POLARIMETRIC FEATURE EVALUATION FOR STRICKEN MAN-MADE OBJECT DETECTION USING FDTD POLARIMETRIC SCATTERING ANALYSIS

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ABSTRACT

This paper investigates polarimetric scattering characteristics for accurately detecting stricken man-made objects. In order to understand the polarimetric scattering features generated from various damaged man-made buildings, we carry out the Finite-Difference Time-Domain (FDTD) polarimetric scattering analysis for deformed and/or collapsed man-made target models. The dependency of the polarimetric scattering feature on the variation of squint angle is in detail investigated. It is confirmed from the estimation based on various polarimetric analyses that the double-bounce scattering, the co-pol correlation coefficient in LR circular porlarization basis, and its normalized one are useful markers for stricken man-made objects detection/identification.

Index Terms— stricken man-made object detection, FDTD analysis, radar polarimetry, polarimetric synthetic aperture radar (PolSAR)

1. INTRODUCTION

In the field of disaster monitoring, observation survey method independent of the weather condition and day and night is strongly required under emergent and severe stricken situation. PolSAR may be one of the best solutions for such purpose.

In PolSAR data utilization, man-made object detection/identification is one of the most important subjects. So there are many useful man-made object detection and identification techniques [1, 2, 3, 4, 5, 6, 7] . For complex urban area monitoring, however, it is sometimes difficult to distinguish the man-made object from other natural distributed ones, since the polarimetric scattering behavior from the man-made object is strongly dependent on the direction or orientation of their alignment. When the man-made objects are obliquely aligned to the PolSAR's illumination direction,

the detection accuracy of each technique may become low, since the useful polarimetric index for classifying the man-made object (strong double-bounce scattering, large LL-RR correlation coefficient, phase of co-pol ratio, etc.) may hardly be observed from the oblique object areas.

In this paper, to realize accurate detection for obliquely oriented man-made object even in strcken situation, we shall try to find out an appropriate combination from the existing techniques, by carrying out polarimetric scattering analysis for simplified man-made objects. Here, we utilize the Finite-Difference Time-Domain (FDTD) method for the analysis. We here consider not only well-regulated man-made object model but also deformed and/or collapsed ones, with assumption that the residential houses are stricken by terrible disaster as big earthquake.

2. FDTD POLARIMETRIC SCATTERING ANALYSIS

As depicted in Fig.1, we carry out polarimetric scattering analysis for simple model, which consists of quad dielectric rectangular parallelepipeds on finite circular plate with rough surface. The rectangular parallelepipeds are considered as a simplified man-made buildings. We consider five models as follows. Fig.1 (a) is well-regulated model (each parallelepiped is well-regulated). Figs.1 (b) and (c) are deformed models (the parallelepipeds are inclined to left or backward to radar illumination direction). Also, Figs.1 (d) and (e) are collapsed models (one of the parallelepipeds is collapsed or removed). The FDTD method [8] is here utilized to obtain the elements (S_{HH}, S_{VV}, S_{HV}) of the scattering matrix $[S]$. We carry out many existing polarimetric analyses and at least obtain the following indices for accurate detection of man-made object.

- Double-bounce scattering from Model-based scattering power decomposition [1, 2, 3]

- Co-pol. correlation coefficient in LR basis, and the normalized one [4, 5, 6]
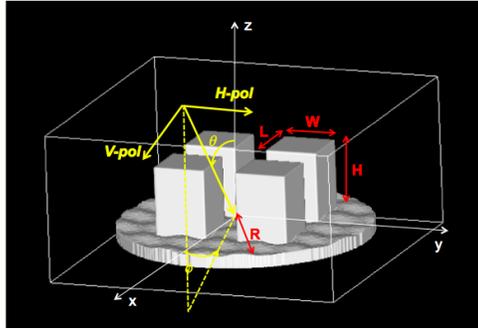
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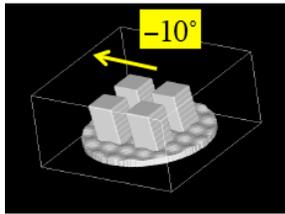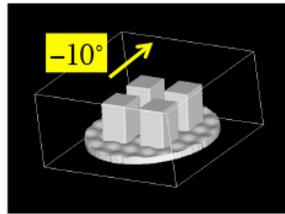
(b) left-deformed   (c) backward-deformed
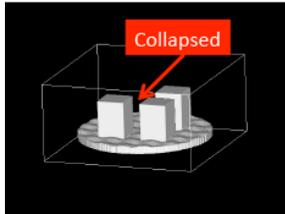
(d) left-back collapsed   (e) right-front collapsed
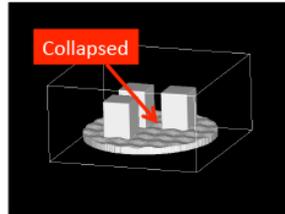
Fig. 1. Geometry of the problem

