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FINAL TECHNICAL REPORT

Research Agreement No. DAAL03-88-K-0105

Microwave and Electronics

**Electrical and Computer
Engineering**

**University of Massachusetts
at Amherst**



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Research Conducted by

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University of Massachusetts**

for the

**U.S. Army Research Office
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13. ABSTRACT (Maximum 200 words) This report describes the results of research of polarimetric radar measurements performed at 95 GHz and 225 GHz by the University of Massachusetts. The targets included various tree species and snow scenes.				
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1. Forward

The polarization dependence of backscatter is important in the design of radars. Studying this dependence can provide information about targets that is unobtainable with conventional radars. The University of Massachusetts Microwave Remote Sensing Laboratory has developed two high power millimeter-wave polarimetric radars, or polarimeters. These instruments, operating at 95 GHz and 225 GHz, were used to measure the polarimetric scattering properties of natural surfaces.

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2. List of Appendices

Not Applicable

3. Body of Report

A. STATEMENT OF PROBLEM

There have been relatively few polarimetric backscatter studies performed at millimeter wavelengths. The University of Massachusetts has developed two radars, operating at 95 GHz and 225 GHz, to measure the polarimetric behavior of natural surfaces. Measurements taken with these polarimeters began in the summer of 1989, at 225 GHz. Within the next year we will have high power polarimeters operating at 35, 95 and 225 GHz. The results of measurements made to date are presented below.

B. RESULTS

Specifications of the 225 GHz polarimeter are shown in Table 1. This radar uses a noncoherent technique whereby the Mueller matrix of a target is measured by transmitting four or six polarizations sequentially. A comprehensive set of such measurements of trees was made, the results of which are detailed in [1] and [2]. Here we will summarize them. Eight species of trees were analyzed. Polarization signatures for Weeping Willow and White Pine trees are shown in Figures 1 and 2.

The 95 GHz polarimeter uses the coherent measurement technique to measure a target's polarimetric scattering matrix. This is then converted to a Mueller matrix for averaging. Specifications of this radar are shown in Table 2. Polarization signatures for White Pine and Weeping Willow are shown in Figures 3 and 4.

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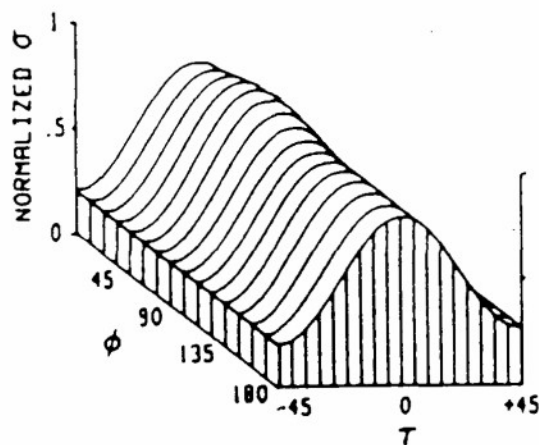


Figure 1

Co-Polarized Signature for White Pine at 225 GHz

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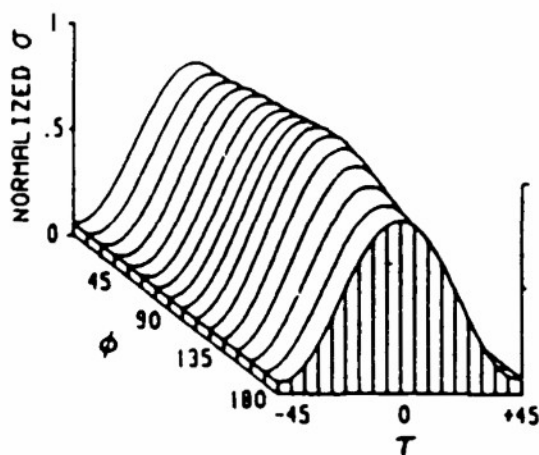


