**Scattering of Electromagnetic Waves by Vegetation Based on Numerical 3D Solutions of Maxwell Equations**

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The interaction of electromagnetic waves with vegetation is an important problem and has been studied extensively. For many years, two methods have been used to calculate the scattering by vegetation: the vector radiative transfer theory (VRT) and the distorted Born approximation (DBA). Recently, we have begun a new approach using Numerical Maxwell Model in 3D Simulations (NMM3D). In this paper, we showed the numerical simulations of the scattering of a vegetation layer consisting of many thin cylindrical scatterers. The full wave approach for solving Maxwell's equations is based on the Foldy-Lax multiple scattering equations (FL) combined with the Method of Moments for bodies of revolution (BOR). In DBA and VRT, there is an effective attenuation/extinction rate $\langle \kappa_e \rangle$ which is a result of assuming that the probability density functions of positions of scatterers are statistical homogeneous in 3D. The results of this assumption of statistical homogenization gives effective permittivity, effective extinction rates and effective phase matrix. In DBA and VRT models, the attenuation rate $\langle \kappa_e \rangle$ is computed using the Foldy's approximation. The effective attenuation rate under such approximation is the single scatterer extinction cross section $\sigma_e$ multiplied by the number of scatterers per $m^3$. $\sigma_e$ is the sum of absorption and scattering cross sections and is further averaged over sizes and orientations However, in NMM3D, an effective attenuation rate $\langle \kappa_e \rangle$ is not needed nor defined in Maxwell equations. Numerical solutions of Maxwell equations for a layer of vegetation scatterers gives the scattering parameters of that layer.

The accuracy of the method FL-BOR is first validated by comparing with the results from the commercial software HFSS for the two and five cylinders' cases. The FL-BOR code is about 18 times faster than HFSS when solving for the five cylinders in cluster. Thus HFSS is not suitable for a large number of cylinders such as 500 used in this paper. Next, the transmission through a vegetation canopy of cylindrical scaterers is calculated using Monte Carlo simulation where the cylinders, as many as 500, are generated in each realization and the scattering is solved by FL-BOR with exact solutions of the matrix equation. The NMM3D full wave simulations solve Maxwell equations for the entire vegetation layer including all the vegetation scatterers, and thus all the coherent wave interactions among the scatterers are considered. A merit of FL-BOR is the much smaller number of surface unknowns than using Rao-Wilton-Glisson (RWG) basis functions in the usual MoM codes. The results of transmission at C-band are compared with those of DBA and VRT. Two cases are studied: short cylinders and long cylinders. Short cylinders mean that the cylinder lengths are much smaller than the layer thickness and the short cylinders are randomly distributed in the vegetation layer. Long cylinders mean the cylinder lengths are the same or comparable to the thickness of the vegetation layer. Long cylinders represent several vegetation types and part of other vegetation types. The NMM3D results of case of long cylinders show there are significant differences of transmission, as much as 6 dB, from that of DBA and VRT.