FARADAY ROTATION DETECTION AND CORRECTION FOR DUAL-POLARIZATION (HH-HV) L-BAND DATA

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1. INTRODUCTION

L-Band SAR, like that on the JAXA's ALOS PALSAR instrument, is much more susceptible to ionospheric effects than other space based SAR missions, mainly operating in C-band or X-Band. While single-band attenuation of instruments such as the single-polarization JERS-1 SAR instrument certainly occurred, it was rarely noted. With the advent of full- and dual-polarization (full-pol and dual-pol) instruments, where channel ratios and phase differences are used for different applications, the ability to screen for, and ultimately correct for, Faraday rotation becomes especially important.

Most dual-pol techniques compare the amplitudes of the HH channel to the HV channel, but this relationship is particularly sensitive to Faraday rotation effects [2]. Because the HH-channel amplitude tends to be orders of magnitude larger than the HV-channel amplitude, even small amounts of HH or VV signal rotated into the HV channel cause dramatic errors in the channel ratios.

Determining and correcting for Faraday rotation in fully polarimetric datasets is largely a solved problem [3,4], but its determination in dual polarimetric data remains problematic. Even less explored is the correction of these effects [5]. In this paper we present novel approaches to determining and correcting for Faraday rotation in dual polarimetric data. We also discuss remaining errors and their implications.

2. METHODS

FR estimations from dual-pol data rely on the cross-channel (HH-HV) correlation, which is typically zero for natural targets with no azimuthal slopes [freeman detection]. The FR is approximated by:

$$\tan \Omega = \langle M_{HH} M_{HV}^{*} \rangle / (n \langle M_{HH} M_{HH}^{*} \rangle) \qquad \text{(eqtn 1)}$$

where Ω is the one-way Faraday rotation, and n is a target-specific value (though usually set between 1.5 and 1.7). The n value is an estimate because the $\langle M_{HH} M_{VV}^{*} \rangle$ is not available for dual-pol data. With *a priori* knowledge of $\langle M_{HH} M_{HH}^{*} \rangle$, the FR can be determined more accurately.

Correction of the HV channel was estimated with two methods. Method 1, referred to as the correlation-squared method, relies on the assumption that the HH-VV channels have a correlation coefficient equal to 1. If we make this assumption and drop minor terms, then we can approximate the FR-corrected HV channel ($<S_{HV}S_{HV}^{*}>$) as:

$$<S_{HV}S_{HV}^{*}>= <M_{HV}M_{HV}^{*}> -<\mathrm{Re}\{M_{HH}M_{HV}^{*}\}>^{2}/<M_{HH}M_{HH}^{*}> \tag{eqtn 2}$$

If instead we assume that $<S_{HH}S_{HH}^{*}>=<S_{VV}S_{VV}^{*}>$, and drop the minor terms, we get the approximation referred to as the correlation-doubled method:

$$<S_{HV}S_{HV}^{*}>= <M_{HV}M_{HV}^{*}> +2<\mathrm{Re}\{M_{HH}M_{HV}^{*}\}> \tan \Omega \tag{eqtn 3}$$

All three equations can be improved with *a priori* knowledge of the HH-VV correlation coefficient and amplitude ratios; however, good estimates can still be obtained without this knowledge, as shown in Figures 1 and 2.

Full-pol datasets from representative target types (desert, agricultural, and rainforest) were used for the study. These datasets were chosen so that results from dual-pol analysis could be compared with full-pol analysis.

Faraday rotation was added in 2-degree increments for each dataset. Data were first analyzed for Faraday rotation (FR) via the Bickel-Bates method [1,4] then by both correlation methods. Data were smoothed using a window size of 100x25 pixels to measure the expected value.

3. CONCLUSIONS

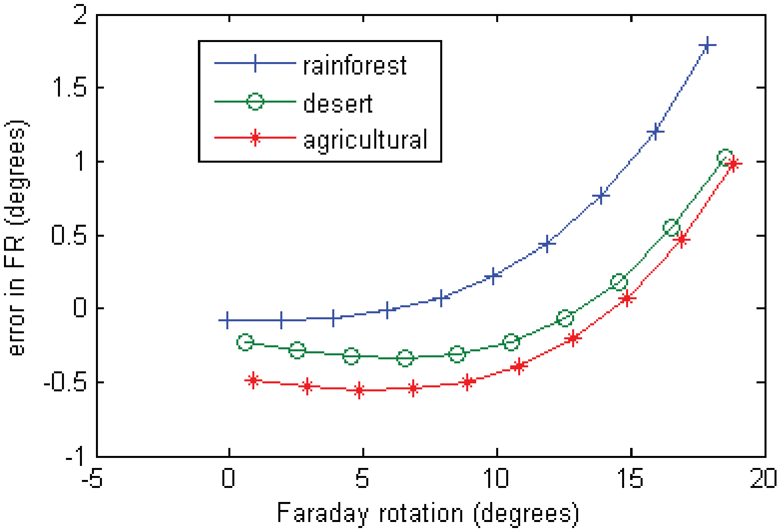

Figure 1. Error in Faraday rotation using eqtn. 1 (HH-HV correlation method) to estimate FR, compared to FR added to data in simulation.

