Polarimetric SAR Tomography of Natural Scenarios: Current Achievements and Perspectives

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SAR imaging is a well established technology for the remote sensing of the Earth's surface. The rationale of such technology is to synthesize a virtual sensor array as long as several kilometers by flying a Radar sensor onboard an airborne or spaceborne platform, resulting in the possibility to produce a Radar image of the illuminated scene with a spatial resolution in the order of few meters. By jointly processing several SAR images, acquired along different paths, the capabilities of SAR imaging get enhanced by one dimension, therefore producing a 3D Tomographic reconstruction of the illuminated scene. Furthermore, modern SAR sensors are capable of transmitting and receiving all the different vector components (or polarizations) of the Electric field, resulting in the possibility to discriminate among different targets basing on electromagnetic diversity. In the last ten years, the availability of spatial and electromagnetic diversity within the data has been widely exploited in the analysis of forested areas, giving rise to the field of Polarimetric SAR Interferometry (PolInSAR). PolInSAR is today a well established technique, mostly used for the retrieval of the vegetation height above the ground basing on 2 multi-polarimetric SAR images. In this paper we outline a new technique for the joint exploitation of several multi-polarimetric SAR images, to the aim of yielding a separate tomographic reconstruction of each of the different objects (often referred to as Scattering Mechanisms) that contribute to the received signal. Such technique extends PolInSAR, and will be referred to as Polarimetric SAR Tomography (PolT-SAR). Under large hypotheses it will be shown that the data second order statistics can be expressed as a Sum of Kronecker Products (SKP) between two matrices, the first accounting for the electromagnetic properties and the second for the spatial structure of each of the Scattering Mechanism that contribute to the received signal. The key to the exploitation of the SKP structure is the existence of a technique for the decomposition of a matrix into a SKP. Such decomposition has the same formal properties as the SVD decomposition, the right and left singular vectors being replaced by two sets of matrices mutually orthogonal under the Frobenius inner product. As a consequence, the important result follows that, given the data covariance matrix, the K scattering mechanisms that contribute to the received signal are uniquely identified by K(K-1) real numbers. The implications of this result will be discussed from both the theoretical and the experimental point of view, showing the current achievements and outlining the future research perspectives.

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