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MULTIBAND RADAR CHARACTERIZATION OF FOREST BIOMES

M. Craig Dobson and Fawwaz T. Ulaby

University of Michigan
Radiation Laboratory
Department of Electrical Engineering
and Computer Science
Ann Arbor, Michigan 48109-2122

Final Report

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1.0 INTRODUCTION

This final report summarizes technical achievements under NASA Grant NAGW-733 during the period March 1, 1985 to February 28, 1990. The initial objectives of this study were to investigate the utility of airborne and orbital SAR in classification, assessment and monitoring of forest biomes. This objective was to be realized through analyses of orbital SAR and multifrequency and multipolarized airborne SAR imagery relying on image tone and texture.

Preliminary airborne SAR experiments and truck-mounted scatterometer observations demonstrated that the 3-dimensional structural complexity of a forest, and the various scales of temporal dynamics in the microwave dielectric properties of both trees and the underlying substrate would severely limit empirical or semi-empirical approaches. As a consequence, it became necessary to develop a more profound understanding of the electromagnetic properties of a forest scene and their temporal dynamics through controlled experimentation coupled with theoretical development and verification. The concatenation of various models into a physically-based composite model treating the entire forest scene became the major objective of the study as this is the key to development of a series of robust retrieval algorithms for forest biophysical properties.

In order to verify the performance of the component elements of the composite model, a series of controlled laboratory and field experiments were undertaken to: (1) develop techniques to measure the microwave dielectric properties of vegetation (El-Rayes and Ulaby, 1987; Sarabandi and Ulaby, 1988), (2) relate the microwave dielectric properties of vegetation to more readily measured characteristics such as density and moisture content (Ulaby and El-Rayes, 1987), (3) calculate the radar cross-section of leaves (Sarabandi, Senior and Ulaby, 1988; Sarabandi and Ulaby, 1989), and cylinders (Whitt and Ulaby, 1989; Ulaby and Sarabandi, 1990), (4) improve backscatter models for rough surfaces (Ulaby and Sarabandi, 1990; DeRoo, Ulaby, Kuga, and Dobson, 1989) and (5) relate attenuation and phase delays during propagation through canopies to canopy properties (Ulaby, Held, Dobson, McDonald and Senior, 1987; Ulaby, Tavakoli and Dobson, 1986; Ulaby, Tavakoli and Senior, 1987; Ulaby, Whitt and Dobson, 1988; Ulaby, Whitt and Dobson, 1990). These modelling efforts, as validated by the measurements, have been incorporated within a larger model known as the MIchigan MIcrowave Canopy Scattering (MIMICS) Model.

2.0 MIMICS Model Development

The MIMICS Model is based upon a first order solution to a vector radiative transfer approach to modelling a vegetation canopy (Ulaby, McDonald, Sarabandi and Dobson, 1988; Ulaby, Sarabandi, McDonald, Whitt and Dobson, 1990). It operates over the frequency range from 1 GHz to 10 GHz and has evolved into a fully polarimetric treatment whereby wave synthesis techniques can be used to express the scattering matrix in terms of backscatter at any transmit and receive polarization combination. The model treats three general layers: (1) a crown layer of leaves and branches, (2) a trunk layer and (3) the ground surface. The crown layer is considered to be homogeneous with a uniform distribution of constituent elements; and characterized by diffuse upper and lower boundaries. Multiple scattering within the crown layer is not considered. The constituent elements of the crown layer (leaves and branches) are each described by probability density functions for size, shape and orientation distributions as well as dielectric properties. The trunk layer is treated as a uniformly distributed array of vertical dielectric cylinders described by pdfs for height, diameter and effective dielectric. The ground surface is treated as a rough dielectric surface in the backscatter case and as a smooth surface for specular reflections.

The model considers the net backscatter as being comprised of that from a number of discrete scattering pathways including those from each layer directly as well as multiple interactions between layers. The model outputs and test points are the extinction matrices of each layer, scattering matrices for each scattering pathway and the net scattering matrix. At present, the model treats only continuous canopies.

