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Analysis of backscattering characteristics of buildings using full-polarimetric airborne SAR images

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Abstract: Airborne SAR has been used for emergency observations after disasters. However, the lack of pre-event data causes the limitation in change detections. As a preliminary study of damage detection for buildings, this study attempts to grasp the backscattering characteristics of flat-roof buildings from Pi-SAR-X2 images. Three target areas were used to estimate the relationship of backscattering conditions and illumination angles. The comparisons were carried out using both the full polarizations and the 4-components scattering powers inside the building layovers. As the result, it was found that the scattering power and backscattering of polarizations were affected by the illumination angles.
Keywords: Pi-SAR-X2, layover, buildings, full-polarimetry, SAR backscatter

1. Introduction

In recent years, the risk of natural disasters is increasing as the rising development in structures and populations. Therefore, in order to reduce these disaster impacts, it is necessary to grasp the damage situations at early stage to prepare the appropriate emergency response. However, after a disaster, communication and transportation networks are usually in the state of disorder. In that case, it is difficult to access the site in order to evaluate the details on damages. As a solution, remote sensing has been used for extracting damage areas. Although the airborne SAR is capable of emergency observation, it is difficult to observe the same area twice with the same acquisition condition. The lack of the pre-event data also causes the limitation in change detection. Therefore, it is important to grasp the condition of damaged areas only from a post-event airborne SAR image. As a preliminary study, this research attempts to investigate the backscattering characteristics of buildings using full-polarization Pi-SAR-X2 images in a normal situation.

2. The Study areas and SAR data used

In this study, three different flat-roof apartment complexes around Tokyo Bay area were selected as targets. Five airborne SAR images taken in the different paths using X-band radar were used. These images (Pi-SAR-X2) are developed by NICT[1)]. The acquisition conditions of three areas are shown in **Table 1**. The backscattering of the target buildings are investigated using full polarizations (HH/HV/VH/VV) and four-component scattering power[2)].

Table 1 Acquisition conditions of the three study areas (Azimuth angle, incidence angle θ)

Apartment complex	No	Date	Az (°)	θ(°)
Tatsumi	K1	2017/11/14	93.2	47.2
	K2	2011/03/31	17.8	51.8
	K3	2013/01/10	267.3	56.4
Takahama	T1	2017/11/14	93.6	36.7
	T2	2015/12/03	90.7	33.6
	T3	2017/11/14	93.3	45.6
Keisei Sankopo	S1	2015/12/03	90.6	47.7
	S2	2013/01/10	36.8	42.6
	S3	2013/01/10	267.3	57.9
	S4	2017/11/14	93.2	47.2

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3. Building reflection model

Based on the Brunner et al.[3)], backscattering models of flat-roof buildings are divided into two categories depending on the building height h and the width w, as well as the incidence angle θ of the radar. In this study, the buildings are in the type of $h > w \tan \theta$. The backscattering of the roof (e) and its corner (d) overlapped the backscattering from the wall (c) and located before the double-bounce reflection (b), as shown in in **Fig. 1**. Therefore, theoretically, there is no backscattering inside the building's outline and the shadow region. Thus, only the backscattering within the layover area was considered.

The backscattering of a building is also affected by the building's orientation. Therefore, in this investigation, building's illumination angle (φ), which is taken clockwise from radar's range direction to the building axis as shown in **Fig. 2**, should be taken into consideration.

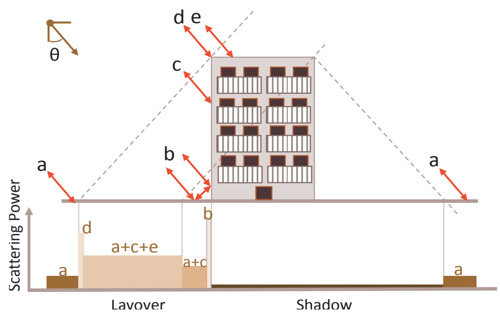
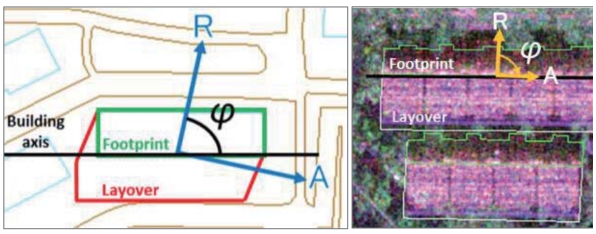


Fig. 1. Backscattering model of a flat roof building



(a) (b)

Fig. 2. Illustration on defining illumination angle (φ) and an example in the SAR image (b)

4. Analysis of full polarizations four scattering components

First, in order to analyze the effect of illumination angle to different polarizations, the full-polarization images in Keisei Sankopo area were investigated. Even though the tendency of backscattering could be seen while comparing to illumination angle, the results in this area showed wide dispersion in the backscattering value. This kind of dispersion is particularly seen in VV polarization (**Fig. 3**), at the same angle of 82°, the result dispersed from -13.81 dB and -22.53 dB. This dispersion may be caused by the different images used in observation, as the acquisition condition of incidence angle and range direction may affect the result of backscattering. Thus it is necessary to analyze the tendency of backscattering from one-time image instead of using multi-temporal images.

