PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

Millimeter-wave Measurements of Natural Surfaces at 35, 95, and 225 GHz

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Introduction

Over the past several years the Microwave Remote Sensing Laboratory, MIRSL, has made extensive measurements of natural surfaces at 35, 95, and 225 GHz. The 95 and 225 GHz radar systems are capable of fully polarimetric measurements whereas the 35 GHz radar is a FM-CW system providing only co-pol and cross-pol radar cross-section information. The polarimetric radars were used to determine the Mueller matrix, $\mathcal{L}$, of various natural targets. $\mathcal{L}$ contains information on a target's polarization transformation properties along with radar cross-section information. In-situ data were correlated with all measurements. Targets studied are grouped into three categories: (1) snowcover, (2) vegetation (trees and crops), and (3) various terrain surfaces (sand, soil, rocks).

Hardware Description

The 95 GHz radar is a 1500W peak-power coherent polarimeter capable of measuring the Mueller matrix of a distriburted target using both coherent and noncoherent techniques simultaneously. The coherent technique requires measurement of the scattering matrix to calculate $\mathcal{L}$. The Mueller matrix is calculated from the transmitted and received Stokes' vectors in the noncoherent technique. These measurements are possible via the multi-polarization antenna subsystem consisting of a ferrite polarization switch in conjunction with two quarter-wave plates. The ferrite switch permits rapid switching between any linear polarizations. When combined with the quarter-wave plates the ferrite switch may be used to switch between orthogonal pairs of linear or circular polarization states. The 225 GHz polarimeter is a 60W peak-power radar system that measures the Mueller matrix using the noncoherent technique described above. The transmitted polarizations are varied using two quarter-wave plates. The 35 GHz radar is a FM-CW system, capable of both co-pol and cross-pol radar cross-section measurements. Additional system specifications for all three radar systems are listed in Tables 1-3.

Two experimental setups were used to facilitate measurements at 35, 95, and 225 GHz. Snowcover measurements were made from the roof of a 25m high building on the University of Massachusetts campus. This vantage point allowed measurements of various snow types at incidence angles of 60°-80°. A sloping hillside was used to obtain measurements at 25° incidence. The second setup involved operating from a truck based platform. The mobility gained from this configuration allowed us to travel to selected measurement sites. This flexibility enhanced our ability to collect data from various natural targets.

Discussion

The ability to make measurements at 35, 95, and 225 GHz combined with the portability of our radar systems has permitted us to compile data on a wide variety of natural targets. A sampling of our data is presented in the following figures. A co-polarized signature of a White Pine tree measured at 95 GHz is shown in Figure 1a. Figure 1b is a co-polarized signature of a Weeping Willow tree measured with the same radar system. The White Pine tree is more depolarizing than the Weeping Willow tree while both trees exhibit orientation independent behavior. The co-polarized response of fresh snowcover at 225 GHz measured at 60° incidence is shown in Figure 2. These signatures are from different snowfall events demonstrating the effect of different snow conditions on the measured polarization response. Figure 3a contains a co-polarized signature for fresh snow measured at 95 GHz at 60° incidence. The same snowcover measured two days later is shown in Figure 3b. Modest metamorphosis of the snowcover is seen to have a significant impact on the polarization response.

Table 1 35 GHz radar specifications

Transmitter		Receiver	
Center frequency	34.82 - 35.12 GHz	Noise figure	4.45 dB
Output power	6 mW	f_{IF_1}	1.42-1.72 GHz
Modulation	FM-CW	f_{IF_2}	30 MHz
		Outputs	I,Q

Antennas	
Transmitter	1.8° 3 dB beamwidth, 30 cm cassegrain dish
Receiver	1.8° 3 dB beamwidth, 30 cm cassegrain dish

Table 2 95 GHz radar system specifications

Transmitter		Receiver	
Center Frequency	94.92 GHz	Noise Figure	9 dB
Source	EIA	Dynamic Range	75 dB
Output Power	1.5 kW, peak	$f_{IF}1$	1320 MHz
Modulation	Pulse	$f_{IF}2$	120 MHz
Maximum PRF	20 kHz	Outputs	$\log\|V\|$, I_V, Q_V, $\log\|H\|$, I_H, Q_H
Pulse Width	50–2000 ns		

Antennas	
Transmitter	.7° 3 dB beamwidth, 12" lens
Receiver	.7° 3 dB beamwidth, 12" lens

Table 3 225 GHz radar system specifications

Transmitter		Receiver	
Center Frequency	225.63 GHz	Noise Figure	15 dB
Source	EIO	Dynamic Range	70 dB
Output Power	60 W, peak	f_{IF}	194.6 MHz
Modulation	Pulse	Outputs	log $\lvert V \rvert$, log $\lvert H \rvert$, I_{rel}, Q_{rel}
Maximum PRF	20 kHz		
Pulse Width	50–600 ns		

Antennas	
Transmitter	.61° 3 dB beamwidth, 6" lens
Receiver	.61° 3 dB beamwidth, 6" lens