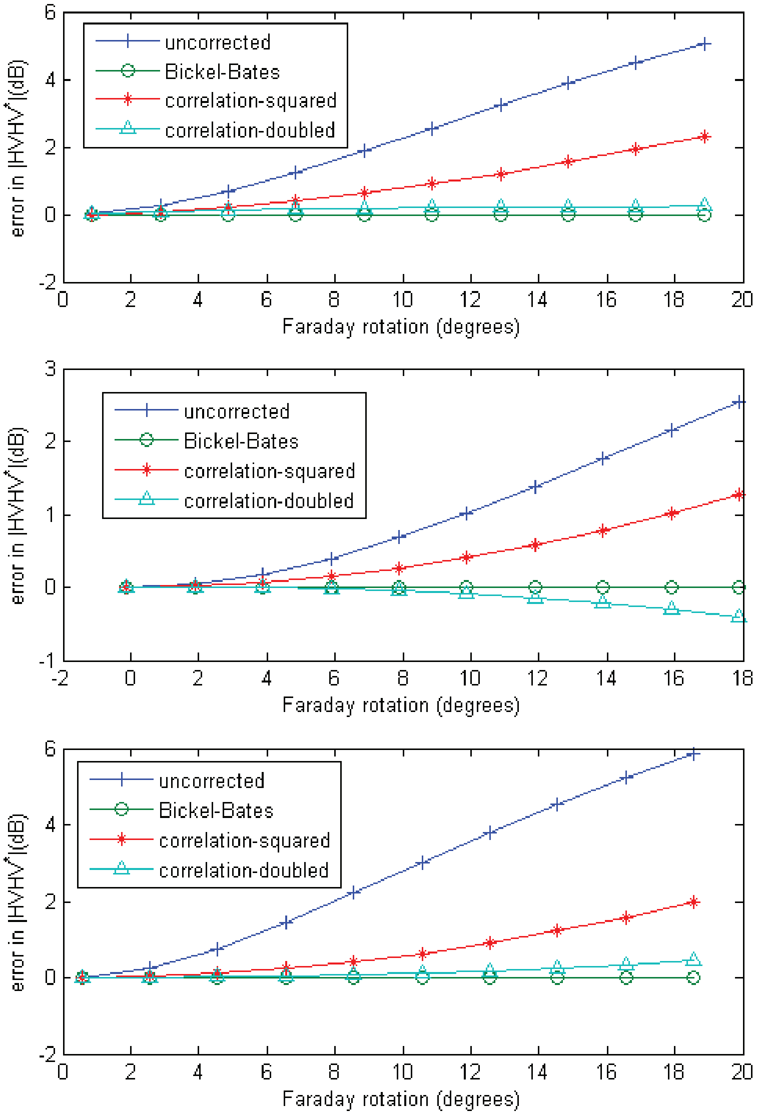

Figure 2. Correction of HV-channel data using three methods. Data have been normalized by the corrected HV channel data before Faraday rotation. Charts are for a) Rainforest, b) Desert (bare soil) and c) Agricultural datasets.

It is apparent from all three equations that any estimation of FR in dual-pol data relies on HH-HV cross-channel correlation, which represents the HH and VV leakage into the HV-channel as a result of Faraday rotation. The approximations are necessary because there is no information in the HH or the HV channels about the VV channel or its correlation with HH. In spite of this weakness, figures 1 and 2 both show that at low FR (less than 20 degrees) good estimates of both the Faraday rotation and the actual HV amplitude can be made. Of the two HV-channel approximations, the correlation-doubled method is more robust and accurate than the correlation-squared method. The correction of the HH-channel is not shown here, as it is trivial to approximate it by $M_{HH}M_{HH}^{*}>/\cos^4\Omega$, and therefore any errors in its measurement stem from errors in the FR determination.

These estimation methods are useful on two fronts. Primarily, data can be screened for FR even for relatively small values (<2°), and any data with large values excluded if precision HH-HV channel ratios are needed.

Datasets can be corrected,as shown in Figure 2, but the error increases in most cases as FR increases, with excessive errors above 20°.

Finally, it should be noted that these results are from simulated FR. As noted in [4], other effects, especially noise, can skew results in data with real FR present.

4. REFERENCES

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