Small Scale Surface Roughness Effects on Enhanced Backscatter from 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 effect of surface roughness on enhanced backscatter from a layer of vegetation is investigated. The vegetation layer is modeled as a discrete random media over a dielectric half-space and a rough surface having a Gaussian height profile. The following scattering components are present within the layer: direct (or volume) scatter, direct-reflected scatter and surface scatter. The direct-reflected scatter consists of two components that have equal path lengths at backscatter, resulting in enhanced backscatter for like-polarized radar returns. The reduction in this enhanced backscatter due to small-scale surface roughness is shown to be less pronounced for layers with low volume scatter and high direct-reflected scatter.**

I. Introduction

A random media model is used to describe a vegetation layer consisting of a layer of dielectric discs and cylinders which represent leaves and stems, over a dielectric half-space. The discs and cylinders have prescribed orientation statistics based on measured field data of the vegetation. The dielectric half-space is described by a complex permittivity, used to represent soil moisture. The surface interface has roughness, described with a Gaussian height profile.

The scattering coefficients can be calculated from the model by two methods. The first is Radiative Transfer (RT) and the second is the Distorted Born Approximation (DBA). The RT theory is a heuristic approach based on conservation of energy, while the DBA is a wave theory based on Maxwell's Equations [1]. The DBA predicts enhanced backscatter, while the RT theory does not. The difference in backscatter predicted from the two methods is called the enhancement factor (EF). The effect of surface roughness on the EF will be studied.

II. Backscattering Terms

The DBA is a first order scattering theory. The single scattering mechanisms that exist within the vegetation layer can be seen in Figure 1. They are direct (or volume) scatter, direct-reflected scatter and surface scatter. The direct scatter is independent of the ground reflection. The direct-reflected scatter consists of two scattering paths. The first path, Type 1, is first reflected from the mean surface and then scattered, while the second path, Type 2, is scattered and then reflected. At backscatter, these two path lengths are the same and will therefore add in-phase resulting in a +3dB positive enhancement for like-polarized returns. For cross-polarized returns, the enhanced backscatter can be either positive or negative [2], [3]. Finally, the surface scatter term varies with surface roughness. For a smooth surface, the reflection is purely specular and the backscatter contribution from this term is zero. As the roughness increases, the specular scatter term decreases and diffuse scattering increases, resulting in a backscatter contribution. The total backscatter is the sum of all these terms.

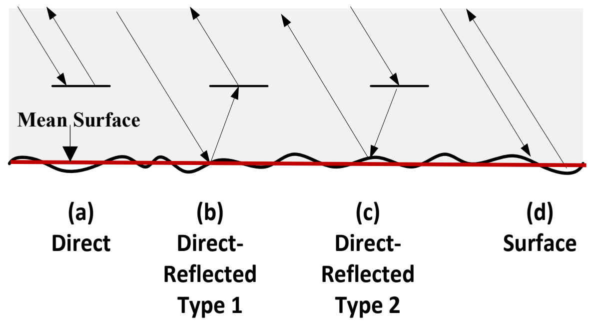

Figure 1 Single Scatter Terms in Vegetation Layer with a Rough Surface

III. Rough Surface Backscatter

A rough surface is characterized by two parameters, the standard deviation of the surface height, σ_h and the correlation length (CL). Analytical techniques such as the Kirchhoff's method, small perturbation approach and semi-empirical techniques can be used to calculate the surface scatter. For this work, a semi-empirical method in [4] is used. This is plotted in Figure 2, along with the specular reflection coefficient from a rough surface [5] versus the RMS height of the rough surface. Parameters used to generate this plot are a 1.2 GHz incident wave and a complex dielectric constant of 10 – j1.2, which corresponds to relatively dry soil.

As mentioned the effect of increasing surface roughness will decrease the specular reflection and increase the surface scatter. Both of these will reduce the effect of the enhancement. However, if the direct-reflected scatter is much greater than the other scattering terms, then the reduction in enhancement due to surface roughness is reduced.

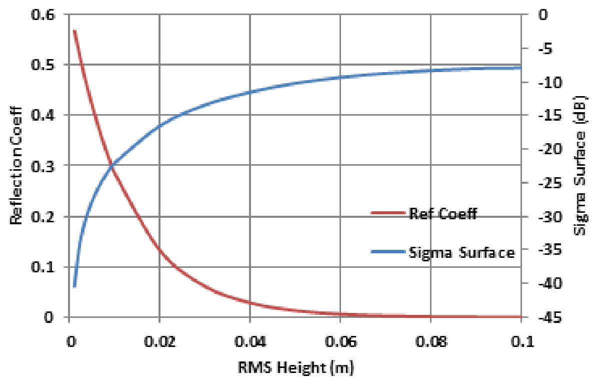

Figure 2 Reflection Coefficient and Surface Scattering Coefficient versus RMS Height

IV. BACKSCATTER SIMULATION RESULTS

Simulations of the scattering coefficient for like-polarization (HH) are performed for two vegetation layer models, excited by a plane wave of frequency 1.2 GHz and an incident angle of -40°. The first model represents a corn field at six weeks into the growing season. For this case the stalks produce high direct-reflected scatter, but the leaves are still small, resulting in low volume scatter. The EF is +3 dB for a smooth surface. As the roughness increases, the EF decreases, as shown in Figure 3. However, for RMS heights less than 0.01 m, which is typical for a corn-field at this stage in the growing season, the EF degradation due to surface roughness is negligible.

