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Study on Scattering Characteristics of Buildings Under Trees Based on Polarimetric SAR

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Abstract: Accurate detection of buildings is of great significance for urban planning and rapid development. Using the rich scattering information contained in polarimetric SAR, relevant information of target features can be extracted. For buildings covered by vegetation, the penetration capability of long-wavelength SAR can be utilized to further extract their scattering characteristic information, enabling more effective detection. This study analyzes experimental data based on ALOS PALSAR imagery of Shenzhen. The results indicate that buildings obscured by trees exhibit different scattering characteristics compared to other buildings, and analyzing their scattering component information holds great potential for land classification and building detection.

Keywords: Yamaguchi decomposition, Deorientation, Polarimetric decomposition, PolSAR, Building detection.

1. Introduction

Urban building detection is crucial for national land spatial planning, land use surveys, and the development of digital cities. As ecological conservation progresses, the increase in urban greening has added complexity to urban building detection. In vegetated areas, issues such as building occlusion arise, significantly increasing the rates of missed and false detections. Polarimetric Synthetic Aperture Radar (PolSAR) can comprehensively record the backscattering information of targets, fully characterizing their polarimetric scattering properties under specific observation frequencies and orientations[1]. Polarimetric decomposition reflects differences in scattering mechanisms and characteristics[2], highlighting the unique features of buildings from various perspectives. Building extraction using PolSAR primarily relies on scattering mechanism-based methods, with model-based scattering decomposition being the most common. The Freeman-Durden decomposition[3] and the four-component decomposition proposed by Yamaguchi et al.[4] are the most widely applied methods. SINGH[5] introduced a new composite dipole coherency matrix, forming the 7SD (Singh Seven-Component Scattering Decomposition) algorithm. FAN Hui[6] proposed an oblique dihedral scattering model, extending the 6SD to a seven-component decomposition. Based on 7SD, MALIK et al.[7] developed a nine-component decomposition method. However, the increased components still fail to provide precise information for extracting complex ground scattering characteristics. Long-wavelength SAR data, due to their strong penetration capabilities, can be used to extract ground scattering information beneath vegetation, facilitating the detection of buildings obscured by vegetation. This study conducts model decomposition of L-band fully polarimetric SAR data and employs the deoriented Yamaguchi decomposition method to extract scattering information of buildings obscured by trees. By analyzing the polarimetric characteristics of buildings beneath the tree canopy, the study further investigates the scattering information of obscured buildings to enhance the accuracy of building recognition in complex terrains.

2. Theory and Methods

2.1. Yamaguchi decomposition

The Yamaguchi polarimetric decomposition builds upon the Freeman-Durden model by accounting for additional asymmetric reflections commonly found in urban environments. It introduces the helix scattering component as the fourth polarimetric parameter. This component arises from scattering by helical structures (equivalent to left-handed or right-handed circular polarization states) and is typically observed in urban areas, while it is generally absent in natural distributed targets. The Yamaguchi decomposition model is expressed as:

$$C = f_S C_s + f_d C_d + f_v C_V + f_h C_h \tag{1}$$

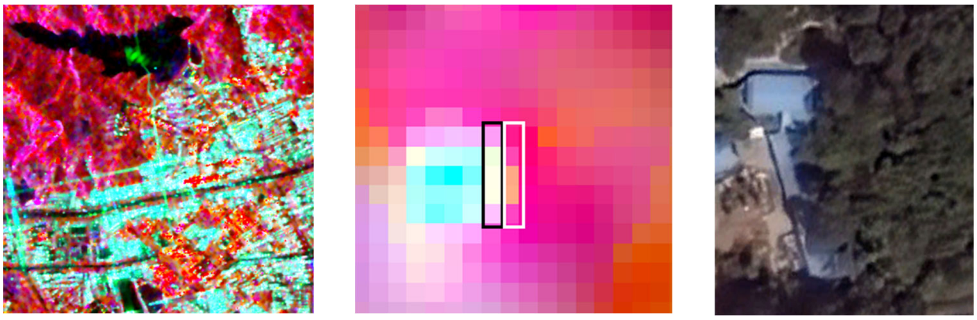
In the formula,C represents the covariance matrix of the pixel.C_s,C_d,C_v and C_h represent the covariance matrices of surface scattering.

