

# L-Band Scattering from a Caucasian Fir Tree with the Inclusion of Near Field Effects

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**Abstract**—Microwave modeling of a Caucasian Fir tree (*Abies Normanniana*) is considered at L-band, where tree trunk and associated branches and needles are divided into cylindrical segments based on previously conducted in situ position measurements. The dielectric properties of the tree segments have been measured with a coaxial dielectric probe. The backscattering is computed by using the Distorted Born Approximation (DBA). The overall tree structure is divided into multiple layers that account for the changing effective medium as waves penetrate deeper into the tree. The near field effects of large branches with the trunk have been considered. In contrast to previously obtained results, this interaction has led to a closer correspondence between the measured and calculated scattering coefficients. Results of simulations using this tree-structure model are compared to experimental data.

## I. INTRODUCTION

Microwave propagation in vegetative and forest environments is a research topic of interest for various applications including remote sensing, communications, and target discrimination for military applications [1,2]. Of particular interest for remote sensing is L-band sensing of backscatter from forest environments by satellites such as the Advanced Land Observing Satellite 4 (ALOS-4) launched in July by the Japanese Space Agency (JAXA) [3] and the NASA/NISAR joint US/India L/C band SAR [4] that is set to launch soon.

Scattering from trees at L band has often been computed by using discrete scattering techniques. The tree is divided into cylindrical, lossy, dielectric cylinders representing the trunk, branches, and needles. The branches and needles take random positions within the outer boundary of the tree. The calculation of the backscattered power can be computed by the Distorted Born Approximation (DBA). In using the DBA, an effective medium is computed for the tree that gives attenuation and phase delay for incident and scattered waves in the tree medium. The tree scattering elements are then embedded in the effective medium, and the backscattering cross section of the tree is computed by coherently summing up over the single scatter from the embedded scatterers [5-7]. At L band, the scattering by needles is small, and the needles only act as attenuators.

Since many of the branches and trunk are in the near field of each other at L band frequencies, several methods have been employed to compute these interaction terms to first order. The first is Fresnel Double Scatter (FDS) via the Discrete Dipole Approximation (DDA) [8]. The method has been successful, but only for the tree elements that have a low dielectric constant. A second technique for computing the interaction of two thin cylinders in the Fresnel zone is given by Hooker and Lang [9].

These methods, however, do not consider the near field scattering within the reactive field zone. In this paper, the near field interaction of two lossy dielectric cylinders will be treated by a Multiple Body of Revolution technique that allows cylinders to be within a wavelength of each other. Following this near-field scattering approach, the contribution from each cylinder, representing either tree trunk or branch, is coherently summed. For large branches and the trunk, however, near field effects are considered through a Multiple Body of Revolution approach, and their interaction is added to the coherent sum. In a recent work, Gu, et. al. [10] has used FEKO to model a small tree without considering the contributions of its individual components; this is an alternate but computationally expensive approach to tree modelling.

## II. SCATTERING MEASUREMENTS OF A 5M FIR TREE

To test the new methodology, previously measured data from the European Microwave Signature Laboratory (EMSL) at the Joint Research Centre (JRC) in Ispra, Italy [11] will be used. There, scattering from a 5-meter-high Caucasian Fir tree (*Abies Normanniana*) was measured in the JRC anechoic chamber as pictured in Figure 1. The tree was positioned in a large planter on the chamber turntable. The turntable and planter were covered with Eccosorb so that the only scatter from the tree would be recorded. Backscatter, bistatic and forward scatter polarimetric measurements were made from 1.5 to 10 GHz over a period of several days. After each measurement, the tree was rotated 10°, and the measurements were repeated. In all, there were 36 measurements (360°/10°) that were averaged to make the data independent of azimuthal tree details.



Figure 1. Caucasian FIR tree (*Abies Normanniana*) in an anechoic chamber at the EMSL JRC in Ispra, Italy [11].

Following the microwave measurement, the architecture of the tree was measured by a technique developed by R. Landry [12]. The tree was viewed as an array of branching nodes. The location of some of these nodes was determined by using a surveying instrument which determined the 3-D coordinates of the nodes. Other nodes not measured were determined from similarity principles. A total of 18,858 branch segments were identified. Coordinates of both ends of each branch segment were determined. Finally, the dielectric constant of the branches, trunk, and needles were determined from 1.0 to 10.0 GHz [13].

### III. NUMERICAL MODELING METHOD

Using the previous dielectric measurements and the tree vectorization scheme, the tree is divided into five regions shown in Figure 2. All tree branch segments are contained in one of these regions. Within these sections, the Foldy Approximation is employed to calculate the effective medium and propagation constant of each layer. An RF propagation model is then used to compute the incident field on each cylinder as the waves propagate through the lossy layers, i.e., effective medium. The scattered field from each cylindrical segment – embedded within the dielectric medium – is coherently summed in the far field.

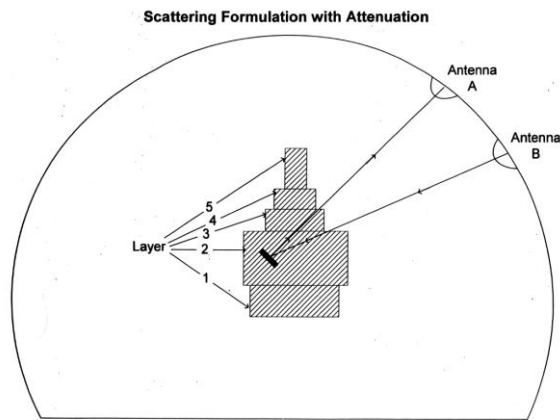


Figure 2. Location of JRC tree in anechoic chamber with effective medium layers shown in the hatched regions.

To improve the model described above, the near field interaction term (1st order) between the large branches and between the large branches and the trunk will be considered using the multi-BOR approximation that has been developed for this purpose [14]. These terms have been added to the coherent summation of the scattered field from each branch and trunk section. The total scattered field is used to compute the scattered power.

To validate the computational model and to account for the stochastic nature of trees and foliage, the backscattering cross section of the Caucasian Fir tree is computed at each 10° rotation of the tree; the average of these backscattering cross sections is then computed. This data is compared to the azimuthally averaged backscattering cross section data from the JRC anechoic chamber measurement at 2.0 GHz. The result has shown that the interaction terms are strong and improve the fit with the experimental data.

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