

PRELIMINARY RESULT OF POLARIZATION PROPERTY ANALYSIS USING FULLY POLARIMETRIC GB-SAR IMAGES

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ABSTRACT

Korea Institute of Geoscience and Mineral Resources (KIGAM) and Kangwon National University (KNU) ground-based synthetic aperture radar (GB-SAR) team has been developed a fully polarimetric and interferometric GB-SAR system over past several years. The objective of this paper is to investigate an application of the obtained fully polarimetric GB-SAR images and an effective polarimetric analysis method to extract polarization properties from different terrain targets as a preliminary study. We utilized an unsupervised classification method for analyzing of a fully polarimetric GB-SAR image, in particular, Cloude and Pottier's method and a combined $H/A/\underline{g}$ and the complex Wishart classifier method based on the $H/A/\underline{g}$ polarimetric decomposition theorem.

Index Terms—GB-SAR, fully polarimetric SAR, polarimetric property, $H/A/\underline{g}$ polarimetric decomposition

1. INTRODUCTION

GB-SAR system operates on similar imaging radar principle in microwave frequencies as airborne and spaceborne SAR systems. The GB-SAR system has real time capability and flexibility for monitoring in emergency cases such as sudden landslide better than other satellite SAR system. Many research papers have been presented about GB-SAR interferometry techniques. These studies were concentrated on a monitoring of natural hazards, in particular, those phenomena producing ground displacements and the landslides or snow covered slope movement, and a terrain mapping. Also GB-SAR systems have been utilized as a monitoring tool for a large artificial structure such as dams, bridges, buildings and so on. The application researches using SAR polarimetry technique in GB-SAR have been presented to investigate vegetation targets. Zhou *et al.* (2004) described a broadband ground-based SAR system and its application results for vegetation monitoring. And Hamasaki *et al.* (2005) discussed a

polarimetric analysis results for a coniferous tree using a polarimetric and interferometric GB-SAR system.

To achieve physical or biophysical information of various targets on the earth's surface, we need to understand scattering characteristics received from different terrain targets. Many researchers have been interested in classification, decomposition, and modeling methods in recent literature to gain the reliable polarimetric information contained in a polarimetric SAR data. Classification of the different terrain types using a fully polarimetric SAR image is one of the important applications of SAR polarimetry technique. SAR polarimetry is concerned with control of the polarimetric properties of radar waves and the extraction of target properties from the behavior of scattered waves from a target.

An entropy based method proposed by Cloude and Pottier (1997) is the one of famous polarimetric analysis methods for extracting average parameters from a polarimetric SAR image. Lee *et al.* (1999) described a combined unsupervised classification method which applied Cloude and Pottier's decomposition scheme to initially classify a polarimetric SAR image and followed by iterated refinement using the complex Wishart classifier. The combined method has the advantage that is its effectiveness in automated classification, and in providing interpretation based on scattering mechanism for each class. This combined method could be ignored the physical scattering characteristics of each pixel.

The main objective of this study is to analyse polarimetric characteristics of terrain targets using the obtained fully polarimetric GB-SAR images and to confirm a compatible and effective polarimetric analysis method to reveal the polarization properties of different targets. In this paper, we focused on the analysis and classification of a fully polarimetric SAR image obtained by our GB-SAR system using the $H/A/\underline{g}$ polarimetric decomposition theorem for SAR polarimetry applications. We described our recent results to investigate the dominant scattering properties of various surface media using an unsupervised polarimetric

classification method based on the $H/A/\underline{a}$ polarimetric decomposition. The $H/A/\underline{a}$ decomposition and the combined classification method was applied to classifying of different terrain targets such as trees, grass, a man-made structure, and a permanent scatterer in the study areas as a preliminary study.

2. METHODOLOGY

The simplified schematic configuration of the developed GB-SAR system is shown in Fig. 1, and measurement specifications are listed in Table 1. The GB-SAR system consists of two instrument parts which are a radio frequency (RF) system part based on a Vector Network Analyzer (VNA) and a motion controlling part. The RF instrumentation composed of a VNA, a power amplifier, and a dual polarization square horn antenna. And PCI eXtensions for Instrumentation (PXI) or a notebook computer controls a VNA, a motion of the antennas, and data recording. This GB-SAR system has a capability of measuring a fully polarimetric and interferometric SAR data and multi-frequency data at C-band (5.3 GHz) and X-band (9.65 GHz) and its flexibility of a measurement for various natural and artificial targets.

