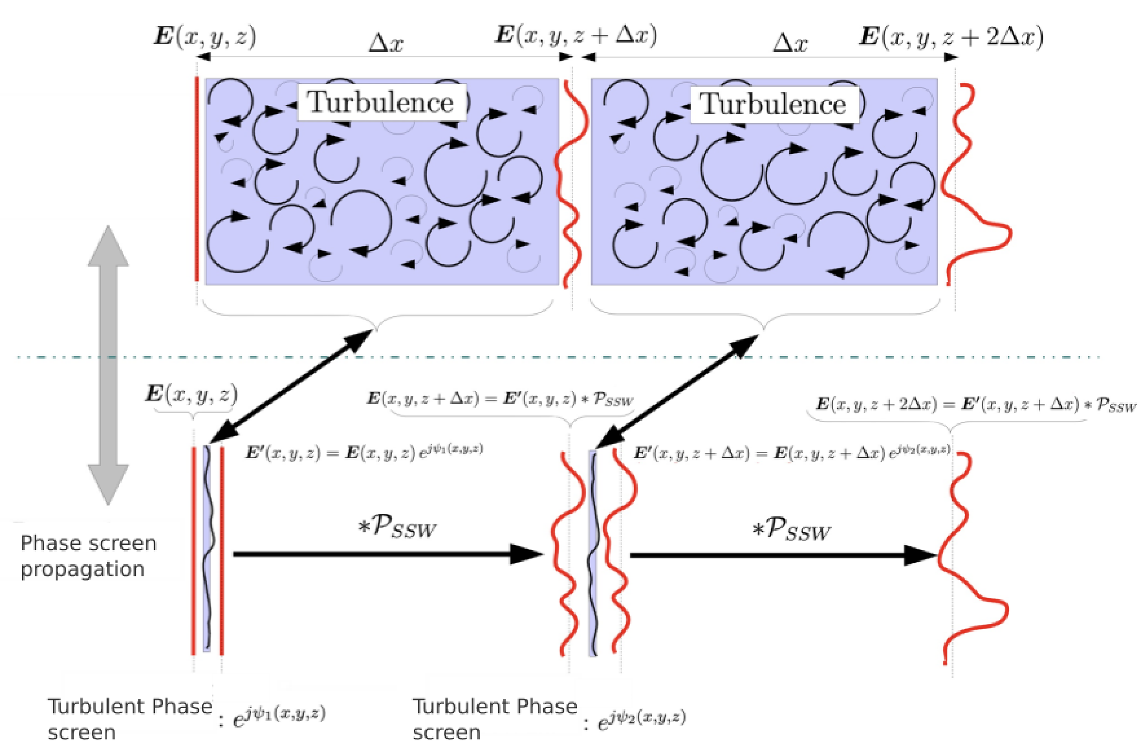

Figure 3: Phase screens propagation principle [3].

Interest of LES vs Kolmogorov

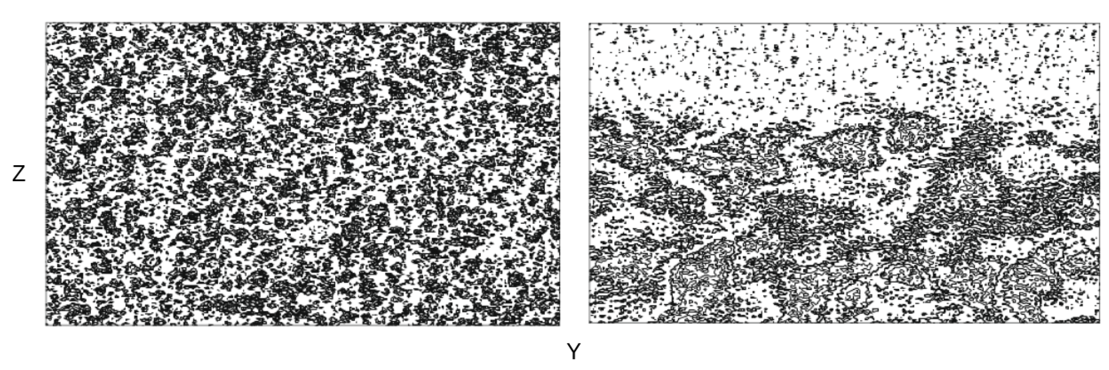

Figure 4: Phase screens obtained with Kolmogorov turbulent model (left) and LES data (right) [4].

- LES-generated phase screen (right) :
  - based on **realistic** atmospheric data
  - **vertical non-homogeneity** of the refractive index
- Kolmogorov-generated phase-screen (left) :
  - **Statistical** description of turbulent atmospheric flows
  - **vertical homogeneity** of the refractive index

Objective : **quantify the error made by a Kolmogorov modelling** of the turbulent refractive vs LES data.

Impact of turbulence

LES ↗ precision in comparison with mean atmosphere

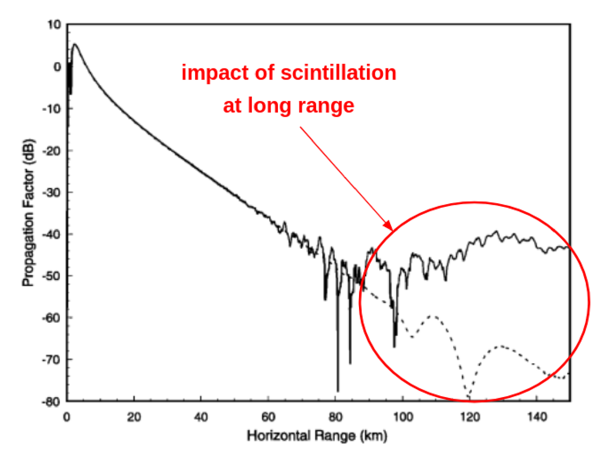

Figure 5: Propagation factor versus range (0.263 GHz) : mean refractivity profile (dashed) vs standard LES refractivity field (solid) [5].

References

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[5] Gilbert, Kenneth E. et al. "Electromagnetic wave propagation through simulated atmospheric refractivity fields." *Radio Science* 34 (1999): 1413-1435.