SCATTERING FROM A CLUSTER OF PLANT OR TREE COMPONENTS: ANALYSIS OF THE INTERACTION EFFECT

Qianyi Zhao and Roger H. Lang

Department of Electrical and Computer Engineering
The George Washington University, Washington DC 20052,USA

1. INTRODUCTION

Scattering from a cluster of leaves or branches in the near field of each other is the subject of this paper. Many past microwave vegetation scattering models [1-3] usually assume all tree components are in the far field of each other. Such models are effective when the tree components are far apart. However, as the interleaf or inter-branch distance becomes less than a few wavelengths, the near field interaction of those vegetation components becomes more important. Several papers [4-6] have attempted to take the interaction partially into account by coherently adding the scattering amplitudes from each scatterer. In this paper the interaction effect between the scatterers is taken fully into account by modeling the whole collection numerically. The numerical approach used here is the Discrete Dipole Approximation (DDA) [7]. It will be applied to a cluster of leaves and a cluster of tree branches. Scattering cross sections computed by the DDA method are compared with cross sections computed by the analytical approach obtained without considering the interaction between neighboring components.

2. SCATTERING FROM A CLUSTER OF LEAVES

Scattering properties of a cluster of leaves are studied in this work using the DDA method. Two or three leaves form a cluster and it is assumed that each leaf is in the near field of the other leaves in the cluster. The interaction between neighboring leaves is examined by this numerical approach. A plane wave is assumed incident on a cluster of leaves whose orientation is prescribed; the leaves are modeled by dielectric disks. The DDA method is applied to formulate a matrix equation to solve the volume integral equation for the internal field within the leaves. Using these internal fields, the scattering amplitude of the cluster is computed.

Analytical results for the dielectric disk are obtained by employing the physical optics approximation [8]. Using the analytical model, the bistatic scattering amplitude for each individual leaf in the cluster is calculated. The total scattering amplitude or the total cross section for the cluster is computed in the following two ways: (1) Incoherent summation approximation: each leaf in the cluster is considered to be an independent scatterer. The total cross section of the cluster is the summation of the cross sections of each leaf. Thus, the phase shifts for the scattering amplitudes of each leaf are ignored. (2) Coherent summation approximation: The total scattering amplitude of the cluster is the summation of the scattering amplitudes of each leaf in the cluster. In this approach, the phase variances of the scattering amplitudes due to different locations of the leaves are captured. But the coupling interactions between leaves in the cluster are not included.

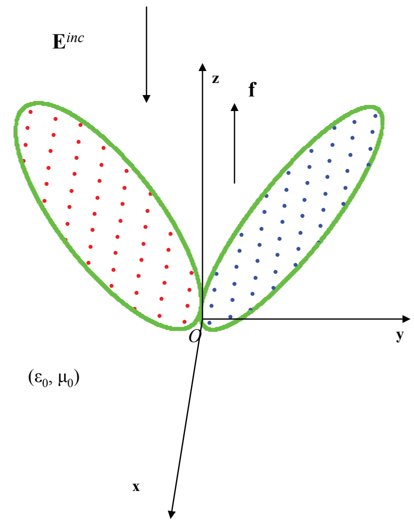

Figure 1 A cluster of two leaves. Points represent the dipoles inside each meshed grid of the cluster.

Some plant leaves are compound structures consisting of a stem (petiole) and several leaflets. As a specific example, clusters of two leaves are considered. To simplify considerations we will neglect the stem and just consider the two leaves (leaflets) as a cluster (Figure 1). Numerical results obtained by the DDA method for the bistatic cross sections are compared with the analytical solutions constructed in the above two approaches. In Figure 2 the bistatic scattering cross sections for a two leaf cluster are shown where the leaves are both at a 45^{o} angle with respect to the vertical. The incident wave has a frequency = 1.4 GHz and propagates parallel to the negative vertical axis. The azimuth angular direction has been chosen slightly off the principal plane ($\phi_i = \phi_s = 10^o$) so cross pol behavior can be observed. The leaves have a radius of 5 cm, a thickness of 1 mm, and a relative dielectric constant $\varepsilon_r = 30 - j12$. The plots are shown as a function of the scattering angle, θ_s. They show that the numerical results differ substantially from the two analytic approximations. In the backscatter direction, ($\theta_s = 0$) for HH polarization, the DAA and the coherent result differ by several db's while for the VV polarization, the DDA and the incoherent differ by 3db's.

