Microwave Scattering Model for a Corn Canopy

Yang Du[1], Wenzhe Yan[1], Zengyuan Li[2], Erxue Chen[2], Bingxiang Tan[2], and Zhihai Gao[2]

1. Department of Information and Electronical Engineering, Zhejiang University, Hangzhou, 310027, China
2. Research Institute of Forest Resources Information Technique, Chinese Academy of Forestry, Wanshoushan, Haidian District, Beijing 100091, China

Email: zjuydu03@zju.edu.cn

In microwave remote sensing of agricultural canopy, the capability of a scattering model to accurately predict the scattering properties is of great importance. In the literature, a "discrete scatter" approach was usually deployed, where scattering behavior of the individual constituent of the canopy was determined, and was either summed up incoherently [1][2], or coherently [3-5] to compute the scattering coefficient of the layer itself. For corn canopy, the stalks are modeled as dielectric circular cylinder with finite length, and the leaves are represented as dielectric disks with elliptic cross section. With the advancement of several scattering models of dielectric cylinder and disks and of rough surfaces, it is interesting to investigate if a coherent combination of these constituent models can improve predictive power of the resultant canopy scattering model. We have been working along this line and have obtained some promising results. We also have carried out a measurement campaign in several test fields in Jiangsu province, China, to collect the in situ ground truth at different growth stages of corn and wheat crops. Corresponding RADARSAT-II data have also been acquired. The overall goal is to develop a canopy scattering model of high fidelity and a reliable inversion algorithm. In this paper we focus on our modeling effort of scattering from a corn canopy.

For a dielectric cylinder of finite length, the generalized Rayleigh-Gans approximation (GRGA) is usually applied in studying its scattering behavior. It approximates the induced current in a finite cylinder by assuming infinite length. Therefore, this method is valid for a needle shaped scatterer with radius much smaller than the wavelength. For corn canopy at C band, numerical comparison of the GRGA results of the bistatic scattering coefficients for the main stalk demonstrate appreciable discrepancy with that of method of moment (MoM) results. Moreover, GRGA fails to satisfy the reciprocity theorem [3]. One alternative approach is the T-matrix method which is based on the extended boundary condition method. Yet a straightforward application of the T-matrix method for scattering from corn stalks will not work, since it has been well known that for scatterers with extreme geometry, for instance, dielectric cylinders with large aspect ratios, this approach may fail. To deal with such difficulty, recently we proposed a method based on an extension of the T-matrix approach, where a long cylinder is hypothetically divided into a cluster of identical sub-cylinders, for each the T matrix can be numerically stably calculated. Special care was paid to fulfill the boundary conditions at the hypothetic surface of any two neighboring sub-cylinders. The resultant coupled equations are different from that of multi-scatterer theory. The model results were in good agreement with the limited experiment data available in the literature [6]. Its validity region has been characterized by extensive comparison with MoM results. The proposed method is found to be applicable to dielectric cylinders of arbitrary length as long as the T matrix is attainable for the elementary sub-cylinder. The applicable relative dielectric constant can go up to 70 (real part), which is normally the upper bound for corn stalks at C band. The radius of the cylinder can be as high as 5 wavelengths, a feature of the model that is expected to be useful for forest applications [7].

Extension of our method from single dielectric cylinder to multiple cylinders is also very promising [8]. The coupling among stalks has been ignored in the literature, yet this simple treatment needs to be justified in view of the typical row structure of a corn canopy, where the interactions among neighboring stalks in the same row at C band may need to be recognized. The current study will examine this aspect.

For dielectric leaves, GRGA is usually used for the EM scattering. Yet the geometry of a typical corn leaf indicates the violation of the GRGA condition at C band, for the width of a leaf is less than the wavelength. In this study, a recently developed model by Koh and Sarabandi [9] will be used for leaves.

When corn canopy is at its early stage of growth, or when the incidence angle is not large, it is important to improve the predictive accuracy of scattering from rough surface. Yet the roughness effect of the underlying bare soil has not been adequately addressed in canopy scattering models. Therefore, in this study, we choose to apply a more rigorous treatment of the rough surface contribution using the recently advanced EAIEM model by the authors [10]. A highly efficient numerical method [11] is used for validity check.

The proposed corn canopy scattering model is validated using RADARSAT-II data in combination with in situ ground truth.

References

1. N.S. Chauhan, D.M. Le Vine, and R.H. Lang, "Discrete scatter model for microwave radar and radiometer response to corn: comparison of theory and data", *IEEE Trans. Geosci. Remote Sensing*, vol. 32, pp. 416-426, Mar. 1994.
2. R. DeRoo, Y. Du and F. Ulaby, "A semi-empirical backscattering model at L-band and C-band for a soybean canopy with soil moisture inversion", *IEEE Transaction on Remote Sensing and Geoscience,* vol.39, no.4, pp. 864-872, April 2001.
3. H.S. 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.390-401, Mar. 1992.
4. T. Chiu and K. Sarabandi, "Electromagnetic scattering from short branching vegetation", *IEEE Trans. Geosci. Remote Sensing*, vol. 38, pp. 911-925, March 2000.
5. Y. Du, Y. L. Luo, W. Z. Yan, and J.A. Kong, "An electromagnetic scattering model for soybean canopy", *Progress In Electromagnetics Research*, PIER 79, pp. 209–223, 2008.
6. W.Z. Yan, Y. Du, H. Wu, D.W. Liu, and B.I. Wu, "EM scattering from long dielectric circular cylinder," *Progress In Electromagnetics Research*, PIER 85, pp. 39-67, 2008.
7. W.Z. Yan, Y. Du, Z.Y. Li, E.X. Chen, and J.C. Shi, "Characterization of the validity region of the extended T-matrix method for scattering from dielectric cylinders with finite length", *Progress In Electromagnetics Research*, PIER96, pp. 309-328, Sept.2009
8. W.Z. Yan, D.W. Liu, Y. Du, and H.T. Ewe, "EM scattering from multiple cylinders", to appear in *Proc. IEEE, IGARSS09.*
9. I.-S. Koh and K. Sarabandi, "A new approximate solution for scattering by thin dielectric disks of arbitrary size and shape", *IEEE Trans. Antennas and Propagation*, vol. 53, pp. 1920-1926, June 2005.
10. Y. Du, "A new bistatic model for electromagnetic scattering from randomly rough surfaces," *Waves in Random and Complex Media*, vol. 18, no. 1, pp. 109-128, Feb. 2008.
11. Y. Du, Y.L. Luo, and J.A. Kong, "Electromagnetic scattering from randomly rough surfaces using the stochastic second-degree method and the sparse matrix/canonical grid algorithm," *IEEE Trans. Geoscience and Remote Sensing*, vol. 46, pp. 2831-2839, Oct. 2008.