Figure 2

Co-Polarized Signature for Weeping Willow at 225 GHz

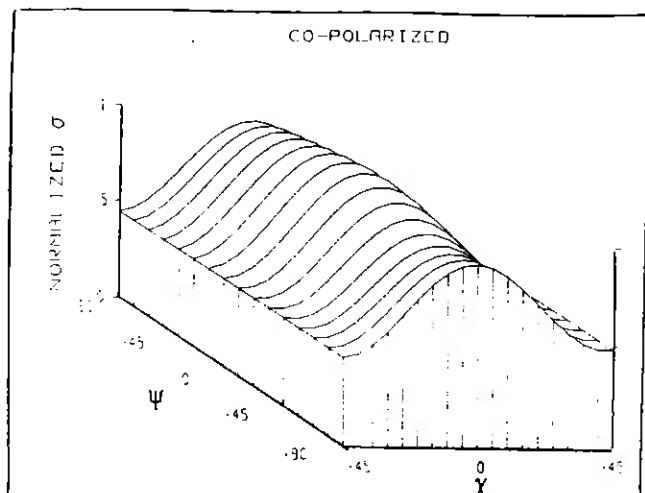


Figure 3
Co-Polarized Signature for
White Pine at 95 GHz

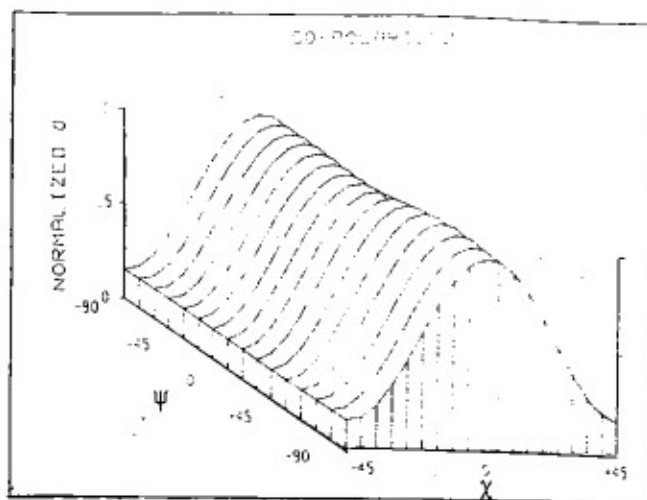


Figure 4
Co-Polarized Signature for
Weeping Willow at 95 GHz

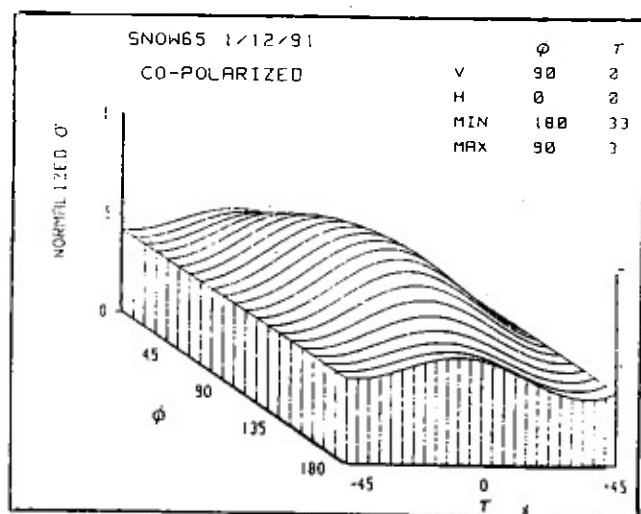


Figure 5
Co-Polarized Signature of Snow
at 95 GHz (65° Incidence)