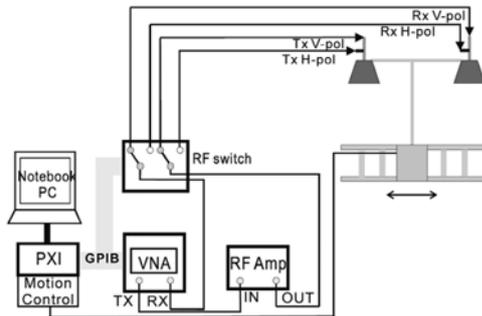


Fig. 1. Configuration of a GB-SAR system.

Table 1 GB-SAR measurement characteristics.

center frequency	5.3 GHz
range bandwidth	600 MHz
IF bandwidth	1 kHz
number of point	1601
power	calibration: VNA -40 dBm, Amp 33 dBm acquisition: VNA 0 dBm, Amp 33 dBm
azimuth sampling step	5 cm
azimuth length	5 m
polarization mode	quad-polarization (HH, HV, VH, VV)
maximum range	~ 200 m

The C-band fully polarimetric SAR data used in this study was obtained at 160 times during 3 days between 3rd and 5th

November, 2008 in late autumn season of Korea. As shown in Fig. 2, the outdoor test site located inside KIGAM field and the radar measurement position where located on 4th floor building height. There are a little hillock area covered with trees and grass, around flat grass field, and several artificial targets such as wooden geomagnetic observation boxes and metallic poles and panels in the test site. Five metallic trihedral corner reflectors (side length: 50 cm) were used to obtain a high radar cross section (RCS) reference.



Fig. 2. GB-SAR system (a), the test site (b and c) inside KIGAM field, and the used trihedral corner reflector (d).

In this work, we used the ‘gbsar’ processor developed by KNU for a GB-SAR focusing processing. Lee *et al.* (2007a; 2007b) already described about the characteristics, advantages, and limitations according to different SAR focusing algorithm such as Deramp-FFT (DF) and Range-Doppler (RD) algorithm. After a SAR focusing processing, an open software package, named ‘PolSARpro’ was used for a polarimetric analysis and classification of the polarimetric GB-SAR image. The observed polarimetric GB-SAR data was processed by the Deramp-FFT (DF) algorithm for a SAR focusing processing. And a multi-looking and the Lee refined SAR speckle filtering (Lee and Pottier, 2009) were applied for speckle reduction and data compression. And $H/A/\underline{a}$ polarimetric decomposition method and the combined unsupervised classification with the Wishart classifier algorithm were processed before and after the speckle filtering processing.

3. RESULTS

Fig. 3 showed a Sinclair color-coded image of VV, HV and HH components as red, green, and blue colors respectively. Five permanent scatterers were represented white and pink-magenta color associated with a strong backscattering property, also appeared at man-made targets such as several wooden boxes and metallic poles. Over the grass area, the green color indicates a dominant HV component, generally characteristics of vegetated field.

Fig. 4 and Fig. 5 showed the unsupervised segmentation images and distribution results in H/α , H/A , and A/α planes based on Cloude and Pottier's method. As shown in Fig. 5, the classification images and H/α distribution results were separated a pixel element of the GB-SAR image into zone 8 and zone 5 dominantly. The zone 8 and 5 characterize low entropy dipole scattering and medium entropy vegetation scattering respectively. The trees and a part of grass area were classified zone 5 and the whole grass area was segmented on zone 8. The five permanent scatterers were appeared red color pixels in the image distributed in zone 7.

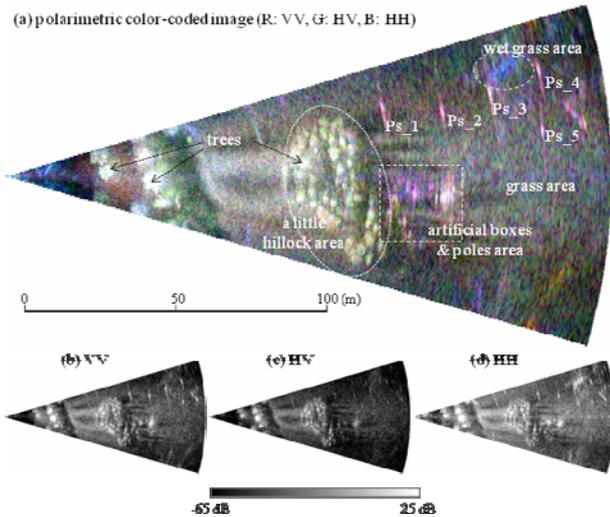


Fig. 3. The polarimetric color-coded image (a) and three polarimetric component amplitude images (b-d) in dB.

