On the use of symmetric scatterers for calibration and validation of PALSAR polarimetric modes

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***Abstract*— PALSAR L-band SAR will be affected by Faraday rotation. In this study, PALSAR system is briefly described, and Freeman's method [6] is considered for the calibration of PALSAR. Unless channel imbalances are measured abroad, a reference point target has to be deployed for each scene to be calibrated. For practical reasons, the use of symmetric targets is investigated for calibration and validation of polarimetric PALSAR data.**

I. INTRODUCTION

PALSAR, L-band SAR onboard ALOS, will be launched in 2005. PALSAR is equipped with an active phased array H-V antenna and two receivers that permit an alternating measurement of the backscattered wave at HH, HV and VV, VH polarizations [9], [13]. The active antenna uses 80 T/R modules, that excite single subarray antenna of about 25 dB isolation in H and V. This might lead to significant antenna cross-talks that variy with incidence angle, and which should be removed for extraction of pure HH, HV, VH, and VV measurements [18], [4], [16]. Measurement of the variation of the antenna cross-talk terms with incidence angle would require the deployment of many reference point targets along the whole swath, which is not convenient in practice. Van Zyl's method [18] based on the use of azimuthally symmetric natural targets provides an excellent solution to such a complex problem. This method, which has been widely validated, will be adopted for removal of PALSAR antenna cross-talk. At the presence of significant topographic relief, a digital elevation model will be used for calibration of antenna cross-talk, as discussed in [19]. The non reciprocity introduced by the T/R active elements should be first removed [5] prior to the application of Van Zyl's method. Antenna gain and cross-talk measurement and calibration will be completed using the Amazonian forest, which has been shown to be stable at L-band [12].

An additional problem should be solved related to the long wavelength wave (L-band) used by PALSAR. Like JERS-1, PALSAR will be affected by Faraday rotation. It is well accepted that Faraday rotation is a significant source of errors [11], [17], [7] that should be removed mainly for POLSAR experimental polarimetric mode. Freeman [6] has recently introduced a step-by-step procedure for calibration of SAR subject to Faraday rotation. In this study, Freeman's method is considered for calibration of PALSAR. It is shown that a reference point target has to be deployed per scene, and this is not convenient in practice. The use of target of significant symmetric scattering is then investigated for calibration and validation of PALSAR polarimetric modes.

II. CALIBRATION OF PALSAR POLARIMETRIC MODE USING REFERENCE POINT TARGET

The Amazonian forest, which should be of high polarization entropy [3], is stable with polarization, and this would explain the long-term stability of JERS-1 σ° measurements presented in [12]. Measurements over the Amazonian forest will be used to:

- measure and remove antenna gain patterns
- measure and remove antenna cross-talk, as done in [18], [5]

The stability of the antenna gain and cross talk patterns [5] should permit the use of the Amazonian extracted parameters for calibration of other scenes collected at various location of the ALOS orbit. After removal of antenna gain parameters, the measured scattering matrix might be expressed as a function of the actual target scattering matrix as [6], [1]:

$$\begin{bmatrix} M_{hh} & M_{hv} \\ M_{vh} & M_{vv} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & f_1 \end{bmatrix} [S]^F \begin{bmatrix} 1 & 0 \\ 0 & f_2 \end{bmatrix} \quad (1)$$

with

$$[S]^F = \begin{bmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{bmatrix} \begin{bmatrix} S_{hh} & S_{hv} \\ S_{hv} & S_{vv} \end{bmatrix} \cdot \begin{bmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{bmatrix}$$

where Ω is the Faraday rotation angle, and f_i channel imbalance. Freeman has expressed the calibration model of (1) in term of the channel imbalances f_1 and f_2 because these parameters may vary over time, and the estimation and removal of these terms should be addressed [6]. An azimuthally symmetric target is used for estimation of the channel imbalance ratio f_2/f_1 [6]. To estimate and remove the residual channel imbalance f_1, a thrihedral corner reflector should be used, unless if a prior internal measurement of f_1 is provided[1]. After f_1 removal, the Faraday rotation angle may be estimated and removed using either Bickel and Bates

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[1] The latter solution might be retained for ALOS

[2] or Freeman [6] method.