The MIMICS model outputs have been validated using truck mounted polarimetric scatterometer data and polarimetric airborne SAR data at L-, C-, and X-bands for both extinction and total backscatter. MIMICS is typically found to predict values within 1 dB of those observed over a wide range of canopy types and conditions (McDonald, Dobson and Ulaby, 1990; Dobson, McDonald and Ulaby, 1989; Dobson and Kasischke, 1989; Dobson, McDonald, Kasischke, Way and Ulaby, 1990; Dobson, McDonald, Ulaby and Way, 1990; McDonald, Dobson and Ulaby, 1991; Dobson, Pierce and McDonald, 1991; Dobson, McDonald, Pierce and Bergen, 1991). In addition, validation of the model has made feasible its use in development of potential applications for orbital SAR in monitoring various hydrologic and biophysical properties of vegetated terrain (Christensen, Kasischke and Dobson, 1990; Kasischke, Way, Christensen and Dobson, 1990; McDonald, Dobson and Ulaby, 1988; Viereck, Slaughter, Way, Dobson and Christensen, 1990).

While the current version of MIMICS treats continuous vegetation canopies on level terrain, it is being extended to apply to discontinuous canopies such as isolated trees, small groups of trees, and nearly-continuous canopies with gaps (McDonald and Ulaby, 1990). Other planned extensions of the model are to consider the case of non-level terrain and incorporation of additional layers for snow-cover, organic surface debris, and a herbaceous layer (DeRoo, Kuga and Dobson, 1991).

3.0 PAPERS PUBLISHED AND PRESENTED

This grant supported wholly or partially a total of 41 publications and presentations at symposia and workshops. These are:

Christensen, N. L., E. S. Kasischke, and M. C. Dobson, "The Use of SAR-Derived Estimates of Aboveground Biomass in Forest Ecosystem Models", International Geoscience and Remote Sensing Symposium (IGARSS'90), IGARSS'90 Digest, Vol. 2, pp. 1209-1212, University of Maryland, College Park, Maryland, May 20-24, 1990.

DeRoo, R., F. T. Ulaby, Y. Kuga, and M. C. Dobson, "Experimental Studies of the Microwave Backscattering by Well Characterized Surfaces," Progress in Electromagnetics Research Symposium (PIERS), MIT, Cambridge, Massachusetts, July, 1989.

DeRoo, R., Y. Kuga and M. C. Dobson, "Effects of Forest Litter Layer on Radar Scattering," submitted to International Geoscience and Remote Sensing Symposium (IGARSS'91), Ispoo, Finland, June 3 -6, 1991.

Dobson, M. C., F. T. Ulaby, and J. Paris, "Radar Backscatter from Tree Canopies", Forest Signatures Workshop, JRC, Ispra, Italy, September 1988.

Dobson, M. C., "Diurnal and Seasonal Variations in the Microwave Dielectric Constant of Selected Trees," International Geoscience and Remote Sensing Symposium (IGARSS '88). Edinburgh, Scotland, September 12-16, 1988.

Dobson, M. C., K. McDonald, F. T. Ulaby, and J. F. Paris, "Diurnal Patterns in Multifrequency, Multipolarization Backscattering by a Walnut Orchard," International Geoscience and Remote Sensing Symposium (IGARSS '88). Edinburgh, Scotland, September 12-16, 1988.

Dobson, M. C. and E. S. Kasischke, "Microwave Attenuation by Boreal Forest Canopies in Winter," 1989 International Geoscience and Remote Sensing Symposium (IGARSS '89), July 10-14, 1989, Vancouver, Canada.

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Dobson, M. C., K. McDonald, F. T. Ulaby, and J. B. Way, "Effects of Temperature on Radar Backscatter from Boreal Forests", International Geoscience and Remote Sensing Symposium (IGARSS'90), IGARSS'90 Digest, Vol. 3, pp. 2481-2484, University of Maryland, College Park, Maryland, May 20-24, 1990.

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El-Rayes, M.A. and F.T. Ulaby, "Microwave Dielectric Spectrum of Vegetation Part II: Dual-Dispersion Model," IEEE Transactions on Geoscience, Vol. GE-25, No. 5, pp. 550-557, 1987.

Kasischke, E. S., J. B. Way, N. L. Christensen, and M. C. Dobson, "Ecosystem Monitoring with the Eos SAR", International Geoscience and Remote Sensing Symposium (IGARSS'90), IGARSS'90 Digest, Vol. 3, pp. 2297-2300, University of Maryland, College Park, Maryland, May 20-24, 1990.

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McDonald, K., M. C. Dobson, and F. T. Ulaby, "Determination of Soil Moisture Beneath a Stalk or Trunk Dominated Canopy by Radar," International Geoscience and Remote Sensing Symposium (IGARSS '88), Edinburgh, Scotland, September 12-16, 1988.

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