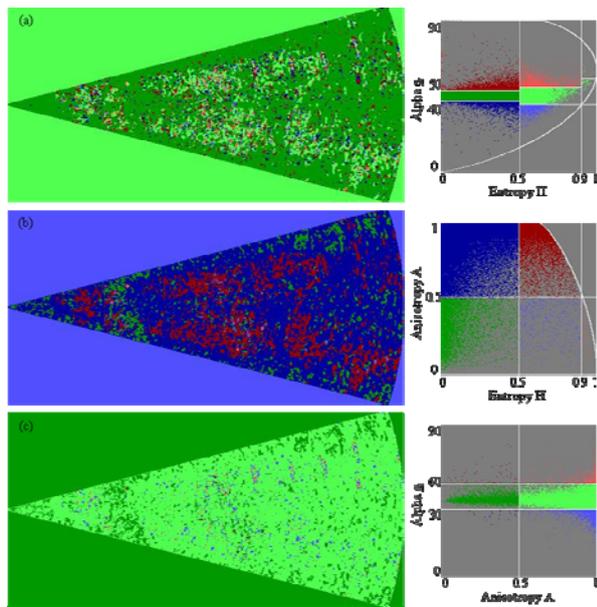


Fig. 4. Unsupervised segmentation result (window size: 1) of the obtained PolSAR image using the $H/A/\alpha$ space.

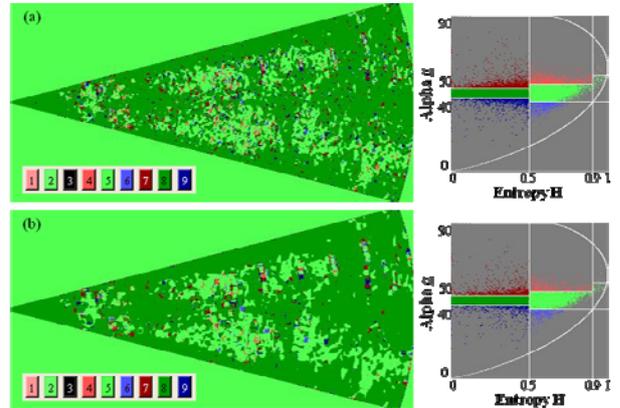


Fig. 5. Unsupervised segmentation result in H/α plane. The left images are classification maps applied window size (a) 3 and (b) 5 respectively and the right distribution results are color coded for each zone.

The unsupervised classification method based on the $H/A/\alpha$ decomposition and the complex Wishart classifier algorithm were used to extract the classification information of different terrain targets for the GB-SAR image. The results using the Wishart- H/α classification method showed that the man-made targets such as 5 trihedral corner reflectors, wooden boxes, and metallic poles were separated from a natural media such as trees and grass area. We thought that the classification results after the Lee refined speckle filter showed better result than ones before the speckle filtering. Fig. 6 showed the Wisahrt- H/α classification images and the enlarged images in which represented the polarimetric parameter measurement points. The polarimetric parameter values listed in Table 2 were extracted from 5 permanent scatterers, 2 artificial targets, and 4 trees positions. The positions for 5 permanent scatterers were represented ps_1, ps_2, ps_3, ps_4, and ps_5. The md_1 and md_2 are the points for 2 man-made targets and tr_1, tr_2, tr_3, and tr_4 are related to a tree area. The HH, HV, VH, and VV values were extracted from an amplitude image and the span value was computed from T3 coherency matrix. We can see that the 5 permanent scatterers and 2 man-made targets were classified to class 4 mainly. The tr_2 position sometimes classified in class 4 that may be a role like as a corner reflector and the other trees area divided to class 2 and 6 dominantly. As shown in Table 2, these example targets were not distinguished only by a numerical difference of polarimetric parameters between a natural media and an artificial target. For example, the ps_2 and tr_3 are similar in HH values but these areas are separated in a different class, class 4 and class 6. And the md_2 and tr_5 also are classified a different class even though they has a few numerical difference.

