Differential Extinction Coefficient

Determined by Plant Morphology Using Polarimetric Analysis

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1. INTRODUCTION

As polarimetric radar contains more information of object spectrum characteristics, it has shown great potential on target detection and classification in remote sensing. Moreover, polarimetric SAR and polarimetric SAR interferometry will gain more attention, and become a development trend in the future [1]. In order to use these techniques, the relationship between observations and vegetation parameters (such as topography, height and extinction coefficient) need to develop. Up to now, the inversion models on extracting physical parameters from backscattering can be divided into three ways: empirical models, electromagnetic scattering models and coherence models. Where, the coherence models [2, 3] are well suit for POINSAR, and some satisfying inversion results for vegetation are obtained in recent years [4, 5]. However, the applications of the models greatly determine by whether the attenuation of plant is related to polarization, and such polarization dependence can be represented by a differential extinction coefficient. For example, many crops, like maize [6], are kind of oriented vegetation dominating by a vertical stem. When electromagnetic wave propagates through these crops, the vertically polarized field will attenuate more rapidly than horizontally polarized ones, and the orientation volume models should be employed to retrieval algorithms. Therefore, the investigation on differential extinction coefficient determined by plant morphology is of great significance.

In the next part, a quantitative expression between co-polarized (HH and VV) backscattering power profiles and differential extinction coefficient is given. Then, a wideband polarimetric measurement system is constructed in a laboratory, and some small fir trees with horizontal branches and leaves are measured. In the third part, the propagation inside the vegetation is analyzed by high resolution time-domain response, and the differential extinction coefficients are compared at many frequencies. The results show that the differential extinction coefficient of co-polarization not only depends on plant morphology, but also relates to frequency.

2. QUANTITATIVE ESTIMATION OF DIFFERENTIAL EXTINCTION COEFFICIENT

If the plant morphology appears a certain oriented direction, and then the extinction coefficient for different polarization channel will be different. Assuming the vegetation exhibits some kinds of horizontal characteristics, then the attenuation of vertical and horizontal polarization are defined as k_v and k_h respectively, expressed in Np/m, the difference between them is $k_{diff} = k_h - k_v$. The difference between co-polarized power ratios can be expressed as

$$VV(dB) - HH(dB) = 10\log_{10}(\sigma_{vv}/\sigma_{hh}) + (20\log_{10} e)\cdot(k_h - k_v)x \quad (9)$$

Where, σ_{hh} and σ_{vv} are the radar cross section (RCS) of HH and VV polarization, x is the propagation distance from the top of vegetation. If an isotropic region of vegetation is limited, and we choose the midpoint of this region, so the ratio of co-polarized RCS can be regarded as a constant. Then the differential extinction coefficient (expressed in dB/m) is

$$k_{diff}(dB/m) = (VV(dB) - HH(dB))/x \quad (10)$$

Note that the derivation is also appropriated to the other two polarizations.

3. INDOOR WIDEBAND POLARIMETRIC MEASUREMENT SYSTEM

The system was constructed in the anechoic chamber of National Key Laboratory of UAV Specialty Technique (shown in figure 2). A vector network and four wideband antennas constitute a radar system that can transmit and receive stepped-frequency signals. The span of frequency is 2GHz to 12GHz, and the interval is 10MHz. The sample consists of a stand of 3×3 small fir trees, uniformly planted in a square container with side length 1.5 m. The distance from antennas to the center of sample is 7m. The sample rotated by 360° in azimuth during the measurement, acquiring the polarimetric radar backscattering at 120 angles with a step of 3°. The antennas maintain downward at an incident angle of 45° with ground.

