Evaluation of DoP-CPD Classification Technique and Multi Looking Effects for RADARSAT-2 Images

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Abstract : This paper give further assessment on the original DoP-CPD classification scheme. This paper provides some additional comparative study on the DoP-CPD with H/A/alpha classifier in terms of multi look effects and classification performances. The statistics and multi looking effects of the DoP and CPD were analyzed with measured polarimetric SAR data. DoP-CPD is less sensitive to the number of averaging pixels than the entropy-alpha technique. A DoP-CPD diagram with appropriate boundaries between six different classes was then developed based on the data analysis. A polarimetric SAR image DoP-CPD classification technique is verified with C-band polarimetric RADARSAT-2 images.

Key Words : SAR, Classification, Degree of polarization, Co-polarized phase-difference, Radarsat-2

1. Introduction

There are various supervised and unsupervised classification algorithms for polarimetric SAR (Kong et al., 1988; Lee et al., 1994; Lardeux et al., 2009; Ersahin et al., 2010). There are also various PolSAR decomposition techniques (Van zyl et al., 1987; Freeman and Durden, 1998; Yamaguchi et al., 2005; Lee and Oh, 2009). The entropy-alpha-anisotropy technique is the most common classification technique for polarimetric SAR images (Cloude and Pottier, 1997). The Cloude-Pottier technique is to classify the polarimetric response of each pixel into an entropy-alpha-anisotropy diagram, in which the entropy, alpha and anisotropy are computed from Eigen analysis of the coherency matrices. Although the Eigen analysis may be an excellent technique to analyze an information matrix, it has some weak points for the SAR image classification. In the process of the Eigen analysis, the magnitudes of the coherency matrix elements are normalized such that the information in the magnitudes is lost, and consequently it prevents us to proceed to the classification process after the Eigen analysis. So, in our previous research, we proposed one unsupervised classification technique using the degree of polarization (DoP) and the co-polarized phase-difference (CPD) statistics (Oh et al., 2009; Rio et al., 2006; Ulaby et al., 1992). This classification technique is simple and intuitive because the DoP and
CPD are physical parameters which can be obtained directly from the covariance matrix, or the Stokes scattering matrix, without Eigen analysis. We proposed a DoP-CPD technique for classification boundary values from experimental data using only L-band polarimetric AirSAR and PALSAR data. Hence, in this paper DoP-CPD classification technique is verified with C-band polarimetric RADARSAT-2 image. In addition, the multi looking effects on the DoP and CPD are also analyzed. Speckle complicates the image interpretation problem and reduces the accuracy of image segmentation and classification. We analyzed the sensitivities of the classification parameters on various targets and the effect of ensemble averaging. The DoP-CPD diagram boundary values are dependent on the number of averaging pixels.

2. Classification parameters

In general, the scattered electric field $E^s$ can be written with the complex $2 \times 2$ scattering matrix $S$ (Sinclair, 1950):

$$
\begin{bmatrix}
E_h^s \\
E_v^s
\end{bmatrix} = e^{-j\phi_r} \begin{bmatrix}
S_{hh} & S_{hv} \\
S_{vh} & S_{vv}
\end{bmatrix} \begin{bmatrix}
E_h \\
E_v
\end{bmatrix}
$$

(1)

where $h$ and $v$ denote horizontally and vertically polarized waves, respectively. The Stokes vector is defined as

$$
\vec{F}^s = \begin{bmatrix}
I^s \\
Q^s \\
U^s \\
V^s
\end{bmatrix} = \begin{bmatrix}
\langle E_h^s E_h^s \rangle + \langle E_v^s E_v^s \rangle \\
\langle E_h^s E_h^s \rangle - \langle E_v^s E_v^s \rangle \\
2\text{Re}(\langle E_h^s E_v^s \rangle) \\
2\text{Im}(\langle E_h^s E_v^s \rangle)
\end{bmatrix}
$$

(2)

where $\langle \cdot \rangle$ indicates the ensemble average (Ulaby and Elachi, 1990). The DoP of the partially polarized wave is then defined as

$$
\text{DoP} = \frac{\sqrt{Q^2 + U^2 + V^2}}{I^s}
$$

(3)

The DoP can be obtained from the Mueller matrix, the Stokes scattering matrix, or the covariance matrix for $h$- and $v$-polarized wave incidences. We used then the DoP value which is the mean of the $h$- and $v$-polarized DoP values.

The DoP could be used as an important factor for classifying image classes, because the DoP measures how much the effect of multiple reflections is contained in a target area (Elies et al., 1997).

The CPD can be defined as the ensemble average of the co-polarized phase-difference between the $hh$- and $vv$-polarized scattered waves. In the backscattering case, the measured scattering matrix by a polarimetric radar system consists of five quantities; $|S_{hh}|, |S_{vv}|$ and $|S_{hv}|, \phi_h = \phi_{hh} - \phi_{hv}$, and $|S_{vh}|, \phi_v = \phi_{hv} - \phi_{vv}$.

$$
S = e^{-j\phi_v} \begin{bmatrix}
|S_{hh}| e^{-j\phi_h} & |S_{hv}| e^{-j\phi_h} \\
|S_{vh}| e^{-j\phi_h} & |S_{vv}| e^{-j\phi_h}
\end{bmatrix}
$$

(4)

The CPD $\phi_c$ can be written as

$$
\phi_c = \phi_{hh} - \phi_{vv} = \tan^{-1} \left( \frac{\text{Im}(S_{hh} S_{vv}^*)}{\text{Re}(S_{hh} S_{vv}^*)} \right)
$$

(5)

For most natural targets, the cross-polarized phase difference $\phi_v$ is almost uniformly distributed over $[0, 2\pi]$, and therefore, contains less target-specific information. On the other hand, the CPD($\phi_c$) shows a Gaussian PDF with both a standard deviation and a mean which depend on the target characteristics. Hence, the CPD contains some target-specific information (Ulaby et al., 1992). For extreme cases, for example, CPD=0° for radar scattering from a flat surface, and CPD=180° for a dihedral-type scattering. Otherwise, the CPD has various values depending on the combination of various scattering mechanisms: single-bounce scattering, double bounce scattering, and volume scattering. Hence, the feature of $\phi_c$ can be a good parameter for classifying polarimetric SAR data.