In order to avoid the deployment of a reference point target for each scene to be calibrated, the use of symmetric targets is investigated in the following for calibration and validation of polarimetric PALSAR data.

III. CALIBRATION OF PALSAR POLARIMETRIC MODE USING SYMMETRIC TARGETS

A. Symmetric target

Kennaugh and Huynen [10], [8], associated Importance to a class of targets termed symmetric. A symmetric target is a target having an axis of symmetry in the plane orthogonal to the radar line of sight direction (LOS) [10], [8]. Symmetric targets have a scattering matrix which can be diagonalized by a rigid rotation about the LOS, and the maximum return is obtained at a linear polarization aligned or orthogonal to the target symmetry axis.

B. Calibration procedure using symmetric targets

The target scattering vector model (TSVM) [14] is used to derive from (1) the following calibration equation after channel imbalance ratio removal:

$$\begin{bmatrix} M_{hh} \\ M'_{vh} \\ M_{vv} \end{bmatrix} = \begin{bmatrix} \frac{((1+f_1)^2}{2} & \frac{((1-f_1)^2}{2} & 0 \\ \frac{((1-f_1)^2}{2} & \frac{((1+f_1)^2}{2} & 0 \\ 0 & 0 & f_1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 2\psi & \sin 2\psi \\ 0 & -\sin 2\psi & \cos 2\psi \end{bmatrix} \begin{bmatrix} \cos\alpha_s \cos 2\Omega \\ \sin\alpha_s e^{j\Phi_{\alpha_s}} \\ 0 \end{bmatrix} \quad (2)$$

where α_s and Φ_{α_s} are the polar coordinates of the complex symmetric scattering type vector [14]. Theses coordinates permit mapping the scattering type as a unique point of the symmetric scattering target Poincaré sphere of Figure 1 introduced in [15]. The knowledge of these orientation invariant parameters permits the estimation and the removal of both the channel imbalance f_1 and the Faraday rotation angle Ω.

IV. CONCLUSION

To avoid the deployment of a reference point target for each scene calibration, the use of symmetric targets is investigated. It is shown that symmetric targets of known scattering type parameters (α_s,Φ_{α_s}) can be used to estimate and correct for the channel imbalance and the Faraday rotation angle. This procedure is applied after antenna gain and cross-talk removal, and the correction for the channel imbalance ratio as done in [6]. Since the target type parameters are orientation invariant [14], ESAR might be used to select potential symmetric targets and determine their scattering type parameters. In order to improve the effectiveness of this method, targets of significant symmetric scattering component can be used. The symmetric scattering characterization method (SSCM) [15] can then be applied to maximize the symmetric scattering component and optimize the exploitation of target symmetric scattering for target characterization. Simulation on ESAR data are currently run to validate and assess the accuracy of the new calibration method.

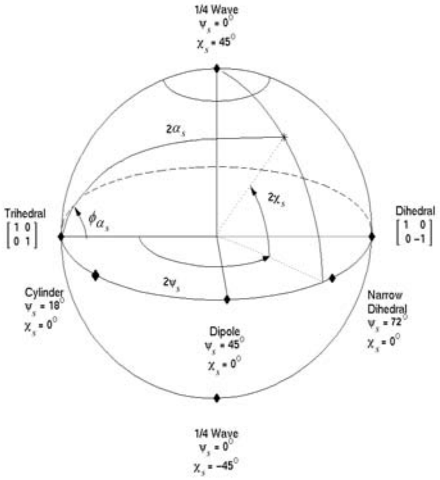

Fig. 1. *Symmetric scattering Target Poincaré Sphere*

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ACKNOWLEDGMENTS

The authors would like to thank Dr. C. Livingstone from the Defence Research and Development Canada for the interesting discussions.

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