A Precise Corner Reflector Characterization Technique

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Motivation

12 corner reflectors were installed El Sosneado site to assist COSMO SkyMed calibration.

- 13 L Band CR
  - 3m leg
  - (Not installed yet)

- 8 X/C Band CR Type 2
  - 1.97m leg

- 4 X Band CR Type 1
  - 1m leg
**Motivation**

Target RCS accuracy has a direct impact on Calibration performance.

Manufacturing defects (orthogonality, flatness and size) may cause significant deviations on the expected RCS.

Traditional measuring methods may not be enough to verify the compliance of the structural requirements.

Using an anechoic chamber may not be representative or feasible.
Corner Reflector Validation Strategy

- Target preparation
- LIDAR 3D Scanning
- Meshing
- Numerical EM Simulation
- Point cloud
- Target Mechanical Validation
- 2D RCS
- Target EM Characterization

7-9th November, 2017
CR structural validation

In order to perform a structural validation after installation a 3D LIDAR scanner was used.

Z+F Imager 5010C

- Range noise: 0.2 mm RMS
- Range resolution: 0.1 mm
- Data acquisition: 1 megasamples/sec
- Vertical Resolution: 0.4 mdeg
- Horizontal Resolution 0.2 mdeg
CR structural validation

A point cloud with approximate 20 million points is obtained and then segmented into the different plates.

- **Flatness**: RMS error of each plate with respect to its best-fitting plane

- **Orthogonality**: Angle between normal vectors of each best-fitting plane
CR structural validation

<table>
<thead>
<tr>
<th>Target</th>
<th>RMSE [mm]</th>
<th>Angle between plates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plate 1</td>
<td>Plate 2</td>
</tr>
<tr>
<td>C00</td>
<td>0.6</td>
<td>0.7</td>
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## CR Structural Validation

<table>
<thead>
<tr>
<th>Target</th>
<th>Type</th>
<th>Scanning Temp [°C]</th>
<th>RMSE [mm]</th>
<th>Angle between plates</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plate 1</td>
<td>Plate 2</td>
</tr>
<tr>
<td>C00</td>
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<td>10</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>C02</td>
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<tr>
<td>C03</td>
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<tr>
<td>C10</td>
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<td>6</td>
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<td>0.7</td>
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<td>C11</td>
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<td>5</td>
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<tr>
<td>C13</td>
<td>1</td>
<td>15</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**Type 1:** 1m leg  
**Type 2:** 1.97 m leg
Geometric Optics doesn’t account for the contribution of the borders of the trihedral.

\[ \sigma_{cr} = \frac{4\pi l^4}{\lambda^2} \left[ \cos \theta_{cr} + \sin \theta_{cr} (\sin \phi_{cr} + \cos \phi_{cr}) - \frac{2}{\cos \theta_{cr} + \sin \theta_{cr} (\sin \phi_{cr} + \cos \phi_{cr})} \right]^2 \]
A diffraction pattern (ripple) is observed when using FEKO’s MLFMM method to simulate the RCS of an ideal CR.

This effect decreases with the size of the target with respect to the wavelength.

See: Van Zyl, “How does Corner Reflector Construction affect Polarimetric SAR-Calibration”
Simulating a CR based on the LIDAR measurements results on an RCS ~0.5dB lower of the expected from the ideal CR.

This loss of RCS was observed in all scanned targets.
End-to-End methodology validation

All targets were scanned.

18 Cosmo-SkyMed images were analyzed to verify the predicted RCS.

All images where within six month of the scanning.
Integration Method

To analyze the RCS response the integration method was used.

The corners where pointed with 0.5 deg of accuracy in azimuth and 0.1 deg in elevation.

The incidence angle was calculated using the CR pointing, state orbits and Doppler polynomial.
Comparison of RCS for 6 CR (4 type-2 and 2 type-1) measured from one image, simulated from 3D model + Feko and ideal theoretical GO.

We are only looking at the relative RCS not at the absolute as that depends on COSMO-SkyMed calibration.

Feko’s RCS seems to follow the image retrieved RCS better than the ideal theoretical one and are always below the GO RCS.
Comparison of RCS for 6 CR (4 type-2 and 2 type-1) measured from one image, simulated from 3D model + Feko and ideal theoretical GO.

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End-to-End methodology validation

All 18 COSMO Images

All images and targets are compared.

As images are from different beams, sensors and satellites, all images were normalized subtracting the mean RCS of all the present CR.

\[
RCS_{X\text{X}nb_i} = RCS_{X\text{X}_i} - \frac{\sum_{j=1}^{N} RCS_{X\text{X}_j}}{N}
\]

With \( N \) the number of CR in the image and \( XX \) the different sources (IMG, GO, Feko)
We define the following metrics

\[ E_{r\text{r}GO_i} = |RCS_{GO nb_i} - RCS_{IMG nb_i}| \]

\[ E_{r\text{r}Feko_i} = |RCS_{Feko nb_i} - RCS_{IMG nb_i}| \]

The best method is the one that has the lowest errors in respect to the images measurements.

\[ E_{r\text{r}GO} = \frac{\sum_{i=1}^{N*M} E_{r\text{r}GO_i}}{N * M} = 0.4dB \]

\[ E_{r\text{r}Feko} = \frac{\sum_{i=1}^{N*M} E_{r\text{r}Feko_i}}{N * M} = 0.3dB \]

N targets, M images.
End-to-End methodology validation

The same study was performed using 6 Sentinel 1 TOPSAR images using only Type 2 CR.
The same validation was performed with 5 Sentinel TOPSAR images and only Type 2 targets.

$$Err_{GO} = 0.17 dB$$

$$Err_{FEKO} = 0.13 dB$$
SAOCOM’s Targets

Second Prototype

<table>
<thead>
<tr>
<th>Side</th>
<th>$6\sigma$ [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side 1</td>
<td>4.62</td>
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<tr>
<td>Side 2</td>
<td>6.48</td>
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<tr>
<td>Side 3</td>
<td>3</td>
</tr>
</tbody>
</table>
L Band CR are less susceptible to deformations but (in our case) as they are smaller in terms of wavelength they present a larger ripple effect.
Conclusions

- A technique to structurally validate a passive target and calculate its RCS has been proposed.

- Real Targets tend to have a lower RCS than the expected from the Geometric Optics formula.

- As describe in the bibliography, a ripple effect was observed on the simulated RCS which can reach around 0.7dB in the boresight. This effect is typically not accounted for SAR calibration and can impact the radiometric accuracy.

- Variations on RCS of different targets within a scene could be predicted using the scanning+simulation technique.

- Predicted absolute RCS values could not verified externally.

- Simulation of ground interaction with the target was not considered.
Thanks for your attention
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