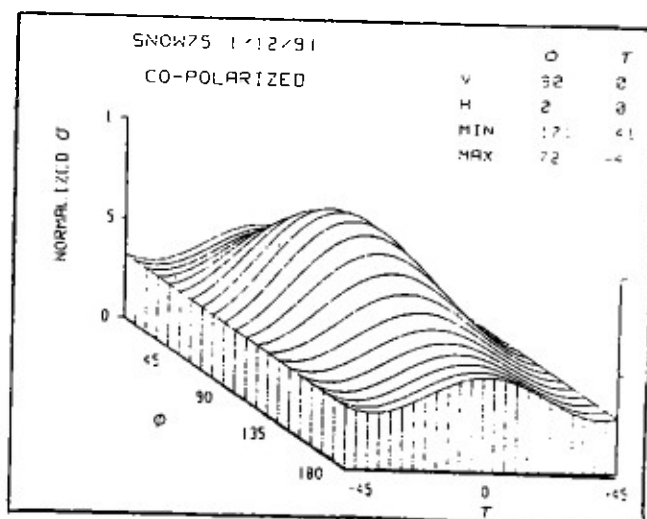


Figure 6
Co-Polarized Signature of Snow
at 225 GHz (75° Incidence)

Both radars were used to measure snow during the winter of 1990-91. The experiment consisted of mounting the instruments on a gantry on the edge of a building overlooking a snow field. Independent samples were obtained by moving the radars horizontally along the gantry while acquiring data. In-situ data were also obtained. Polarization signatures for snow at 95 and 225 GHz are shown in Figures 5 and 6. Measurements will continue for the winter 1991-92.

The depolarization ratio χ , is defined as

$$\chi \triangleq \frac{\sigma_{VH}^o + \sigma_{HV}^o}{\sigma_{VV}^o + \sigma_{HH}^o}$$

where σ_{ij} are the 4 co- and cross-pol backscatter coefficients. χ is a convenient parameter to compare among different tree types and snow conditions. A model has been developed that greatly simplifies the Mueller matrix by using χ as the single parameter [2]. The degree of polarization is described by

$$P_{\text{linear}} = \frac{1 - \chi}{1 + \chi}$$

for linear polarizations, and

$$P_{cp} = \frac{|1 - 3\chi|}{1 + \chi}$$

for circular polarizations. A comparison of this model and data is shown in Figures 7 and 8.