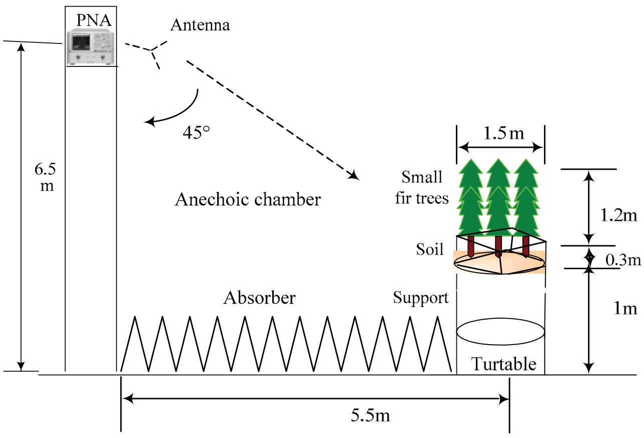


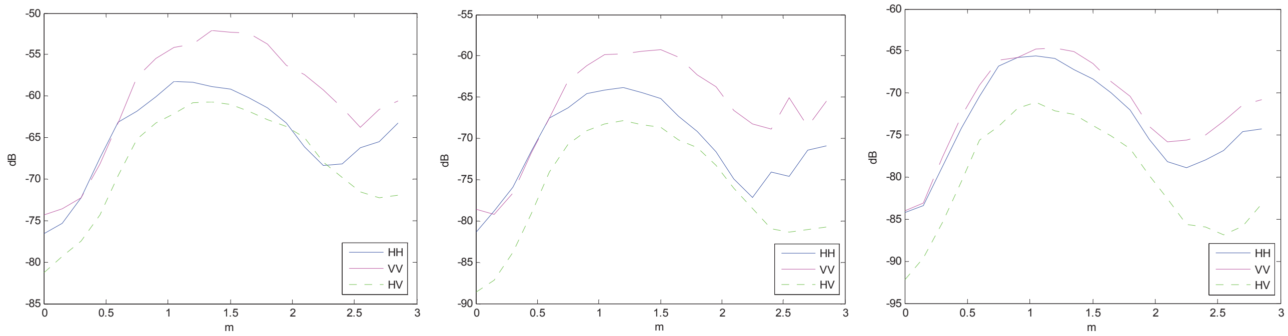
Fig.2. Experimental system

Fig.3. Photo of small fir tree

The small fir tree is shown in figure 3. It has a vertical stem with diameter about 2.5 cm. The stem carries 5-6 horizontally oriented branches at every certain distance, whose diameter is about 1 cm. A number of needle-like leaves grown on the branches are also horizontal distribution. The soil with 20 cm thickness filled in the bottom of trees.

4. EXPERIMENTAL RESULTS

The data are processed by using 1GHz bandwidths centered at S-band (2-4GHz), C-band (4-8GHz), X-band (8-12GHz). After averaging each angle, the frequency-domain data on different polarization are transformed into time-domain response (shown in figure 4). The start coordinate is the position when waves propagate into vegetation.



(a) S-band (b) C-band (c) X-band

Fig.4. backscattering power profiles at different polarization

From the figure of backscattering power profiles, we can see that the co-polarized responses are nearly close at the beginning of propagation, and the cross-polarized response is slightly lower, which can be explained by the random distribution of canopy. As the depth of penetrability, the horizontal branches and leaves are more and more obvious. Meanwhile, the ground begins to contribute backscattering, the attenuation of horizontal polarization waves is greater than vertical polarization ones. All of bands show such phenomenon and the trend is clearer at lower frequency. It indicates that the variation of differential extinction coefficient is related to frequency. At the end of penetrability, the response of vegetation trends to disappear, and the backscattering is mainly caused by ground, so each polarized echoes increase gradually.

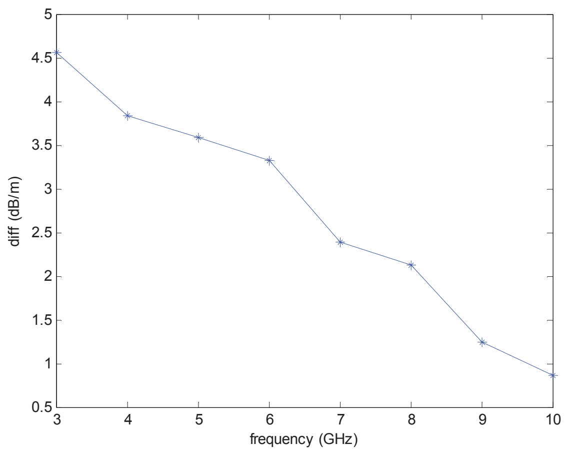


Fig.5. differential extinction coefficients as a function of frequency

According to the equation (10), the differential extinction coefficients are drawn as a function of frequency.

Compared with the results in reference [7], the values are larger for the horizontal branches and leaves are more intensive. The results explain the propagation of polarimetric wave greatly depends on plant morphology.

5. CONCLUSION

In this paper, a sample of fir trees has been measured with a wideband polarimetric measurement system in the laboratory condition. Backscattering profiles reveal an expected behavior of differential extinction coefficients, due to the horizontal orientation of vegetation, and this attenuation difference is strongly determined by frequency. At low frequency, the co-polarized difference is large. However, it reduces when the frequency increases. It has been observed that the main scattering sources come from canopy at high frequency, and the impact of inner morphology can be ignored.

All of these conclusions give a useful help for the application of coherence models based on PLOINSAR. At the same time, the qualitative scattering mechanism of oriented vegetation is investigated at different frequency. It’s important to note that the results need to care duo to the limited sample.

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