P and L Band Coherent Wave Propagation through a Tree Covered Mountainside

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***Abstract*— Coherent wave attenuation is calculated for a tree covered mountainside at P and L bands. The layer of trees is represented as a set of discrete scatterers such as trunks, branches, leaves and needles of different sizes and orientations. The ground surface along the sloping axis is characterized using Kirchhoff's method. Ground truth measurements are done to acquire information about the scatterers. The attenuation and conversion of different types of polarizations are inferred. The effects of these findings will be used to further solve the bistatic scattering problem for the given sample of random media.**

***Keywords*— Remote sensing; forest models; random media; rough surfaces**

I. Introduction

A continuing investigation on the scattering mechanisms of forests on mountainous terrain is being done by researchers from the Applied Electromagnetic Labs of the George Washington University (GW) and the Cold Regions Research and Engineering Labs (CRREL). The researchers are interested in calculating coherent and incoherent bistatic scattering for P and L band frequencies due to the trees on a sloped rough surface.

The present paper will treat the coherent wave which propagates through the trees on the mountainside. As Fig. 1 depicts, the zenith direction makes an elevation angle α with respect to the layer normal. The wave is incident from a point outside of the forest; the coherent wave propagates through the forest layer and is reflected from the underlying average ground surface. Even though the scatterers can be assumed to have an azimuthal symmetry around zenith axis, they are asymmetrical around layer normal. This causes a polarization mixing due to the inclination of the trees.

II. Theory

The forest is treated as a discrete random media with a small fractional volume. An equation for the mean field for a layer of discrete scatterers over a rough surface is obtained via the Foldy-Lax approximation by Lang [1-3]. Tree trunks, branches and needles are modeled by lossy dielectric cylinders and leaves by lossy dielectric disks. Due to the growing pattern of the trees on the sloped terrain, the mean equation must treat the tree trunks as growing in the zenith direct toward the sun. The leaves and the branches are assumed to be evenly distributed and oriented in the azimuthal direction with respect to the zenith. However, due to the inclination of the trees, the orientation probability density functions of the leaves and branches are not evenly distributed with respect to the normal to the forest layer. Consequently, the azimuthal asymmetry in the surface normal direction produces cross-polarization.

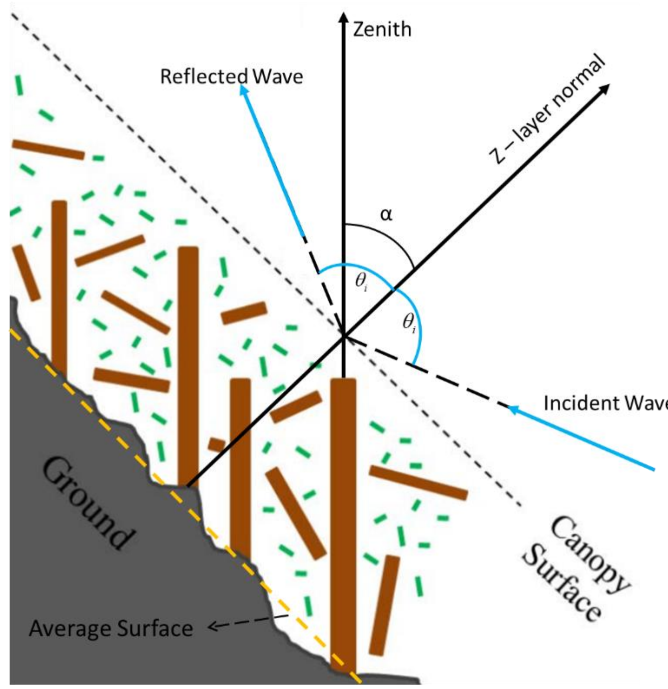

Fig. 1. Geometry of the problem

The forward scattering amplitude of each type of scatterer is calculated; incident and reflected propagation constants are computed [4-5]. These constants are related to the attenuation in the forest layer for a given type and geometry of specific scatterers. Because of the inclination of the tree trunks, the fields have a like polarized and a cross polarized component, namely, a horizontally incident wave will induce both horizontal and vertical components as it propagates through the layer.

