Antenna Beamwidth Effect in Detecting Microwave Enhanced Backscatter in a Layer of Vegetation

Avinash Sharma
The Johns Hopkins University Applied Physics Laboratory
Laurel, MD 20723, USA
Avinash.Sharma@jhuapl.edu

Roger H. Lang
Department of Electrical and Computer Engineering
The George Washington University
Washington, DC 20052, USA
lang@gwu.edu

***Abstract*—The importance of antenna beam width in detecting enhanced backscatter in a layer of vegetation is studied. First, the vegetation is modeled as a layer of random media over a flat dielectric half space. The random media consists of thin dielectric discs and cylinders. The polarimetric bistatic scattering coefficients are calculated using the Distorted Born Approximation (DBA) taking into account scattering mechanisms such as direct scatter, direct-reflected scatter, and double ground reflected scatter. The polarimetric bistatic scattering coefficients can have an enhancement factor that is positive for like-polarized returns or can be negative for cross polarized returns at and around the backscatter angle for the direct-reflected scattering component. Depending on model parameters, the magnitude and the angular width of the scattering coefficients can vary. In order to maximize received power due to the enhancement factor at backscatter, an antenna with a narrow beam width with respect to the angular width of the scattering coefficients for the layer is required. Conversely, an antenna beam width that is on the order of the angular width, will receive a fraction of the enhancement backscattered power, and this can cause inaccuracies in problems such as soil moisture retrieval through a vegetation canopy.**

I. Introduction

Enhanced backscatter from a vegetation canopy is studied by first modeling the vegetation as a random media layer over a flat dielectric half-space. The layer consists of thin dielectric discs and cylinders that are randomly oriented with prescribed probability density functions and with azimuthal symmetry. The polarimetric backscattering coefficients are then determined by using the Distorted Born Approximation (DBA). Finally, the enhancement factor is calculated for different antenna beam widths.

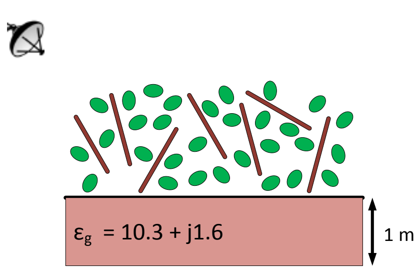

Fig. 1 Model of Vegetation over Half Space

The DBA is chosen since it is based on wave theory and takes into account coherent effects between field components. The Radiative Transfer (RT) theory, on the other hand, uses the principle of energy balance in deriving a governing equation for propagation and scattering, and does not predict the enhancement.

II. Enhanced Backscatter

The scattering mechanisms that occur in vegetation can be categorized as: direct-scatter, direct-reflected scatter, double ground reflected scatter. Direct-scatter, as shown in Fig. 2a, occurs when the incident field propagates into the layer and is directly scattered back to the antenna. Direct-reflected scatter is composed of two scattering mechanisms, as shown in both Fig. 2b and Fig. 2c. The first mechanism occurs when an incident field is reflected from the ground and then scattered back to the antenna and the second mechanism occurs when an incident field is scattered and then reflected off the ground back to the antenna. The final mechanism, double ground reflected scatter, as shown in Fig. 2d, will generally contribute less than the other scattering mechanisms and will be ignored in this study.

Enhanced backscatter occurs when the amplitude and phase of two conjugate scattering paths are equal. This occurs for direct-reflect scatter, as shown in Fig. 2b and Fig. 2c. In addition, if the polarization of the incident field and the scattered field are the same, a 3 dB enhancement peak is expected at the backscatter angle. If the polarization of the incident and scattered field are completely orthogonal, such as hv or vh, an enhancement null can occur at backscatter.

In addition, the relative magnitude of the direct-reflect scatter must be on the order of or greater than the other scattering mechanisms (especially direct-scatter) in order for the enhancement to be discernible.

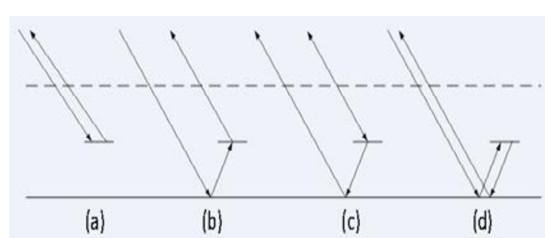

Fig. 2 Scattering Mechanisms in Random Layer

III. BACKSCATTER SIMULATION RESULTS

The backscattering coefficient for a typical agricultural vegetation canopy at L-Band, as shown in Fig. 1 is calculated for like-polarization (HH) under plane wave incidence and is plotted in Fig. 3. A 3dB enhancement peak above the incoherent scattering coefficient is due to the direct-reflected scatter being the dominant scattering mechanism. The null-to-null angular width is 10.5°. For cross polarization (HV) a null exists that is 8.6dB below the incoherent scattering coefficient. The angular width is the same, at 10.5°, as seen in Fig. 4

