A Reflection Symmetry Approximation of Multi-look Polarimetric SAR Data and its Application to Freeman-Durden Decomposition

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Abstract: Freeman-Durden decomposition is a frequently used technique to analyze the scattering characteristics of multi-look Polarimetric Synthetic Aperture Radar (POLSAR) data. When it is applied to real POLSAR data, two problems emerge which are the volume scattering overestimation and negative powers. Many researchers think these two problems are caused by the insufficient decomposition algorithm, and several improvements are proposed. However, the improved decomposition algorithms become more and more complicated, and some new problems such as the decomposed component is not model-based also emerge. In this article, we try to solve the two problems through another way. We think they are caused not by the insufficient decomposition algorithm but by the dogmatic input. Freeman-Durden decomposition explicitly assumes reflection symmetry. Its input is a direct truncation of the measured coherency matrix. Both T_{13} and T_{23} elements are directly set to zero in the truncation. The truncation can be regarded as an approximation of the measured coherency matrix under the reflection symmetry condition. Namely, it is a Reflection Symmetry Approximation (RSA) rather than the original measured coherency matrix that is decomposed by Freeman-Durden decomposition. We firstly give four reasons why we do not think the truncation is a good RSA of the measured coherency matrix. Then a new RSA is proposed based on the sum of three reflection symmetry components derived from the measured coherency matrix. The first component is based on the classic volume scattering model of Freeman-Durden decomposition, and it is extracted with the generalized eigendecompositon approach to prevent negative powers. The other two components are derived with two transformations. The first one is the orientation angle compensation. The second one is also a unitary transformation which we suggest calling as helix angle compensation. After applying the two transformations, the second and third components are derived with an uncorrelated incoherent decomposition approach. We find that the forms of the second and third components are consistent with surface scattering and double-bounce scattering. Experimental results with several real POLSAR images derived with GF-3, RADARSAT-2 and ESAR show that, if the new RSA is used as the input of Freeman-Durden decomposition, the abovementioned two problems no longer exist.

Keywords: Model-based incoherent decomposition; polarimetric decomposition; polarimetric synthetic aperture radar; radar polarimetry