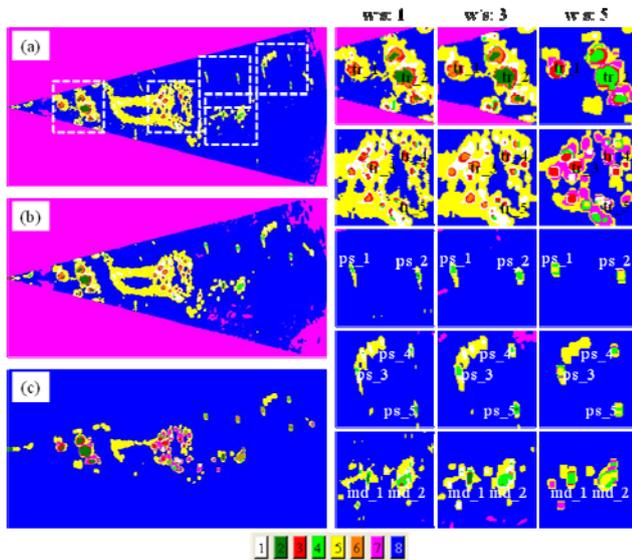


Fig. 6. Wishart-H/ α classification results applying 4% ratio value after 6 iterations and the used window size are (a) 1, (b) 3, and (c) 5 respectively. The 5 white boxes area in (a) showed the positions extracted the polarimetric parameters listed in Table 2 and the enlarged images of these boxes area were arranged on right side.

Table 2 The HH, HV, VH, and VV components and span values at 5 permanent scatterers, 2 man-made targets, and 5 trees positions corresponding to Fig. 6(b).

Target	Pixel		Class w/s:3	Values (dB)				
	x	y		HH	HV	VH	VV	Span
tr_1	87	128	2	16.68	7.67	5.49	9.29	31.44
tr_2	124	131	2	23.45	-7.52	1.69	13.50	39.90
tr_3	252	119	6	11.43	-2.21	-5.33	-0.24	19.64
tr_4	277	112	6	7.53	-14.04	-13.55	2.79	8.39
tr_5	276	149	3	5.27	-2.44	-4.12	-10.95	9.82
ps_1	318	76	4	9.46	-20.83	-23.60	7.94	16.07
ps_2	369	81	4	11.85	-15.15	-22.68	11.74	21.81
ps_3	409	65	4	8.28	-11.58	-13.86	8.74	14.96
ps_4	450	48	4	3.39	-19.23	-22.12	2.19	2.24
ps_5	454	94	2	15.28	-13.02	-17.53	11.96	26.54
md_1	345	142	2	26.06	-15.14	-11.31	14.96	44.48
md_2	372	143	4	4.45	-12.04	-25.64	-1.43	13.59

4. CONCLUSIONS

The polarimetric characteristics of terrain surface targets contained in the fully polarimetric GB-SAR image were discussed to confirm an effective polarimetric analysis method for SAR polarimetry application. In this study, we utilized the H/A/ α polarimetric decomposition theorem to reveal a polarization property of different terrain targets. The unsupervised segmentation result using Cloude and

Pottier's method and the Wishart-H/ α classification result showed that the used polarimetric methods based on H/A/ α polarimetric decomposition can be effective and useful to discriminate between a natural and an artificial target. And the developed GB-SAR system could be used as a convenient tool for the analysis of polarimetric properties for different terrain targets.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

- H. Lee, S. -J. Cho, N. -H. Sung, and J. -H. Kim, "Development of a GB-SAR (I): System Configuration and Interferometry," *Korean Journal of Remote Sensing*, vol. 23, no. 4, pp. 237-245, 2007a.
- H. Lee, S. -J. Cho, N. -H. Sung, and J. -H. Kim, "Development of a GB-SAR (II): Focusing Algorithms," *Korean Journal of Remote Sensing*, vol. 23, no. 4, pp. 247-256, 2007b.
- J. -S. Lee, M. R. Grunes, T. L. Ainsworth, L. -J. Du, D. L. Schuler, and S. R. Cloude, "Unsupervised Classification Using Polarimetric Decomposition and the Complex Wishart Classifier," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 37, no. 5, pp. 2249-2258, 1999.
- J. -S. Lee and E. Pottier, *Polarimetric Radar Imaging from Basics to Applications*, CRC Press, Boca Raton, FL, USA, 2009.
- S. R. Cloude and E. Pottier, "An Entropy Based Classification Scheme for Land Applications of Polarimetric SAR," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 35, no. 1, pp. 68-78, 1997.
- T. Hamasaki, M. Sato, L. Ferro-Famil, and E. Pottier, "Natural Objects Monitoring Using Polarimetric Interferometric Ground-Based SAR (GB-SAR) System," *IGARSS 2005 Proceedings*, pp. 4092-4095, 2005.
- Z. -S. Zhou, W. -M. Boerner, and M. Sato, "Development of a Ground-Based Polarimetric Broadband SAR System for Noninvasive Ground-Truth Validation in Vegetation Monitoring," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 42, no. 9, pp. 1803-1810, 2004.