POTENTIALS OF A COMPACT POLARIMETRIC SAR SYSTEM

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1. INTRODUCTION

The compact polarimetry (CP) mode has already been presented in three forms: π/4 [1], π/2 [2] and the hybrid mode [3], the latter being a particular case of the π/2 mode. Previously, some applications using compact polarimetric data have been shown [4], e.g. a classification of the scattering types with the conformity coefficient, the Faraday rotation estimate modulo π and the soil moisture estimate. In this paper, we study the possibilities to calibrate a compact polarimetric system. To calibrate a system, ground targets are often used. It could be either point targets with known radar cross section or distributed targets with known scattering characteristics. Freeman has already shown a possible manner to calibrate such a system using trihedral corner reflector and ignoring cross-talk terms and noise [5]. Dubois-Fernandez [2] and Freeman et al. [6] noted that it is not possible to correct for an imperfect transmission afterwards because a single transmit polarisation does not allow polarisation synthesis. Assuming a spaceborne system with a perfect transmission (i.e. cross-talk and channel imbalance corrected) operating at low frequencies thus subject to the Faraday rotation, we present a method correcting for cross-talk and channel imbalance at reception and for Faraday rotation. Once the system is calibrated, the interferometry concept is added to analyse the abilities of a compact polarimetric system to estimate the volume height at low frequencies. The Random Volume over Ground (RVoG) [7-8] model allowed to obtain volume height estimate from full-PolInSAR (F-PolInSAR) data. This model used the extinction value and the total least-squares line fit computed from the different loci of the complex interferometric coherences at different polarisations on the complex plane. Dubois-Fernandez et al. [2] presented the direct application of RVoG model to Compact PolInSAR (C-PolInSAR) data. They showed that it is possible to estimate the forest height but in some cases, the canopy height estimate can be degraded compared to the results obtained by using F-PolInSAR data. Lavalle et al. [9] tried to reconstruct a "pseudo" F-PolInSAR matrix from C-PolInSAR data. The estimation relied on assumptions such as reflection symmetry and rotation invariance of cross-pol terms which degrade the inversion. All of these studies show that the model to retrieve canopy height from F-PolInSAR data can be directly applied to C-PolInSAR data but for some cases the estimate is degraded. This study consists in finding another method to estimate forest height with C-PolInSAR data. First, we present the results of applying directly the RVoG model to C-PolInSAR data [2]. Next, we show an alternative approach to plot the line that best fit the coherence region using Tabb algorithm [10-11]. Then we performed the height volume inversion using this regression line and the height curve performed with a fixed extension value. Finally, an analysis of the effect of baseline will be explored over different datasets.

2. CALIBRATION OF A CP SYSTEM

In a full-polarimetric context, the calibration system model is written:

$$M = A(r,\theta)e^{j\varphi}D_R R_\Omega S R_\Omega D_T + N$$

Where M is the measured matrix, $A(r,\theta)e^{j\varphi}$ is the system gain function, D_R and D_T are the distortion matrices in reception and transmission respectively, R_Ω is the Faraday rotation matrix, S is the Sinclair matrix and N is the noise vector. Ignoring the system gain function and noise, once the different distortions are estimated, it is possible to correct by multiplying the measured matrix by the inverse of the reception and transmission distortion matrices as:

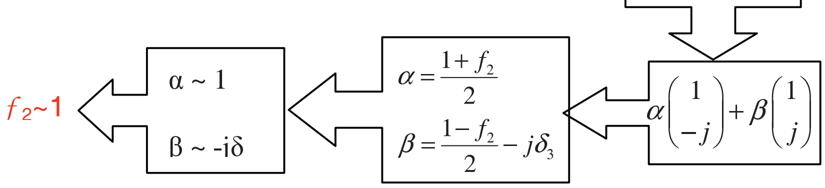
$$S = R_\Omega^{-1} D_R^{-1} M D_T^{-1} R_\Omega^{-1}$$

In the $\pi/2$ context with a right circular transmission, the calibration system model is represented by the following expression:

$$M = A(r,\theta)e^{j\varphi}D_R R_\Omega S R_\Omega D_T \begin{pmatrix} 1 \\ -j \end{pmatrix} + N$$

Where (1,-j) is the transmission vector. This expression is completely developed in the equation below where δ's are the cross-talk terms and f the channel imbalance terms. Even ignoring the system gain function and noise, it is obviously not possible to make the same inverse computation as in full-pol mode to retrieve the scattering elements of the Sinclair matrix. By expanding the last multiplication between D_T and the transmission vector, the distortion in transmission can be modeled as a left contribution. The right component being the most important part, the requirement on channel imbalance on transmit is that its amplitude has to be close to 1 and its phase close to 0 since it is not possible to correct afterwards.

