POLARIZATION PLANE ROTATION EFFECTS ON SAR POLARIMETRIC ATTRIBUTES

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Abstract

The potential and usefulness of SAR (Synthetic Aperture Radar) data for mapping and monitoring land use and land cover classes have been proved in several researches over the past few decades [1]. The cloud cover over tropical regions, which is very common situation along of the year, can difficult (drastically affect) a systematic mapping using optical data since these kinds of data are strongly influenced by the atmospheric conditions. Therefore, the use of SAR data for monitoring tropical regions is highly indicated. The orbital SAR data are recommended to map large areas, however depending of the operating frequency, the local time of data acquisition, the area's geographic location, and solar activity, among others factors, the SAR data can be strongly influence by Faraday rotation. The Faraday rotation is a typical electromagnetic phenomenon, which is characterized by the rotation of the wave polarization plane, when this wave propagates through the ionosphere (a plasma medium). The strength of rotation will depend of the path of the electromagnetic wave, the physical properties of the ionosphere and the SAR operating frequency. According to [2] the rotation effects are more critical for SAR operating in low frequencies, as L- and P-bands. The wave polarization plane rotation can leads to an erroneous interpretation of polarimetric SAR data, conducting to a misclassification of these kinds of data. In this context, the purpose of this work is to analyze the influence of wave polarization plane rotation on the some estimated polarimetric attributes.

A polarimetric image representing an acquisition of a monostatic SAR operating in L-band (1.25 GHz) and having grazing angle of 35^o was simulated using the methodology presented in [3]. The generated image was based on an idealized image (a phantom image) containing four different regions, as shown in Fig. 1. The local orientation of the elementary scatters (printed planar dipoles) was used as main electromagnetic characteristic to differentiate the regions. In the phantom red region (region D) the dipoles were oriented totally random (TR) and in the magenta (region A), green (region C) and blue (region B) regions the dipole have a local preferential orientation of 10º, 20º and 30º, respectively. This orientation is referred to the azimuth-axis (*az*) and the origin of the system coordinate is located at image center. The spatial resolution and pixel spacing were fixed, respectively, at 3.0 m and 2.8 m, both in range and azimuth directions. Dipoles sizing 50×1 mm were used to represent the elementary scatters.

Using the Faraday rotation model proposed by [2] and varying the rotation angle (Δ) from -180^o to $+180^o$ in step 1^o, it was generated 359 new sets of polarimetric SAR images. In this model the total rotation angle is considered for the round-trip range (downward and upward satellite links). The data analysis was firstly carried out by comparing the covariance matrix for each image region with and without polarization plane rotation. The Manhattan, the Euclidean, the Bartlett and the revised Wishart distances between covariance matrices [4] were used in this comparison. These four distances were also unified in only one distance measure by computing the Euclidean distance (d_e) between the point formed by the normalized distances and the origin of the $\mathbb{R}^4$ space. A graphic showing the variation of d_e in terms of Δ for each image region is depicted in Fig. 2. From this graphic it can be noticed the influence of rotation angle in the covariance matrix of each image region.

The effect of rotation angle in others six polarimetric attributes was also analyzed. These attributes include the α-angle (derived from standard Cloude-Pottier decomposition [5]), the Co-Polarized Ratio (*CPR*), the Co-Polarized Phase

Difference (*CPPD*), the Complex Co-Polarized Correlation Coefficient (ρ) and two measures used to estimate moisture content: the polarization descriptor ratio (*PDR*), proposed in [6] and the polarization descriptor squared (*PDS*), proposed in [7]. An image based on each polarimetric attribute was generated for each rotation angle. The difference between a rotated polarimetric attribute band and the polarimetric attribute band without rotation effect was calculated by normalized root mean squared error (*NRMSE*). The *NRMSE* was computed taking into account the total number of pixels of each image region. As an example of the effect of rotation angle over polarimetric attributes is illustrated in Fig. 3 for the PDS attribute.

From the results it was noted that the rotation angle affects differently all polarimetric attributes, including the covariance matrix, of each image region. Therefore, the orbital SAR data subject to Faraday rotation must be corrected before its use in mapping or monitoring land class and land use applications. The data correction is extremely important if a temporal series of SAR images is used for these applications.

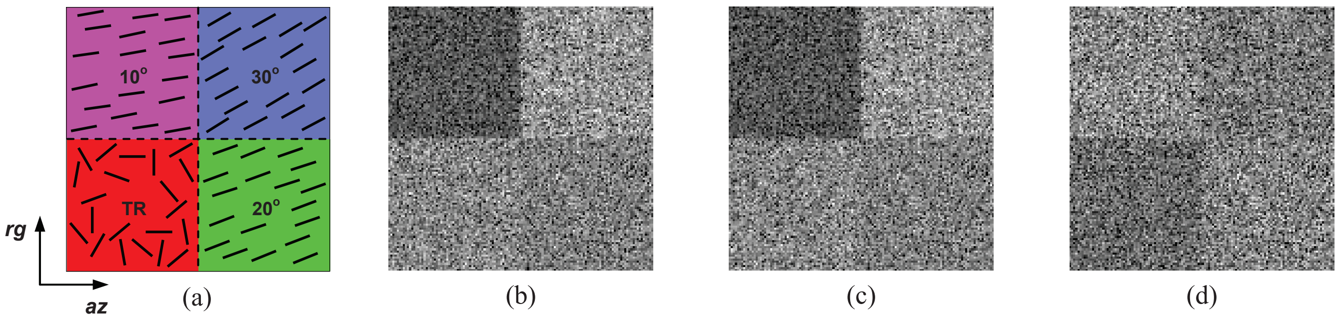

Fig. 1 - Simulated polarimetric SAR images: (a) Phantom, (b) HH, (c) HV and (d) VV.

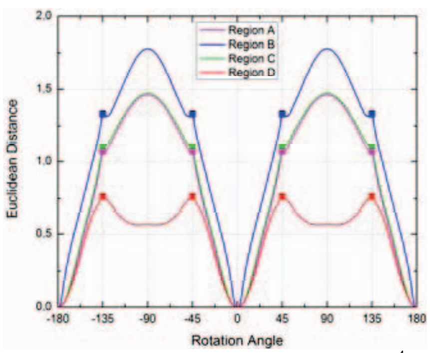

Fig. 2 – Euclidean distance variation in $\mathbb{R}^4$ space.

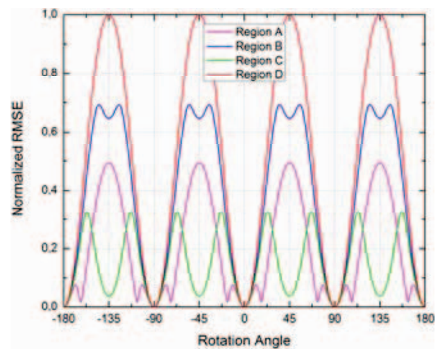

Fig. 3 – *NRMSE* for *PDS* attribute.

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