POLARIMETRIC SAR MEASUREMENT FOR BUILDING COLLAPSE USING AN FM-CW RADAR

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1. Introduction

One of the polarimetric SAR applications is a surveillance or monitoring system for disaster such as earthquake, fire, etc. Although prediction of disaster is difficult, it seems easy for the satellite/airborne SAR to monitor earth cover before and after the disaster and identify where the situation changes. This kind of civil applications is really important in social activity. Since the airborne or satellite-borne synthetic aperture radars (SAR) will be equipped with fully polarimetric capability in the near future, it is worth investigating the applicability of polarimetric SAR information.

This paper presents a basic research result for the estimation of building collapse in urban areas using scattering matrix information. The main purpose is to examine how polarimetric information is utilized in identifying or discriminating the destroyed area versus non-destroyed area. In case of disaster or earthquake, buildings may be declined or collapsed. This situation would produce rather different scattering nature in polarization, frequency, etc., compared to the normal undamaged situation. It is anticipated in repeat pass observations that the scattering mechanism will be different, which results in the different polarimetric Sinclair scattering matrix generation. This matrix has 2×2 elements and plays a decisive role in radar polarimetry. If the scattering matrix is obtained, the collapsed area seems to be related to the appearance of the matrix. This point is the motivation for surveillance possibility.

2. Building Model and Experiment

In order to examine the discrimination capability between normal undamaged area and destroyed area, we first carried out a laboratory experiment (Fig.1) to check the change in elements of the scattering matrices. Since theoretical analyses based on the electromagnetic boundary value problem is too complex, we tried polarimetric analyses to retrieve useful information on the collapse situation, by using data sets of scattering matrix acquired with a fully polarimetric and synthetic aperture FM-CW radar developed at Niigata University.

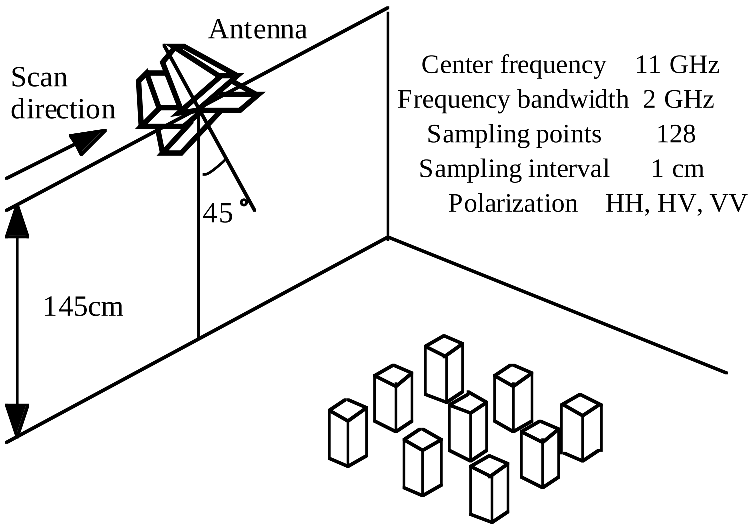

Fig.1 Experimental situation

The targets used are 9 blocks covered with alumni foil, imitating urban buildings, and are aligned in three lanes as shown in Fig.1. The collapse situation is modeled by crushing some blocks. The X-band radar has two transmitting and two receiving antennas for HH, HV, and VV polarization measurement. The bandwidth of the radar signal was 2 GHz. These antennas were scanned horizontally so that the radar simulates an actual SAR system (Fig.1). The off-nadir angle was set 45 degrees.

3. Estimation of Building Collapse

After the entire scene is imaged by the synthetic aperture radar, the scattering matrix corresponding to each pixel in the image can be obtained. If scattering matrices covering the densely built area are obtained, it is possible to derive relevant information. The candidate indexes for discriminating the destroyed area and/or non-destroyed area are, for example,

(1) change in scattering matrix elements
(2) decomposition of scattering matrix into three fundamental components [1] and their variation
(3) variation of polarization anisotropy coefficient [2]
(4) polarization entropy and angle $\bar{\alpha}$ [3]

The methodology (1) is to check the variation in the element and is the simplest method. It is possible to observe the change in the magnitude and phase in each element. The three component decomposition methodology (2) is proposed by E. Krogager [1]. The basic idea is to decompose a measured scattering matrix into three basic and theoretically known scattering matrices, i.e., sphere (plate) component, diplane (dihedral corner reflector) component, and helix component. Three components physically correspond to single bounce, double bounce, and generation of circular polarization, respectively. After the decomposition, the measured scattering matrix is assigned to one of the best match types. This technique has advantage in real time classification because it deals with scattering matrix directly (there is no transformation). The methodology (3) is rather a robust method and has been proposed by A. I. Kozlov [2]. The entropy method is recently proposed by S. R. Cloude and E. Pottier [4] and has a superior classification capability.