Since this work considers the coherent wave propagation, the rough surface beneath the forest layer is replaced by an average surface with an effective reflection coefficient consisting of the Fresnel reflection coefficient times an effective attenuation factor due to the rough surface. This factor is calculated by the Kirchhoff technique for a given frequency, wave polarization, incident elevation angle, and surface roughness [5].

Finally, attenuation values for different polarizations are calculated by using the incident wave, reflected wave and the surface scattering.

Fig. 2. Surveyed mountainside

III. Ground Truth Data

Researchers of the GW traveled to New Hampshire and joined the CRREL team for ground truth measurements in the White Mountains on two consecutive summers. Tree diameter at breast height (DBH), species, inclination, height, dielectric constant, surface roughness profile, and average slope data were measured.

A picture of the mountainside is shown in Fig. 2. The forest consists of coniferous and deciduous trees. In the chosen ground truth measurement area, the dominant plant species are fir and birch trees. On average, fir trees are taller yet smaller in diameter than birches; however, the birch trees are older. Different tree types are observed, length, thickness and radius measurements are done. Some of the data can be seen on Fig. 3 and Table 1.

GW team used the dielectric constant measurement probe with a portable Network Analyzer to measure the trunks, branches, leaves and needles on P and L bands at 437MHz and 1270MHz, respectively.

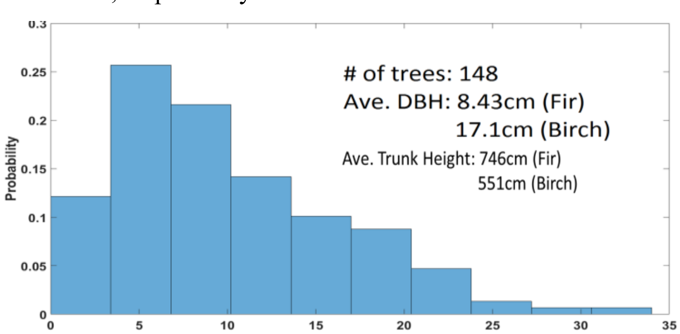

Fig. 3. Fir – Birch Site DBH histogram

TABLE I. Branch, Leaf and Needle Measurements

	Kind	Ave. Length	Ave. Radius	Density
Fir	Pri. Branch 1	142cm	1.905cm	0.9882 /m3
	Pri. Branch 2	76cm	1.27cm	1.2890 /m3
	Sec. Branch 1	25.4cm	0.318cm	3.9100 /m3
	Sec. Branch 2	35.56cm	0.476cm	3.6951 /m3
	Sec. Branch 3	50.8cm	1.27cm	1.7616 /m3
	Needles	2cm	0.05cm	7132 /m3

	Kind	Ave. Length	Ave. Radius	Density
Birch	Pri. Branch 1	121.92cm	3.175cm	0.0558 /m3
	Sec. Branch 1	152.4cm	1.27cm	0.279 /m3
	Sec. Branch 2	91.44cm	0.635cm	1.395 /m3
	Leaves	0.02cm*	3cm	68.3 /m3

The standard deviation of the surface roughness is estimated to be within 5 – 10cm which approximately corresponds to $\lambda/6$ for P band and $\lambda/3$ for L band. The average slope of the surveyed mountainside, shown in Fig. 2, is evaluated to be approximately 30 degrees.

IV. Results

The lack of symmetry of the scatterers about the normal propagation direction leads to coupling of horizontal and vertical waves in the forest layer. The amount of coupling and attenuation for an incident horizontal (vertical) wave will be evaluated as a function of depth into the forest. The dependence on angle of incidence and frequency will also be discussed. Since the wave incident on the average ground surface consists of both horizontal and vertical waves, polarization conversion will occur upon reflection. Due to the Kirchhoff rough surface attenuation factor, the value of the reflected waves will be smaller especially at the L band frequency. Propagation characteristics of the reflected wave will be treated as well.

These results will be used in the calculation of the distorted Born Approximation (DBA) to find the bistatic scattering cross-sections of the scatterers throughout the forest layer in the future.

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