

Extraction of Area-Averaged Orientation Angle from POLSAR Measurement

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1. INTRODUCTION

It is very useful to know urban structure parameters, such as size and orientation angle of buildings, even as macroscopic average values over area of concern. Especially in highly urbanized area such information is very important for not only development planning but also large disaster recovery planning. In Table 1 some application examples of such information are shown. It is well known that POLSAR measurement is quite powerful tool for the above application because of its capability that it can observe regardless of weather, day/night, smoke, clouds or dust. By using data analysis using full-polarimetric measurement results, such as scattering decomposition, we can derive or estimate such area-averaged urban parameters which can not be observed from simple HH, HV and VV pseudo-color map due to insufficiency of spatial resolution of POLSAR. Similar analysis for estimation of urban buildings density or building orientation are reported[1,2,3,4] We analyzed airborne Pi-SAR and satellite-borne PALSAR data as POLSAR observations measured over Tokyo area together with high-resolution optical observation data from QuickBird and 1/2500 POLYGON map surveyed by Tokyo Metropolitan Office.

2. POLSAR DATA AND GROUND-TRUTH DATA

We used the following POLSAR measurements over Tokyo urban area;

- PALSAR : L-band, 9-times repeated measurements over the same area during 1.5 year, 2 kinds of azimuth observation directions (Ascending and Descending)
 - Pi-SAR : L- and X-band repeated measurements during several years, 3 azimuth observation directions
- We also used the following data to assist to obtain ground-truth values regarding area-averaged urban structure parameters;
- 1/2500 buildings POLYGON map: this includes not only buildings size, shape and height information but also classification of land, road, building usage and so on.

Figs.1 shows observation example by Pi-SAR. Fig.2 shows POLYGON map at where we used to extract area-averaged structure orientation information in the following sections. They are pictures at the same area of Tachikawa, western part of Tokyo.

3. EXTRACTION OF AREA-AVERAGED BUILDINGS ORIENTATION ANGLE

3.1. Derivation of structure orientation angle

We aimed to derive urban structure orientation angle objectively from POLYGON data. As shown in Fig.3, we apply 2-dimensional FFT over the region of interest and from this spatial spectrum the area-averaged structure orientation angle, θ is extracted. This ground-truth data are derived from many areas in Tachikawa.

3.2. Analysis of POLSAR observation data

In order to carry out unified analysis using POLSAR data, registration is applied to all POLSAR data into Pi-SAR based observation coordinates. As shown in Fig. 4, average structure orientation angle relative to POLSAR incident direction mentioned in the previous section is derived using these 10-by-10 pixels. Simultaneously, POLSAR data analysis explained below is done over these same 10-by-10 pixels. By using knowledge that there is correlation between ground structure orientation angle and argument of complex correlation coefficient, gamma, on circularly polarized POLSAR measurement bases[1,2], we derive this argument for each area of concern. The definition of this correlation coefficient is shown in Eq.(1) below. The brackets in this equation mean average over the area mentioned in the previous paragraph. The argument, phi, can be derived from contains components of scattering matrix of linearly polarized POLSAR measurement bases.

$$\gamma_{rr_{-ll}} = \frac{\langle S_{rr} S_{ll}^* \rangle}{\sqrt{\langle S_{rr} S_{rr}^* \rangle \langle S_{ll} S_{ll}^* \rangle}} = |\gamma_{rr_{-ll}}| \angle \phi_{rr_{-ll}} \quad (1)$$

where S denotes components of scattering matrix and its suffixes represents components of polarization. The suffixes r and l mean circularly polarized bases and h and v mean linearly polarized ones.

3.3. Examples of analysis

In Fig.5, relations between structure orientation angle (abscissa) and argument phi(ordinate) derived from phi (ordinate) based on several POLSAR observation including Pi-SAR L-band and X-band, and PALSAR ascending and descending are shown. In this figure each dot represents the relation derived from one average area. From this figure, clear correlation between orientation angles and arguments is observed even different measurement conditions. Then, for efficient derivation of area-averaged structure orientation angle over wide area, we obtain linear regression relationship. By using this simple linear regression relation, we can estimate area-averaged structure orientation angle over wide area systematically. For example, Fig.6 shows result of this approach on the area shown in Fig.1 and 2. Fig.7 shows urban structure orientation map derived POLYGON map in the same area. We cannot estimate the structure orientation angles from Fig.1 because of poor spatial resolution. However, we clearly observe similarity between two orientation maps, Fig.6 and 7. Fig.8 shows scatter plot between Fig.7(abscissa) and Fig.6(ordinate) which is unwrapped. It is also clearly observed that Fig.8 has good correlation. We confirmed that by using full polarimetric POLSAR measurement data and data processing mentioned previously, we can estimate area-averaged buildings orientation in urban area which can not be observed from simple received signal component intensities.