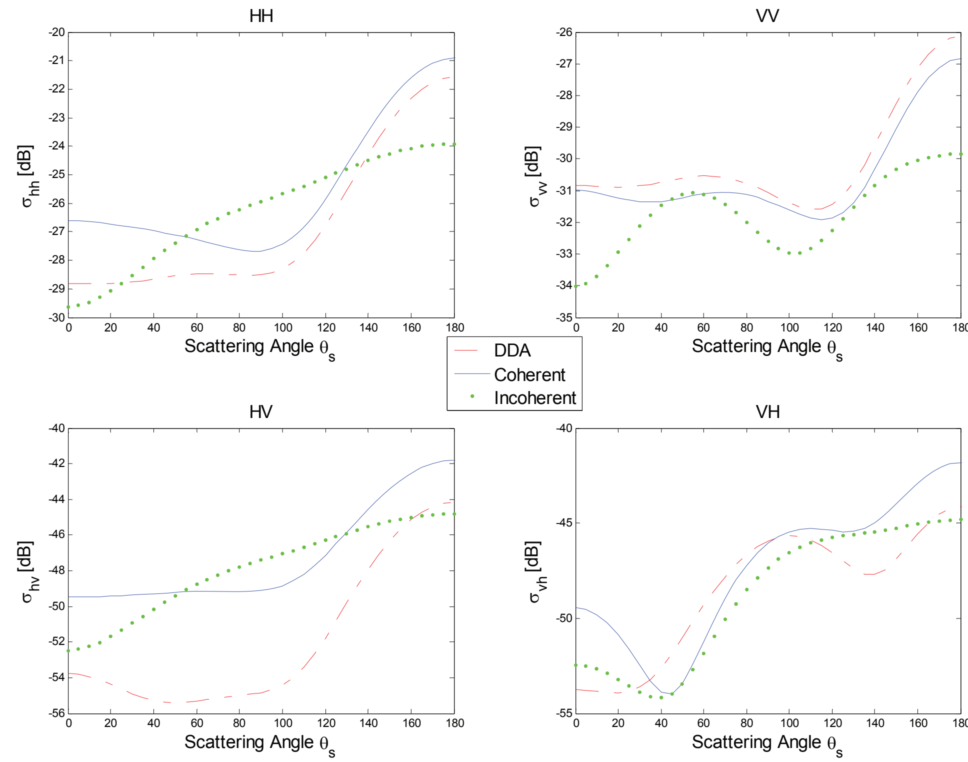

Figure 2 Bistatic scattering cross sections for a two leaf cluster at 1.4 GHz

3. SCATTERING FROM A CLUSTER OF TREE BRANCHES

The study of scattering from a cluster of leaves is extended to tree branches which usually have a stronger interaction. Branches are modeled by dielectric cylinders. Due to the larger size of tree branches, the CG-FFT method [9] is applied to speed up the computer calculations when solving the matrix equation using the DDA method. A similar comparison is made between bistatic scattering cross sections for the numerical approach and the analytic methods. The analytical model used has been proposed by [10] to model the cylinders.

4. MICROWAVE VEGETATION SCATTERING MODEL IMPROVEMENT

A vegetation canopy is usually modeled by a layer(s) of scatterers with random locations and orientations. A cluster of leaves or tree branches can be considered as an individual scatterer and averaged over random locations and rotation angles. Using this approach the standard Distorted Born approximation [11] can be employed with these clustered elements as scatterers.

6. REFERENCES

[1] N. Chauhan, R.H. Lang, and K. Jon Ranson, “Radar modeling of a boreal forest,” *IEEE Trans. Geosci. Remote Sensing*, vol. 29, no. 4, pp.627-638, Feb. 1991.

[2] P. Ferrazzoli and L. Guerriero, “Radar sensitivity to tree geometry and woody volume: a model analysis,” *IEEE Trans. Geosci. Remote Sensing*, vol. 33, no. 4, pp.360-371, Mar. 1995.

[3] F.T. Ulaby, K. Sarabandi, K. McDonald, and M. C. Dobson, “Michigan microwave canopy scattering model,” *Int. J. of Remote Sensing*, vol. 11, no. 7, pp. 1223-1253, July 1990.

[4] S.H. Yueh, J.A. Kong, J.K. Jao, R.T. Shin, and T. Le Toan, “Branching model for vegetation,” *IEEE Trans. Geosci. Remote Sensing*, vol. 30, no. 2, pp. 390-402, Mar. 1992.

[5] L. Tsang, K.H. Ding, G. Zhang, C.C. Hsu, and J.A. Kong, “Backscattering enhancement and clustering effects of randomly distributed dielectric cylinders overlying a dielectric half space based on Monte-Carlo simulations, ” *IEEE Trans. Antennas Propagat.*, vol. 43, no.5, pp. 488-499, May. 1995.

[6] N.S. Chauhan and R.H. Lang, “Radar backscattering from alfalfa canopy: a clump modeling approach,” *Int. J. of Remote Sensing*, vol. 20, no. 11, pp. 2203-2220, July 1999.

[7] G.H. Goedecke and S.G. O’Brain, “Scattering by irregular inhomogeneous particles via the digitized Green’s function algorithm”, *Appl Opt*, vol. 27, pp. 2431-2438, 1988.

[8] D.M. LeVine, R. Meneghini, R.H. Lang, and S.S. Seker, “Scattering from arbitrarily oriented dielectric disks in the physical optics regime,” *J. Opt. Soc. Am.*, vol. 73, no. 10, Oct. 1983.

[9] T.K. Sarkar, E.Arvas, and S.S. Rao, “Application of FFT and the conjugate gradient method for the solution of electromagnetic radiation from electrically large and small conducting bodies,” *IEEE Trans. Antennas Propagat.*, vol. 34, no.5, pp. 635-640, May. 1986.

[10] S.S. Seker and A. Schneider, “Electromagnetic scattering from a dielectric cylinder of finite length,” *IEEE Trans. Antennas Propagat.*, vol. 36, no.2, pp. 303-307, Feb. 1988.

[11] R. H. Lang, “Electromagnetic backscattering from a sparse distribution of lossy dielectric scatterers,” *Radio Sci.*, vol. 16, no. 1, pp. 15–30, Jan./Feb. 1981.