HYBRID OF THE METHOD OF MOMENTS/ MONTE CARLO TECHNIQUE AND A SURFACE SCATTERING MODEL FOR ESTIMATING THE RADAR BACKSCATTERS OF HARVESTED FARM FIELDS

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Abstracts: The method of moments/ Monte Carlo technique is used to compute numerically the Mueller matrix for radar backscattering from stem-cut cluster sections of a harvested farm field, and a semi-empirical surface scattering model is employed for scattering from a rough soil surface. The full-wave numerical technique and the surface scattering model are combined to compute the Mueller matrix and consequently the backscattering coefficients of a harvest farm field. This hybrid technique is verified comparing the numerical computations with the experimental measurements for the backscattering coefficients of harvested rice fields.

1. INTRODUCTION

A full-wave analysis can be applied for a sparsely vegetated surface, even though the radiative transfer method is commonly used for estimating the backscattering coefficients of vegetated surfaces [1]. A harvested farm field is usually comprised with sparsely-positioned stem-cut clusters and a rough soil surface. For the bare soil surface, the theoretical scattering models such as the small perturbation method (SPM), physical optics (PO), geometrical optics (GO) models, and the integral equation method (IEM) [2-3], and empirical models such as Oh et al.'s model [4] can be used. Among various numerical techniques, the method of moments is used for vegetation parts in this study, while the Oh et al.'s semi-empirical model is used for scattering from the soil surface.

In this paper, the stem-cuts are considered as randomly positioned lossy dielectric cylinders forming clusters, and the soil surface beneath the stem-cut clusters as an impedance surface. At first, an integral equation is formulated for the equivalent volume current of the lossy dielectric cylinders above the impedance surface [5]. Then, the method of moments/ Monte Carlo technique is used to compute the volume current distributions in the stem-cut clusters for a given incident field. The scattering and Mueller matrices for radar backscattering from the stem-cut clusters are computed, and combined with the matrices for scattering from the rough soil surface. The backscattering coefficients of harvested rice fields are measured with a well-calibrated polarimetric C-band scatterometer, and compared with the radar backscatters computed using the hybrid technique.

2. MEASUREMENTS

A ground-based polarimetric C-band scatterometer consists of an automatic vector network analyzer, an orthogonal mode transducer (OMT), a horn antenna, an 8-m boom structure, an antenna support, and two step motors for controlling azimuth and elevation angles. The backscattering coefficients of harvested rice fields are measured with the scatterometer at various incidence angles and vv-, hh-, hv-, and vh-polarizations at 5.3 GHz. The polarimetric scatterometer is calibrated with the differential-Mueller-matrix calibration technique [6] by measuring the polarimetric responses of a conducting sphere at the main beam of the antenna system.

We also collects the ground truth data of the harvested rice fields such as number of clusters per unit area, number of stem-cuts per cluster, areas of clusters, stem heights, stem diameters, stem vertical angles, moisture contents of stems, height profiles of the soil surface, soil moisture contents, etc. The rms height and correlation length of the soil surface are obtained from the surface height profiles which are collected using a pin-type profilometer. The ground truth data are used as input parameters for computing the backscattering coefficients of the fields.

3. NUMERICAL COMPUTATION

The Mueller matrix for radar backscattering from stem-cut clusters above a soil surface is obtained using the full-wave numerical computation; *i.e.*, the method of moments/ Monte Carlo technique. The integral equation for the equivalent volume current distribution in the stem-cuts above a wet soil surface is formulated using the dyadic Green's function for an infinitesimal current element above an impedance sheet. The integral equation can be cast into a matrix equation using the method of moments with appropriate basis and testing functions. The equivalent volume current distribution can be obtained solving the matrix equation. Then, the scattered fields from the stem-cuts can be calculated using the dyadic Green's function. Other independent stem-cut clusters can be formed with randomly selected positions, lengths, diameters, and angles using a series of random numbers. The Mueller matrix of this numerical method includes all higher-order multiple scatterings in the stem-cut clusters above the soil surface.

While the Mueller matrix for vegetation parts is obtained using the full-wave numerical computation, the Mueller matrix for radar backscattering from the rough soil surface is computed using the Oh et al.'s semi-empirical model. The vv-, hh-, hv-polarized backscattering coefficients as well as the co-polarized phase-difference parameters; *i.e.*, the degree of correlation and the co-polarized phase-difference, of a rough soil surface can be computed using the semi-empirical model, which results in the Mueller matrix [4]. Both Mueller matrices for the vegetation part and the bare surface are combined to give the vv-, hh-, and hv-polarized backscattering coefficients for the harvested farm field. The numerically computed backscattering coefficients are compared with the experimentally measured backscattering coefficients for two different harvested rice fields. It was found that the numerical computations agree quite well with the measurements.

4. CONCLUDING REMARKS

The method of moments/Monte Carlo technique is used to compute numerically the scattering and Mueller matrices for the stem-cut clusters above a soil surface. The numerical results for the vegetation parts are combined with the radar backscatter computed using the Oh et al.'s surface scattering model. The hybrid technique is verified with experimental data measured by a ground-based polarimetric C-band scatterometer. This hybrid technique may be applied for other harvested farm fields.

REFERENCES

[1] L. Tsang, J. A. Kong, and R. T. Shin, *Theory of Microwave Remote Sensing*, John Wiley and Sons, 1985, 1st edn.

[2] F.T. Ulaby, M.K. Moore, and A.K. Fung, *Microwave Remote Sensing, Active and Passive*, vol. 2, Artech House, Norwood, MA, USA, 1982.

[3] A.K. Fung, *Microwave Scattering and Emission Models and Their Applications*, Artech House, Boston, MA, 1994.

[4] Y. Oh, K. Sarabandi, and F. T. Ulaby, "Semi-empirical model of the ensemble-averaged differential Mueller matrix for microwave backscattering from bare soil surfaces," *IEEE Trans. Geosci. Remote Sensing*, vol. 40, no. 6, pp. 1348-1355, June 2002.

[5] Y. Oh, Y-M Jang, and K. Sarabandi, "Full-wave analysis of microwave scattering from short vegetation: An investigation on the effect of multiple scattering," *IEEE Trans. Geosci. Remote Sensing*, vol. 40, no. 11, pp. 2522-2526, Nov. 2002.

[6] K. Sarabandi, Y. Oh and F.T. Ulaby, "Measurement and calibration of differential Mueller Matrix of distributed targets," *IEEE Trans. Antenna Propagat.*, vol.40, pp. 1524-1532, Dec. 1992.