As a solution, one-time image from 14 November 2017 were investigated. This image contained the footage from three apartment complexes, and the average value of the backscattering coefficients within each building's layover was calculated. The result of each polarization is shown in **Fig. 4**. **Fig. 5** shows the color composites of different polarizations (HH in red, HV in green, and VV in blue) in each area. As shown in **Fig. 4**, as the φ getting closer to 90°, the backscattering intensity in the HH and VV polarizations increased, whereas in the HV and VH polarizations, that showed an inverted parabolic trend as they peaked around 40°, and slightly declined on 90°.

Similarly, the scattering power within the building layovers decomposed from the full-polarizations are shown in **Fig. 6**. By using this method, the scattering mechanism can be observed clearer than the single polarization. According to the graph, the scattering of buildings was mainly dominated by the double-bounce scattering *(P_d)* and the surface scattering *(P_s)*. Both of those scattering powers increased as the illumination angle got closer to 0° and 90°. On the contrary, the volume scattering *(P_v)* is significantly low. The low percentage of P_v was due to fewer high trees in the target residential areas, there were fewer high trees.

5. Conclusions

As a preliminary study of use of high-resolution airborne SAR data in disaster response, the observation of the backscattering characteristics of flat-roof buildings was carried out using full polarizations and 4-component scattering power. It was found that the backscattering intensity and components are affected by the radar incidence angle as well as the building orientation. As results, the scattering intensity of the HH and VV polarizations were stronger when the illumination angle got closer to 0° and 90°, whereas the HV and VH polarizations had the opposite trend. On the other hand, in the 4-component decomposition, the backscattering is mainly dominated by surface scattering and double-bounced scatterings. However, this finding should be reviewed in the future by adding more variations in the illumination angles.

Acknowledgement: The Pi-SAR-X2 data used in this study are owned and provided by NICT.

References

1) Nation Institute of Information and Communication Technology (NICT): https://pi-sar.nict.go.jp/
2) G. Singh, Y. Yamaguchi, S. Park: General four-component scattering power decomposition with unitary transformation of coherency matrix, IEEE Trans. on Geosc. and R. Sensing, 51(5), pp. 3014-3022, 2013.
3) D. Brunner, G. Lemoine, L. Bruzzone: Earthquake damage assessment of buildings using VHR optical and SAR imagery, IEEE Trans. on Geosc. and R. Sensing, 48 (5), pp. 2403-2420, 2010.

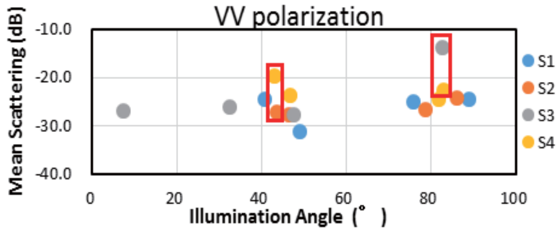


Fig. 3. Relationship between the mean value of the backscattering coefficients in VV polarizations in Keisei Sankopo and the value dispersion at 43° and 82°.

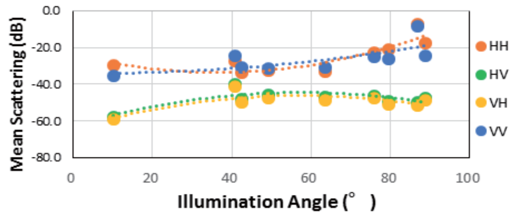
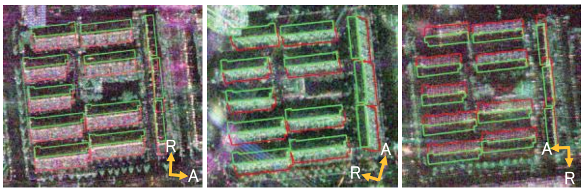


Fig. 4. Relationship between the mean value of the backscattering coefficients in the different polarizations and the different illumination angles.



(a) Tatsumi apartment complex (K1-K2-K3)

(b) Takahama apartment complex (T1-T2)

(c) Keisei Sankopo apartment complex (S1-S2-S3-S4)

Fig. 5. Color composite of HH, HV and VV polarizations for the three target apartment complexes

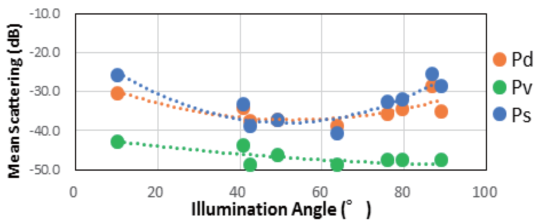


Fig. 6. Relationship between the mean value of the backscattering coefficients in the different scattering components and the different illumination angles.