In the evaluation of scattering matrix data, we employed methods (1)-(4). For page limitation, we show the three component decomposition and entropy results in this paper.

Figure 2 shows three component images as collapse rate increases from 0, 44, and 100 %. The pixel dimension is 1 cm by 0.9 cm. The scanned area is 128 cm by 216 cm. It is seen in Figs.2 and 3 that the single bounce (plate) component Ks increases as collapse rate increases, whereas the double bounce (corner reflector) component Kd decreases. In the normal situation, the double bounce component is dominant, while in the damaged situation, the single bounce component increases. This fact supports our intuition from the phenomenological point of view. This fact is also seen in Fig.4 in which entropy of the scene becomes high (random) and wire component increases in destroyed area. It is anticipated these indices become one of indicators.

4. Concluding Remarks

We tried to retrieve a relation among three decomposed components ratio, entropy and angle for the collapse rate of buildings. Although a definite conclusion cannot be derived from a model experiment, this polarization information is one of good indicators. Robust characteristics will be useful for monitoring destroyed area by airborne or satellite SAR. In addition, more inclusion of other indices may serve accurate estimation of collapse situations. This will be treated in the near future.

Acknowledgment

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References

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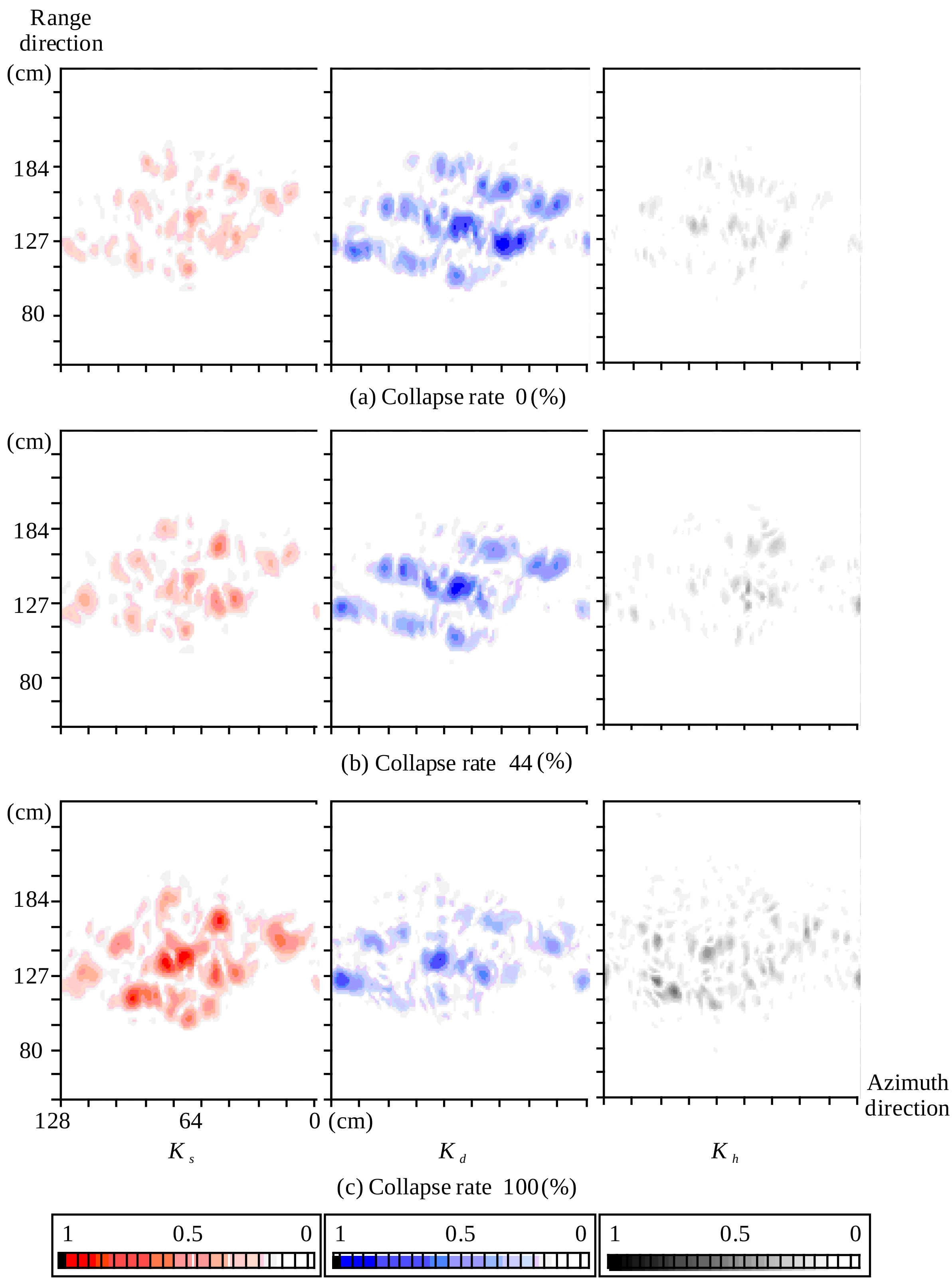