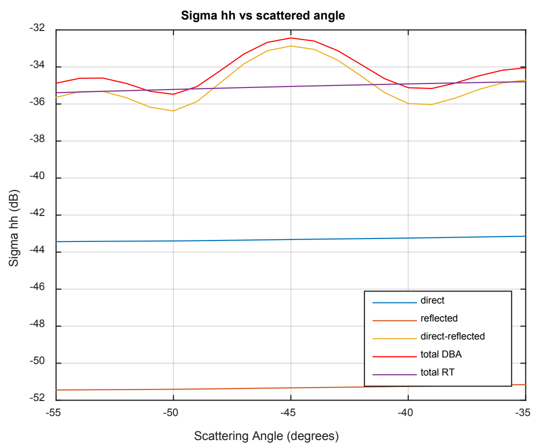

Fig. 3 Sigma HH vs scattering angle

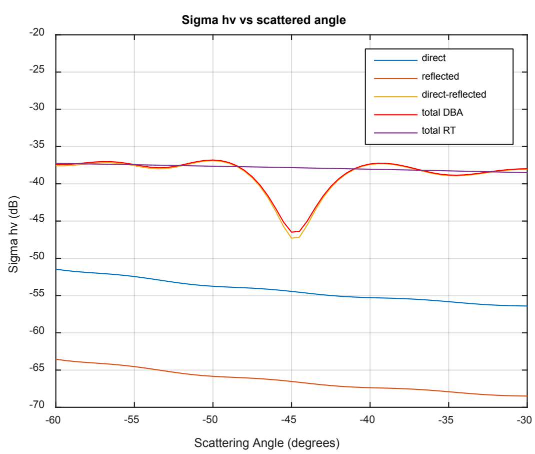

Fig. 4 Sigma HV vs scattering angle

IV. EFFECT OF ANTENNA BEAM WIDTH

The received backscattered power due to coherent scattering and incoherent scattering is calculated using the Radar Equation for a typical truck mount L-Band radar. The difference between these two is called the enhancement factor. The enhancement factor is then calculated for a normalized Gaussian antenna with varying beam widths of 0 to 30 degrees for both HH and HV cases. For the HH case, Fig. 5 shows that

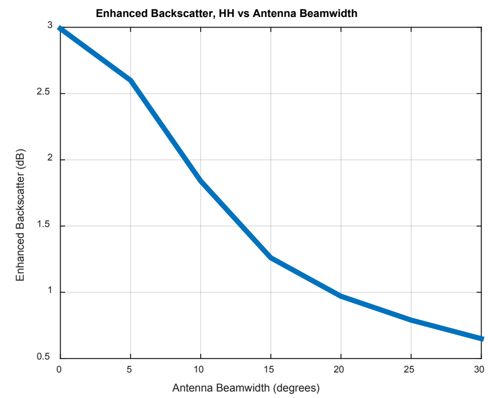

Fig. 5 Enhancement Factor vs Antenna Beam width, HH

the 3dB enhancement, as shown in Fig.3, is detected with only a very narrow beam width antenna. As the beam width increases to 10.5°, or the angular width of the enhancement scatter, the enhancement is reduced from 3dB to 1.8dB.

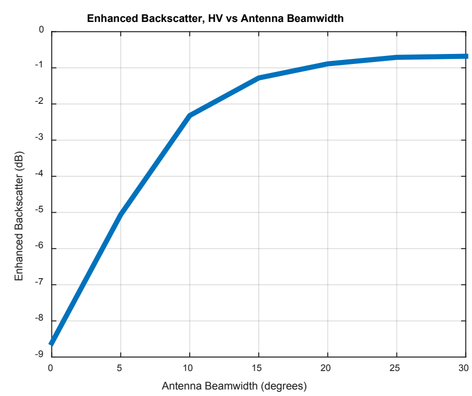

Fig. 6 Enhancement Factor vs Antenna Beam width HV

For the HV case, as shown in Fig. 6, a negative enhancement of -8.6dB is detected with a narrow beam width antenna. As the antenna beam width approaches the angular width of the enhancement, the detected power increases to -2.3dB.

In conclusion, enhanced backscatter can result in either a positive peak or negative null depending on like or cross-polarization. In order to detect the enhanced backscatter, the antenna beam width needs to be much less than the enhancement's angular width.

V. REFERENCES

[1] R.H. Lang and N. Khadr, "Effects of backscattering enhancement of soil moisture sensitivity," in Proc. IGARSS, Houston, TX, 1992, pp. 916-919

[2] N. Khadr, "Wave Correlation Effects in Active Microwave Remote Sensing of the Environment," Ph.D.Dissertation, Dept. of Electrical Engineering, The George Washington University, Washington, DC, 1994

[3] S.S. Saatchi and K.C. McDonald, "Coherent Effects in Microwave Backscattering Models for Forest Canopies," IEEE Trans. Geosci. Remote Sensing, vol. 35, NO. 4, July 1997