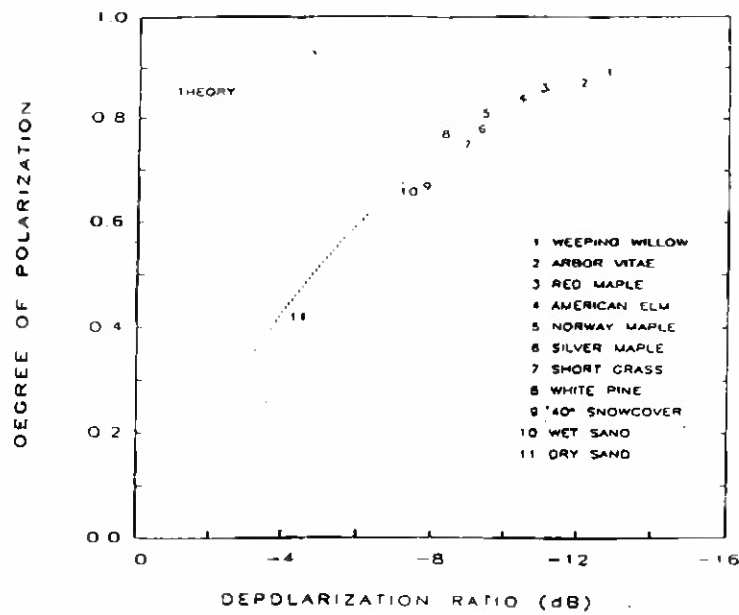


Figure 7

Degree of polarization versus depolarization ratio, linear polarization

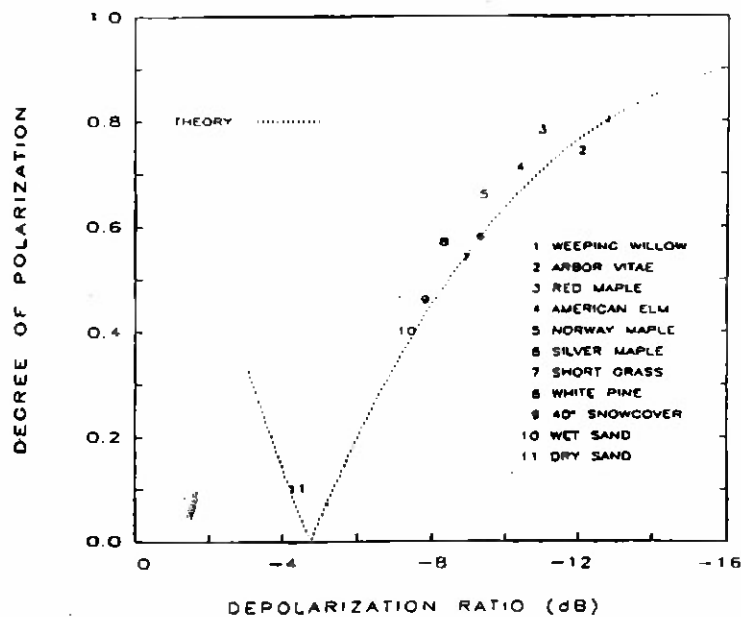


Figure 8

Degree of polarization versus depolarization ratio, circular polarization

C. LIST OF PUBLICATIONS

Journal

"A 225 GHz Polarimetric Radar", IEEE Transactions on Microwave Theory and Techniques", Vol. 38, No. 9, Sept. 1990.

"Polarimetric Backscatter Measurements of Deciduous and Coniferous Trees at 225 GHz", IEEE Transactions on Geoscience and Remote Sensing, Vol. 29, No. 1, Jan. 1991.

"Polarimetric Scattering from Natural Surfaces at 225 GHz", IEEE Transactions on Antennas and Propagation, Vol. 39, No. 9, Sept. 1991.

"Polarimetric Observations and Theory of Millimeter-wave Backscatter from Snow-cover", submitted to the IEEE Transactions on Antennas and Propagation.

Theses

"Polarimetric Measurements of Foliage and Terrain at 225 GHz", Ph.D Dissertation, James B. Mead, University of Massachusetts at Amherst. November 1989.

"Construction and Calibration of a 95 GHz Coherent Polarimeter", Master's Thesis, Philip M. Langlois, University of Massachusetts at Amherst, May 1991.

Conference

"Millimeter-wave Polarimetry at 95 GHz and 225 GHz", workshop on "Detection, Discrimination and Classification of Targets in Clutter", MICOM, Huntsville, AL, 13-15 November 1990.

"Pulsed Polarimetric Millimeter-wave Radars that Utilize Extended Interaction Amplifier and Oscillator Tubes", AESS National Telesystems Conference, Atlanta, GA, 27 March 1991.

"Polarimetric Techniques and Measurements at 95 and 225 GHz", presented at the AGARD Conference on Target and Clutter Scattering, Ottawa, Canada, 6-10 May 1991.

D. PARTICIPATING PERSONNEL

Dr. Robert E. McIntosh

Dr. James B. Mead (Ph.D November 1989)

Sharon Gadonniex (M.S. May 1990)

Philip M. Langlois (M.S. May 1991)

Paul S. Chang (Ph.D Candidate)

Steve Lohmeier (Ph.D Candidate)

4. Bibliography

- [1] Mead, J.B. and R.E McIntosh: "Polarimetric Backscatter Measurements of Deciduous and Coniferous Trees at 225 GHz", IEEE Transactions on Geoscience and Remote Sensing, Vol. 29, No. 1, January 1991
- [2] Mead, J.B., P.M. Langlois, P.S. Chang, and R.E. McIntosh: "Polarimetric Scattering from Natural Surfaces at 225 GHz", IEEE Transactions on Antennas and Propagation, Vol. 39, No. 9, September 1991

5. Appendices

Not Applicable