Fig. 2 Three component images

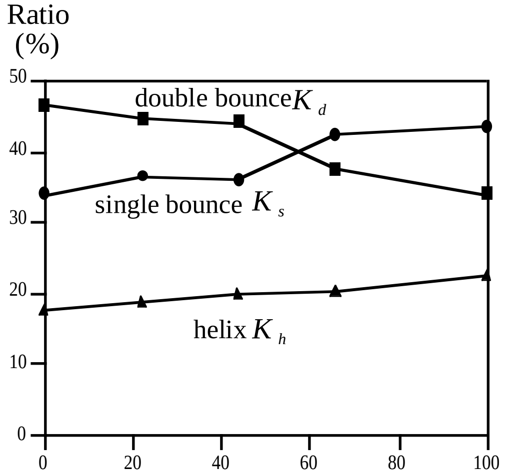
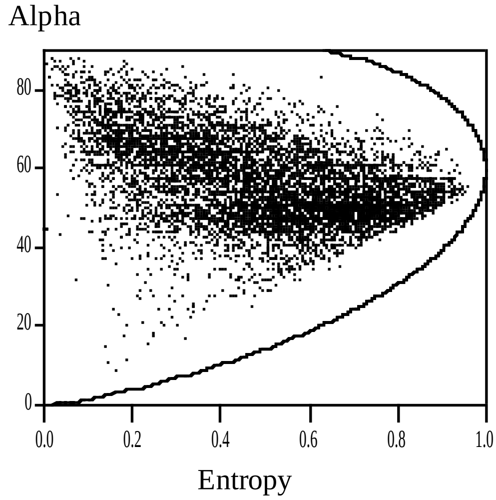
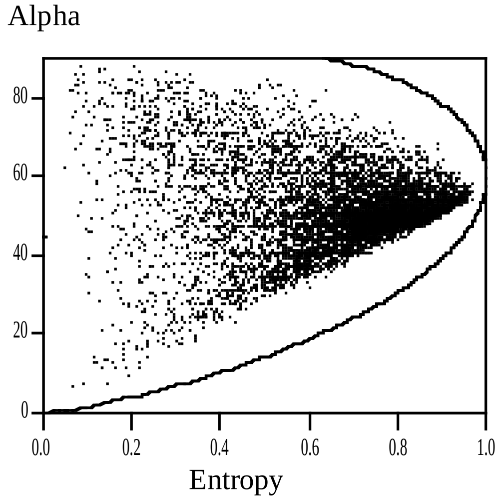


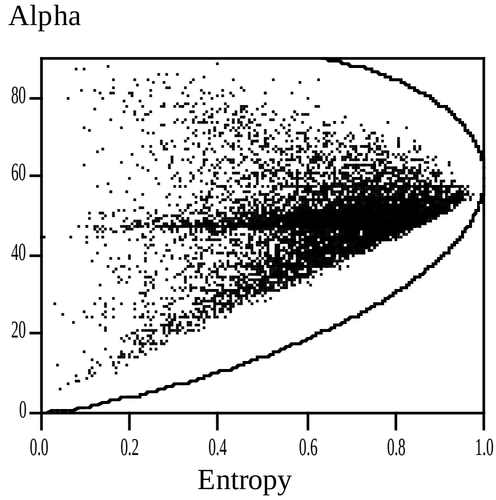
Fig. 3 Variation of three fundamental components by collapse rate



(a) Collapse rate 0 (%)



(b) Collapse rate 44 (%)



(c) Collapse rate 100 (%)

Fig. 4 Polarimetric entropy and $\bar{\alpha}$ ((a) Collapse rate 0 (%), (b) 44 (%) and (c) 100 (%))