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EXTERNAL CALIBRATION OF POLARIMETRIC RADAR IMAGES USING DISTRIBUTED TARGETS

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1. INTRODUCTION

A new technique is presented in this paper for calibrating polarimetric synthetic aperature radar (SAR) images using only the responses from natural distributed targets. The model for polarimetric radars is assumed to be (Yueh et al., 1990)

$$X = cRST \tag{1}$$

where X is the measured scattering matrix corresponding to the target scattering matrix S distorted by the system matrices T and R (in general $T \neq R^t$). To allow for the polarimetric calibration using only distributed targets and corner reflectors, van Zyl (1990) assumed a reciprocal polarimetric radar model with $T = R^t$; when applied for JPL SAR data, a heuristic symmetrization procedure is used by POLCAL to compensate the phase difference between the measured HV and VH responses and then take the average of both. This heuristic approach causes some non-removable cross-polarization responses for corner reflectors, which can be avoided by a rigorous symmetrization method based on reciprocity (Yueh et al., 1991). After the radar is made reciprocal, a new algorithm based on the responses from distributed targets with reflection symmetry is developed to estimate the cross-talk parameters (Yueh et al., 1992). The new algorithm never experiences problems in convergence and is also found to converge faster than the existing routines implemented for POLCAL. When the new technique is implemented for the JPL polarimetric data, symmetrization and cross-talk removal are performed on a line-by-line (azimuth) basis. After the cross-talks are removed from the entire image, phase and amplitude calibrations are carried out by selecting distributed targets either with azimuthal symmetry along the looking direction or with some well-known volume and surface scattering mechanisms to estimate the relative phases and amplitude responses of the horizontal and vertical channels.

2. APPLICATIONS TO SAR DATA

After this new technique is applied to the L-band polarimetric data collected over the Mt. Shasta area in 1989, the responses of corner reflectors were extracted after each step to assess the effectiveness of the methods. Tables 1 and 2 show the covariance matrix parameters of the corner reflectors after cross-talk removal. The data presented in Table 1 are symmetrized by the POLCAL's approach before cross-talks are removed, whereas the data shown in Table 2 are symmetrized based on reciprocity. Comparing Tables 1 and 2 for both e and γ indicates that the new technique yields superior performance. Note that the same algorithm for cross-talk removal is applied for both cases; therefore the difference is caused by the symmetrization procedure alone.

Trihedral	e	γ	ρ	β	ξ
CR1	−16.78	−1.34	0.997∠31.6	0.92∠145	0.95∠ − 113
CR2	−21.46	−0.97	0.995∠29.9	1.04∠144	1.05∠ − 115
CR3	−24.79	−1.67	0.991∠31.9	0.96∠114	0.98∠ − 86
CR4	−16.04	−1.2	0.958∠35.5	0.97∠133	1.02∠ − 96
CR5	−20.27	−2.41	0.983∠30.3	1.02∠127	1.04∠ − 99
CR6	−13.59	−3.01	0.985∠22.1	1.01∠126	1.00∠ − 101
CR7	−13.44	−1.68	0.99∠22.1	0.99∠124	1.02∠ − 102
CR8	−19.64	2.40	1.00∠10.9	0.85∠ − 31.5	0.86∠40.6

Table 1. Covariance parameters of trihedral reflectors after symmetrization (POLCAL) and cross-talk removal. $e = |HV|/|HH|$, $\gamma = |VV|/|HH|$, ρ: correlation of HH and VV, β: correlation of HH and HV, and ξ: correlation of HV and VV. e and γ are in dB. The phases of ρ, β, and ξ are in degrees.

Trihedral	e	γ	ρ	β	ξ
CR1	−24.0	0.07	0.994∠80.6	0.76∠176	0.79∠ − 100
CR2	−100	0.00	0.991∠81.6	-	-
CR3	−100	−0.96	0.984∠83.8	-	-
CR4	−24.07	−0.07	0.969∠84.6	1.01∠137	1.15∠ − 42
CR5	−100	−1.38	0.992∠81.2	-	-
CR6	−100	−0.34	0.992∠69.6	-	-
CR7	−100	0.21	0.998∠68.7	-	-
CR8	−100	0.48	0.991∠64.0	-	-

Table 2. Covariance parameters of trihedral reflectors after symmetrization and cross-talk removal based on the new technique.

For the phase calibration, we determined the relative phase errors between H and V channels for nine arbitrarily selected areas in the image, and linearly fit the phase correction factors along the range. Each azimuthal line is then calibrated by the interpolated phase factor. The resulting responses of corner reflectors are shown in Table 3. Comparing the phases of ρ between Tables 2 and

3, we can see that the relative phase errors between HH and VV are greatly reduced.

From the γ of the corner reflectors, it seems that the amplitudes of H and V channels are well balanced for L-band. Thus, additional correction on channel imbalance does not seem to be necessary.

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Trihedral	e	γ	ρ	β	ξ
CR1	-24.0	0.07	$0.994\angle-8.7$	$0.76\angle131$	$0.79\angle-145$
CR2	-100	0.00	$0.991\angle-8.2$	-	-
CR3	-100	-0.96	$0.984\angle-6.5$	-	-
CR4	-24.07	-0.07	$0.969\angle-3.3$	$1.01\angle94$	$1.15\angle-86$
CR5	-100	-1.38	$0.992\angle-7.0$	-	-
CR6	-100	-0.34	$0.992\angle-10.5$	-	-
CR7	-100	0.21	$0.998\angle-11.8$	-	-
CR8	-100	0.48	$0.991\angle-16.7$	-	-

Table 3. Covariance parameters of trihedral reflectors after symmetrization, cross-talk removal, and phase calibration based on the new technique.