Table 1. FDTD fundamental parameters

Analytical region	$700 \times 700 \times 350$ cells
Cubic cell size Δ	0.01 m
Time step Δt	1.925×10^{-11} s
Incident pulse	Lowpass Gaussian pulse
ABC	PML (8 layer)

nusoidal rough surface with $\lambda/2$ height amplitude. The other fundamental FDTD parameters are shown in Table 1. The incident or look angle $\theta = \theta_0$ is fixed at $44°$, and the squint angle $\phi = \phi_0$ is variable($1° - 44°$). In order to do statistical evaluation for mean squint angle, the ensemble average processing is carried out for 9 degrees squint angular range.

Figure 2 shows the result of the FDTD analysis obtained by the scattering power decomposition. Here, we utilize the nonnegative eigenvalue decomposition (NNED) [9] and *a unitary rotation* [10] to the 3×3 covariance matrix. All figures show the mean squint angle dependency. It is found from the results that the double-bounce scattering (red) is considered as a useful marker of the man-made objects when the squint angle is relatively small (less than $15°$), regardless of geometry of the stricken building models.

Figure 3 shows the result of the co-pol. correlation coefficient in LR polarization basis γ_{LL-RR} [4], and the normalized one γ'_{LL-RR} [5]. It is observed from Fig.3 (b) that γ_{LL-RR} keeps large value for the wide squint angular range (up to about $30°$). Also, the normalized correlation coefficient γ'_{LL-RR} shows outstanding large values for relatively large squint angular ranges. Hence, γ'_{LL-RR} may be one of the candidates as useful polarimetric markers for obliquely oriented stricken man-made object detection.

We will also execute the other analyses as "Entropy H, Angle $\bar{\alpha}$, Anisotropy A" based on Eigen-value decomposition [7], and "Phase of co-pol. ratio in HV basis" in the presentation.

After getting the above indices, we carefully evaluate them and try to find out appropriate combination from them for man-made object detection.

3. RESULT OF FDTD ANALYSIS

We shall show the FDTD results for the well-regulated, deformed/inclined, and partially collapsed models, as in Fig.1.

The geometrical parameters of the model are W=L=4.8λ (1.2m), H=6.4λ (1.6m), D=1.2λ (0.3m) and R=$12.0\ \lambda$ (3.0 m) at L-band frequency (1.2 GHz). The complex relative permittivities are set as $\varepsilon_{r1} = 4.0 + i0.2$ for main parallelepiped part (Concrete) and $\varepsilon_{r2} = 7.0 + i0.1$ for base part of the circular plate (Dry soil) at the same frequency. The base part has si-

4. CONCLUDING REMARKS

In this paper, we have examined polarimetric scattering characteristics from simplified man-made structure models, in order to improve the accuracy of detection/classification of the stricken man-made object in POLSAR image analysis. Here, the Finite-Difference Time-Domain (FDTD) method has been utilized for the detailed analysis. It has been found from the FDTD analysis that the double-bounce scattering, the co-pol correlation coefficient in LR circular porlarization basis, and its normalized one are very useful tools for finding out peculiar scattering feature for detecting/ classifying deformed and/or partially collapsed man-made objects.

Furthermore, we will investigate the features of other polarimetric indices, by carrying out additional FDTD polarimetric scattering analysis.