4. CONCLUSION

We have shown that area-averaged structure orientation angles relative to incident angle of POLSAR in urban area can be estimated from argument of correlation coefficient of circularly-polarized observation bases. It is quite interesting that by this approach we can estimate area-averaged urban parameters even if we can not distinguish them from conventional received signal component intensity map due to lack of spatial resolution.

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5. REFERENCES

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Table 1 Examples of parameters in urban area

	How useful? (Application Examples)	
	[Spatial Aspects]	[Temporal Change]
Degree of Structural Order	•Classification of Land Usage (Artificial or Natural, % of Road, Houses, Farm, Garden, ...)	•Urbanization history and Development Planning •Disaster Recovery Strategy
Average Size of Structures	•Classification of Area Usage (Factory, House...)	• Urbanization history and Development Planning
Average Orientation Angle	•Access Simulation •Living Environment (Duration of Sun-shine, ...)	•Urbanization or road Development history and Planning •Disaster Recovery Strategy
Density of Structures	•Access Simulation •Living Environment •Development Planning	•Urbanization history and planning •Disaster Recovery Strategy



Fig.1 Pi-SAR Observation (L-band)

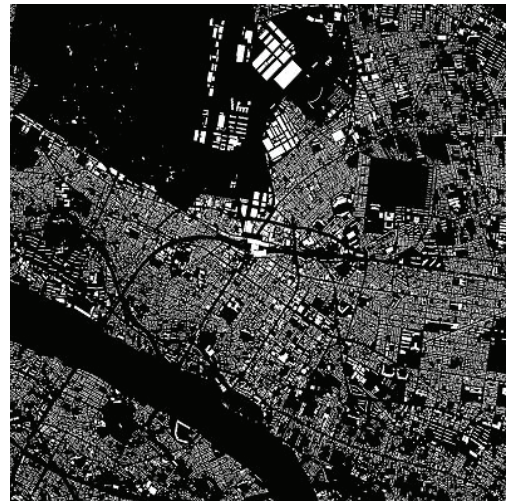


Fig.2 1/2500 POLYGON map

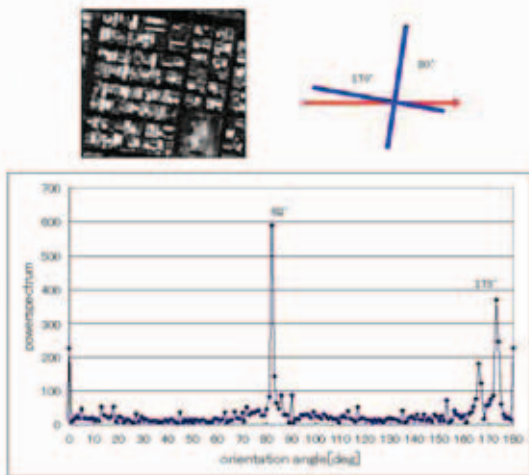


Fig.3 Derivation of urban structure orientation angle

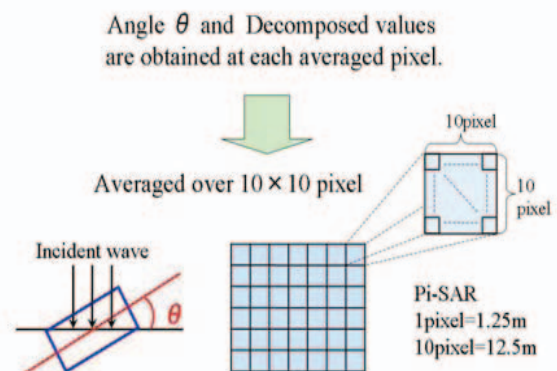


Fig.4 Area average of POLSAR data analysis

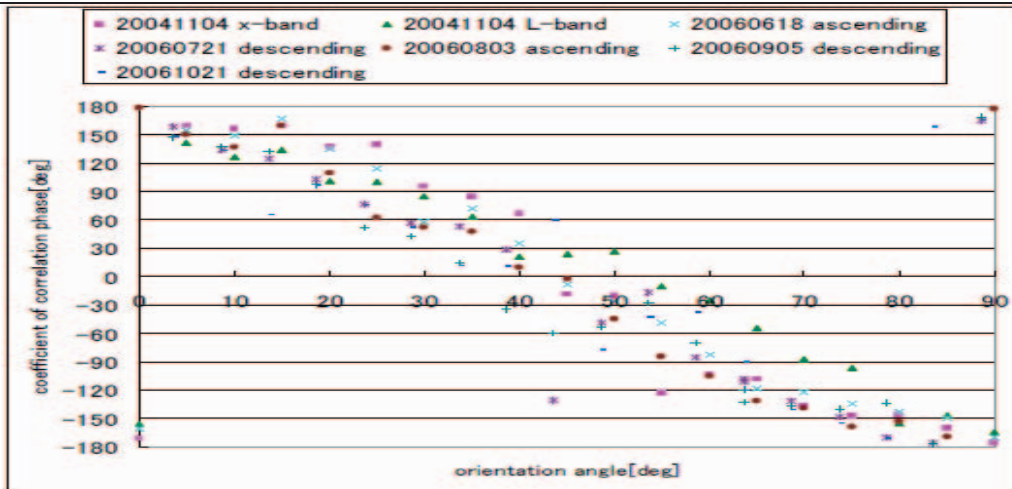


Fig.5 Orientation and POLSAR Phase (Median Values)

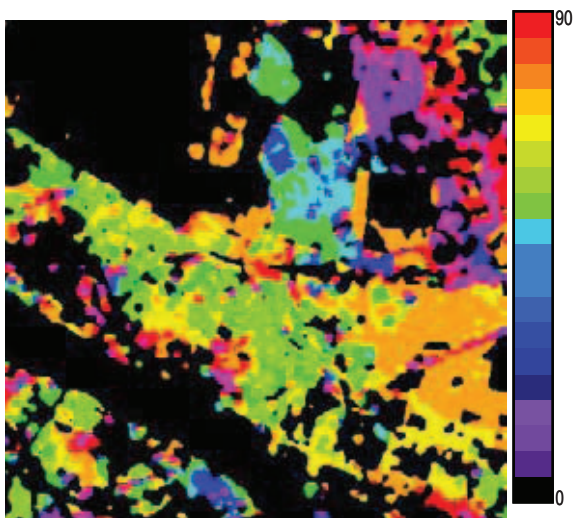


Fig.6 Urban Structure Orientation Map at Area of Fig.1 and 2

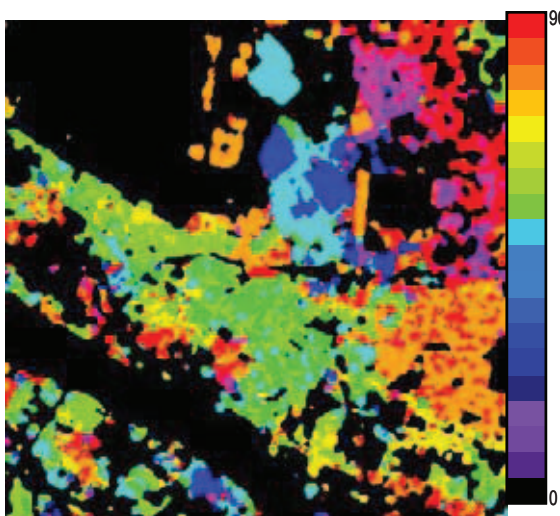


Fig.7 Urban Structure Orientation Map derived POLYGON map analysis

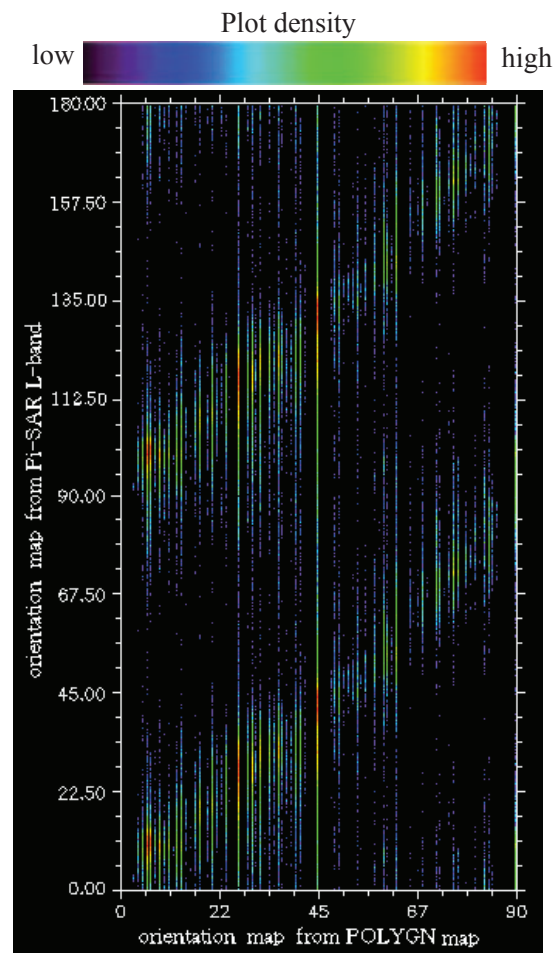


Fig.8 Scatter plot between Fig.6 and Fig.7