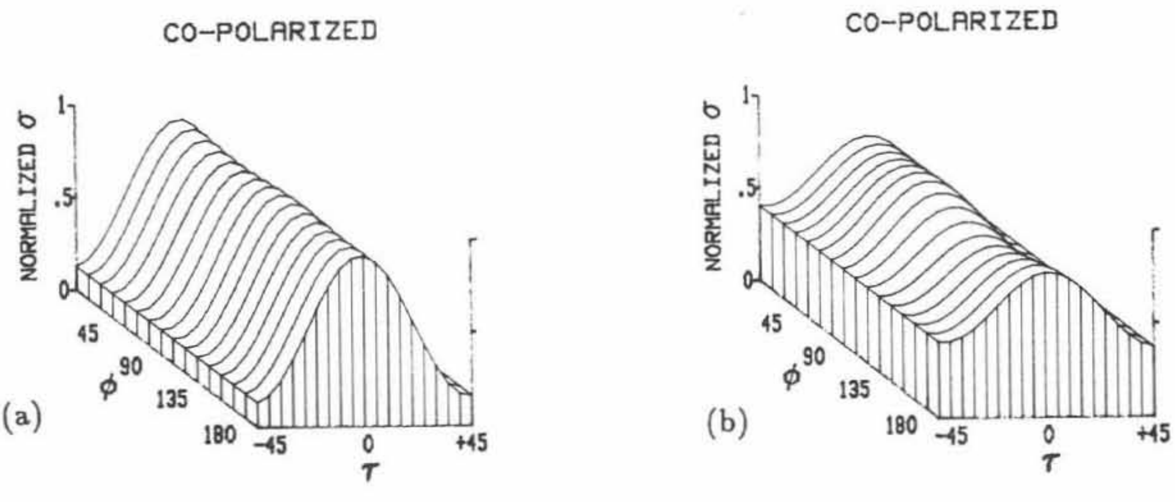

Figure 1: (a) Polarization signature for a White Pine tree measured at 95 GHz, (b) Polarization signature for a Weeping Willow tree measured at 95 GHz.

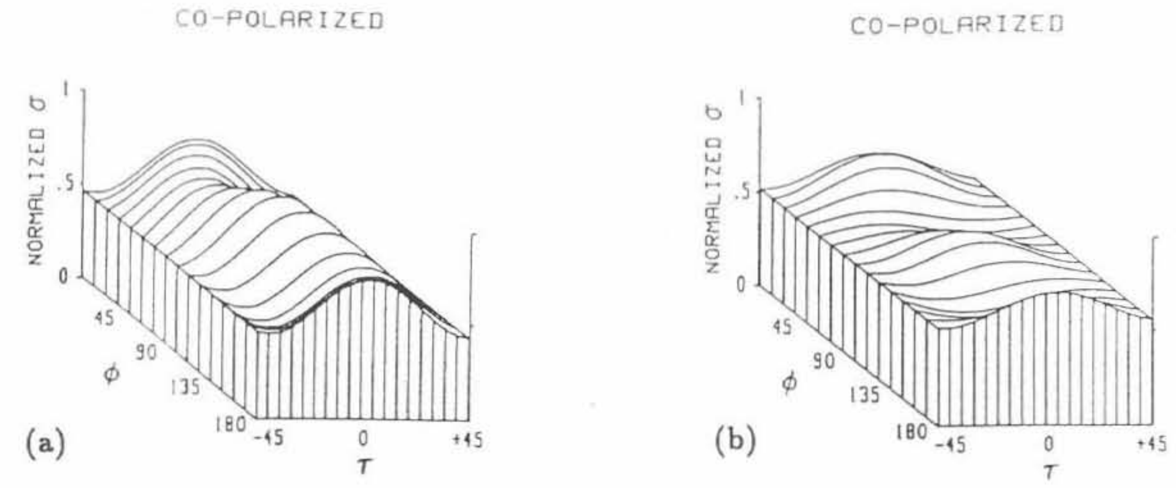

Figure 2: Polarization signatures for fresh snowcover measured at 225 GHz on two different snowfall events at 60° incidence.

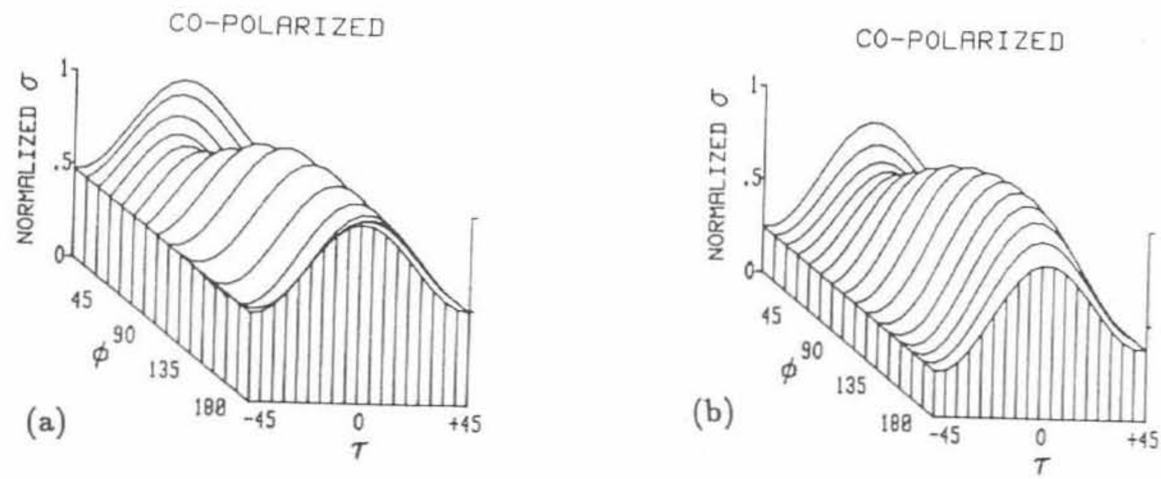

Figure 3: (a) Polarization signature for fresh snowcover at 60° incidence measured at 95 GHz. (b) The same snowcover measured two days later.