2.2. Deorientation processing

In polarimetric SAR image measurements, each pixel target has a corresponding orientation angle. To eliminate the randomly distributed orientation angles, each target must be counter-rotated by an angle θ, aligning the target to a standard position at a 0° orientation angle. Subsequent data analysis and processing are then performed based on this alignment. This process is referred to as deorientation[8].The formula for calculating the orientation angle in multi-look data is[9]:

$$2\theta = \frac{1}{2}\left(\tan^{-1}\frac{2\,\mathrm{Re}(T_{23})}{T_{22}-T_{33}} + n\pi \right), n = 0,1 \tag{2}$$

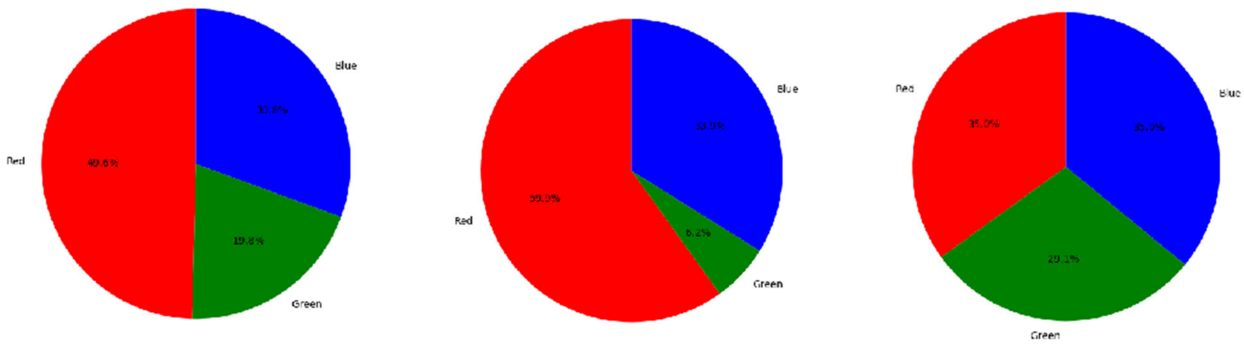
3. Experiment



(a) (b) (c)

Figure 1. VDS compisite image

As shown in Figure 1(a), we synthesized the volume scattering component (Vol), double-bounce scattering component (Dbl), and surface scattering component (Odd) from the deoriented Yamaguchi decomposition image to generate the VDS composite image. In this composite image, red represents volume scattering, green represents double-bounce scattering, and blue represents surface scattering. It can be observed that urban buildings exhibit a higher proportion of double-bounce scattering due to their structural characteristics. Additionally, due to the high building density, the proportion of volume scattering is greater than that of surface scattering. In areas covered by vegetation, volume scattering appears to be more dominant.The region shown in Figure 1(b) was selected for the analysis of scattering information of buildings obscured by vegetation. It can be seen that the volume scattering component is highest in the obscured parts. This indicates that due to the vegetation covering the rooftops, the scattering information in the obscured areas exhibits a significantly higher volume scattering component compared to the unobscured areas



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(d) (e) (f)

Figure 2. Component proportion diagram,(d) represents the scattering information of vegetation near the selected target, (e) represents the scattering information of unobscured buildings, and (f) represents the scattering information of obscured targets.

It can be observed that the volume scattering component of the target's scattering information is higher than that of unobscured buildings but lower than that of vegetation areas. Compared to unobscured buildings, the target shows a significant decrease in the proportions of double-bounce scattering and surface scattering. This reduction in scattering components is converted into volume scattering due to the obstruction caused by vegetation.

4. Conclusion

Based on the deoriented Yamaguchi decomposition model, a systematic analysis was conducted on fully polarimetric ALOS-2 PALSAR data for Shenzhen. The penetration characteristics of L-band SAR images provide favorable results for extracting scattering information of buildings obscured by trees. This results in significant differences in scattering characteristics between obscured and unobscured buildings, primarily reflected in the notable enhancement of volume scattering.Therefore, analyzing the scattering information of buildings obscured by trees can significantly improve the recognition and detection of urban buildings. It helps reduce occurrences of false detections and missed detections to a certain extent. The extraction of scattering characteristic information for tree-obscured buildings shows great potential in urban planning and development.

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