Surface and Volume Scattering from Rough Heterogeneous Media in the Optical Domain

H. Chanal, **J. P. Segaud**, **and P. Borderies**
ONERA Centre de Toulouse, France

M. Saillard
Université de Toulon et du Var, France

Scattering from rough heterogeneous media involves both surface and volume effects. This issue has many applications in geophysics, remote sensing (from the microwave domain to the optical one) and biomedicine, for instance. In optics, the total diffraction problem must be addressed accurately to understand the scattering properties of coatings. But volume and surface scatterings are both difficult issues that are usually studied separately. There is a need for rigorous methods that are able to handle in the same way both phenomena without any coupling hypothesis. We choose to use the Finite Difference Time Domain (FDTD) method as such a reference one. A Monte Carlo process is built to access to the statistical properties of rough heterogeneous media. It is composed of two steps:

- the generation of one deterministic medium realization;
- the FDTD computation over this realization to derive the electromagnetic near and far fields.

This process is repeated and the successive results are averaged to give the statistical response of the inhomogeneous medium. This work is restricted to the bidimensional geometry with the aim of investigating fine surface-volume coupling effects.

In a first part, we study the scattering of rough surfaces (homogeneous medium). Random profiles with gaussian height distributions and gaussian or exponential autocorrelation functions (ACF) are considered. Our method is compared with the Method of Moments (MoM) on a unique deterministic realization and on the average scattering patterns. The agreement proves to be always excellent for gaussian ACF and to decrease when the roughness increases for exponential ones due to the representations of the fine structures in the surface profiles which are different in both methods.

Then, we investigate the volume effects with randomly distributed cylindrical scatterers embedded in a semi-infinite homogeneous binder with flat interface. Effective propagation parameters are derived from the evolution of the near field with depth. These numerical results are compared to the Maxwell-Garnett and Bruggeman mixing laws and the Foldy-Twersky and Keller perturbative models for both polarization modes, validating the process implementation and allowing to precise the validity domain of approximate approaches.

Finally, we tackle the general case of rough heterogeneous media. Several interface types (the previous gaussian and exponential ACF surfaces and a new type of surfaces with profile correlated to the scatterers distribution in volume) are considered on top of heterogeneous media over a large range of volume fractions, particle sizes and optical constants. The hypothesis of surface and volume scattering splitting is systematically tested and surface -volume coupling effects are analyzed.