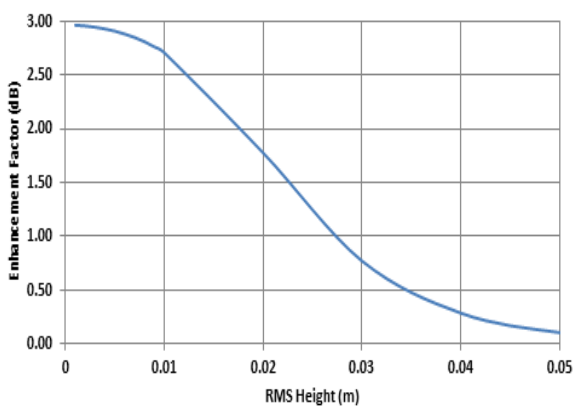

Figure 3 Enhancement Factor versus RMS Height

(Low Volume Scatter)

The second model represents a corn field about twelve weeks into the growing season. The leaves are now much larger, increasing volume scatter while decreasing direct-reflected scatter. This decreases the EF for a smooth surface from +3 dB to +2.2 dB. The EF is again seen to decrease with increasing surface roughness, as shown in Figure 4. However, for RMS heights of 0.01 m and less, the EF degrades more for the higher volume model than the lower volume model. At

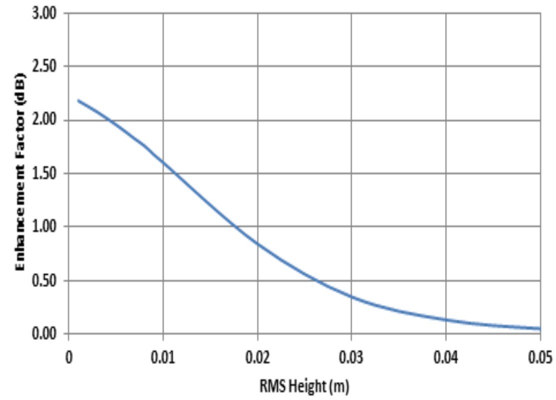

Figure 4 Enhancement Factor versus RMS Height (High Volume Scatter)

0.01 m the EF is reduced by 0.25dB for the low volume scatter layer, whereas a 0.6 dB reduction is seen for the higher volume layer.

V. SUMMARY

The effect of surface roughness was shown to decrease enhanced backscatter. This occurs due to the reduction in specular reflection from the mean surface and the increase in backscatter due to rough surface scatter.

Example simulations using the DBA and a semi-empirical model for surface scattering for a corn-field at six weeks and twelve weeks into the growing season was presented. At six weeks, the degradation in the enhancement factor for RMS heights less than 0.01 m is negligible due to low volume scatter and high direct-reflected scatter. At twelve weeks, over the same range of RMS heights, the degradation in enhancement factor is more pronounced, due to the increased level of volume scatter, which when combined with the surface scatter will tend to reduce the effect of the direct-reflected scatter, resulting in a decrease in the enhancement factor.

VI. REFERENCES

[1] R.H.Lang and J.S. Sidhu, "Electromagnetic scattering from a layer of vegetation: A discrete approach," IEEE Trans. Geosci. Remote Sensing, vol. GE-21, pp. 62-71, 1983.

[2] R.H. Lang and N. Khadr, "Effects of Backscattering Enhancement on Soil Moisture Sensitivity," Geoscience and Remote Sensing Symposium, 1992.

[3] A. Sharma and R.H. Lang, "Antenna Beam Width Effect in Detecting Enhanced Backscatter in a Layer of Vegetation," URSI/NRSM, 2017.

[4] R.D. De Roo, Y. Du, F.T. Ulaby, and M.C. Dobson, "A Semi-Empirical Backscattering Model at L-Band and C-Band for a Soybean Canopy with Soil Moisture Inversion," IEEE Trans. Geosci. Remote Sensing, vol. 39, NO. 4, April 2001.

[5] N.S. Chauhan, R.H. Lang, and K. Jon Ranson, "Radar Modeling of a Boreal Forest," IEEE Trans. Geosci. Remote Sensing, vol. 29, NO. 4, July 1991.