5. REFERENCES

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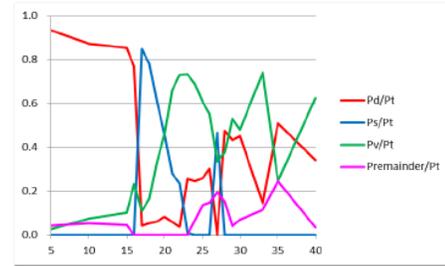
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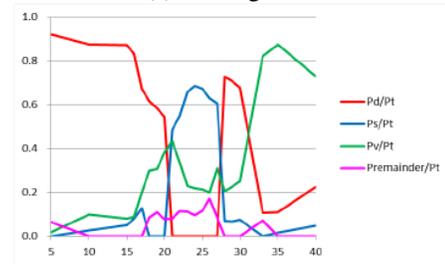
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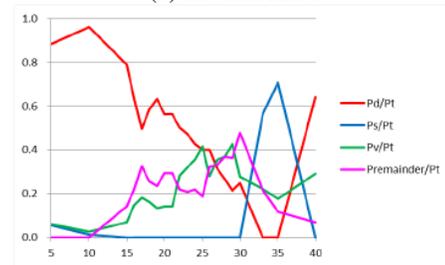
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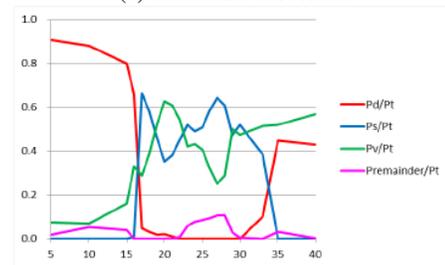
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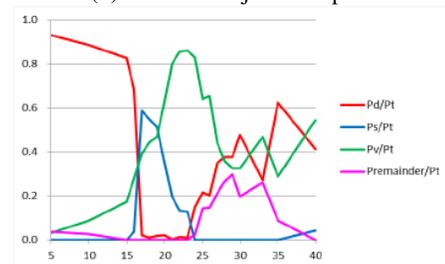
(e) right-front object collapsed

Fig. 2. Result of the FDTD analysis (scattering power decomposition)
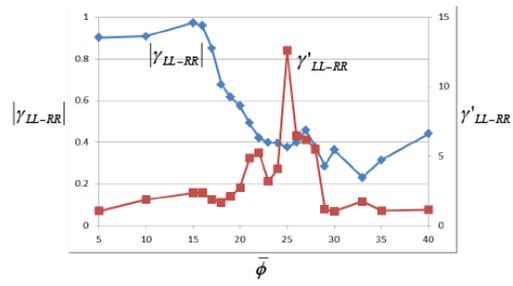
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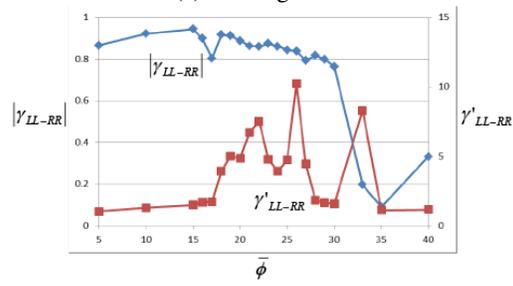
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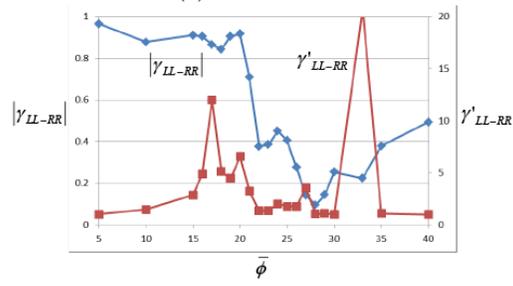
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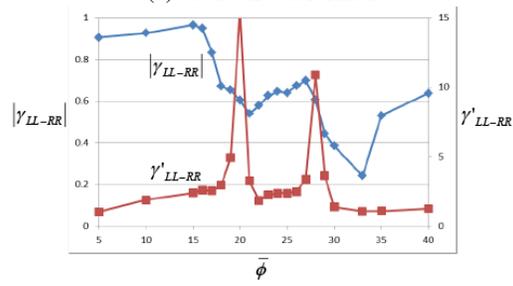
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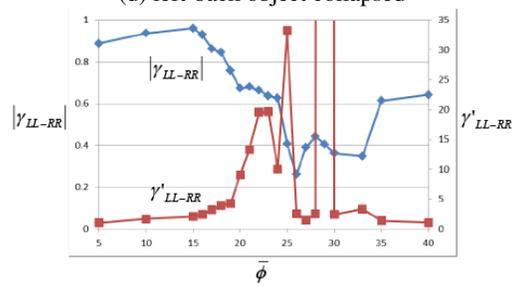
(e) right-front object collapsed

Fig. 3. Result of the FDTD analysis (correlation coefficient in LR circular polarization basis)