$$\begin{pmatrix} M_{RH} \\ M_{RV} \end{pmatrix} = A(r,\theta)e^{j\varphi}\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & \delta_2 \\ \delta_1 & f_1 \end{pmatrix}\begin{pmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{pmatrix}\begin{pmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{pmatrix}\begin{pmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{pmatrix}\boxed{\begin{pmatrix} 1 & \delta_3 \\ \delta_3 & f_2 \end{pmatrix}\begin{pmatrix} 1 \\ -j \end{pmatrix}} + \begin{pmatrix} N_h \\ N_V \end{pmatrix}$$



So, considering now that the system is perfect in transmission, the calibration system model can be written as:

$$M = A\left(r,\theta\right)e^{j\varphi}D_R R_\Omega S R_\Omega \begin{pmatrix} 1 \\ -j \end{pmatrix} + N$$

$$\begin{pmatrix} M_{RH} \\ M_{RV} \end{pmatrix} = A(r,\theta)e^{j\varphi}\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & \delta_2 \\ \delta_1 & f_1 \end{pmatrix}\begin{pmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{pmatrix}\begin{pmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{pmatrix}\begin{pmatrix} \cos\Omega & \sin\Omega \\ -\sin\Omega & \cos\Omega \end{pmatrix}\begin{pmatrix} 1 \\ -j \end{pmatrix} + \begin{pmatrix} N_h \\ N_V \end{pmatrix}$$

We will show that using two calibration reflectors, it is possible to correct for channel imbalance, cross-talk and Faraday rotation.

3. COMPACT POLARIMETRIC SAR INTERFEROMETRY

In this paragraph, we start by going over the results of applying the RVoG model to C-PolInSAR data and compare the results of height estimate with the full PolInSAR (F-PolInSAR) data. The compact interferometric scattering vector using a single circular transmission and two independent receptions is a two-element vector which allows the representation of the compact-PolInSAR information by a 4x4 matrix. In F-PolInSAR mode it is a three-element vector allowing the representation of the complete PolInSAR information by a 6x6 matrix. However, the compact measurement vectors can always be synthesized from the F-PolInSAR data, implying that the C-PolInSAR coherence region is included in the F-PolInSAR coherence region. Now applying the RVoG model to the C-PolInSAR mode to compute the volume height clearly shows a very good agreement with the inversion computed with F-PolInSAR data. But in some cases, this inversion can be degraded. Using the Tabb algorithm [10-11], we show another method to define the regression line of the PolInSAR coherence region and then the inversion of the volume height with this line. The results are compared with the current RVoG method processing with full-pol data and show very good agreement.

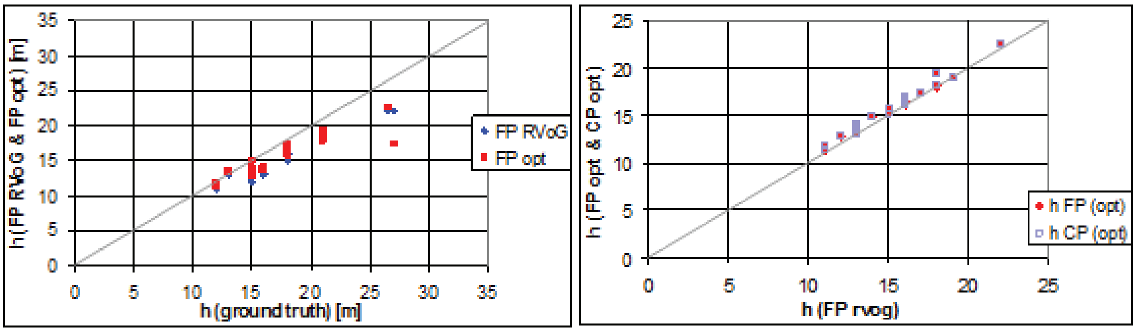


Fig. 1 : On the left, the comparison between volume height computed with RVoG in blue and with the method presented in this paper in red with FP data vs ground truth. On the right, comparison between the volume height computed with our method in FP in red and CP in purple vs the volume height computed with RVoG from FP data.

The results presented in figure 1 show the assessment of our method in computing the volume height with respect to the results observed with the RVoG model. A very good agreement is noticeable from this comparison.

4. CONCLUSION

In this paper the abilities of a compact-pol system as an alternative mode to the standard dual-pol mode is explored. We present a method allowing the calibration of a compact-pol system including the Faraday rotation effect using corner reflectors and assuming a perfect transmission. Then, a technique for retrieving the volume height from a compact polarimetric SAR interferometry system using the Tabb algorithm is described and its performances are assessed over several datasets, including different forest types and different sensors.

5. REFERENCES

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