# Study of the impact of Polarization for Distributed Targets Interferometry


Alessandro Parizzi, German Aerospace Agency (DLR), alessandro.parizzi@dlr.de, Germany
Fernando Rodriguez Gonzalez, German Aerospace Agency (DLR), fernando.rodriguezgonzalez@dlr.de, Germany
Michael Eineder, German Aerospace Agency (DLR), michael.eineder@dlr.de, Germany



## Abstract

The effect of the choice of polarization for Distributed Scatterers interferometry has been investigated taking in considerations standard linear polarizations (HH,VV and HV), the Hybrid polarizations (RH and RV) and the circular polarizations (RL,LL and RR. The distribution of the DSs in the different polarizations is discussed and compared with PSs distributions analyzed in [1]. The approach is purely experimental and it has the aim to give an idea of the impact that the different polarimetric bases can provide for DInSAR.


## 1 Introduction

The study has been performed using an L-Band Quad-Pol mode ( ALOS-PALSAR ) stack. The HH, VV and HV polarizations have been independently stacked. Hybrid polarizations RH and RV (Right Circular/Horizontal and Right Circular/Vertical) and Circular Polarizations RR, RL and LL ( Right circular/Right Circular, Right Circular/Left Circular and Left Circular/Left Circular ) have been derived from the Quad-Pol stacks. The data used for the analysis is a 20 acquisition PALSAR Polarimetry-Mode stack acquired between 2006 and 2011 over the South-West area of Munich. The data cover an area of 24 x 60 square kilometers and it is characterized mainly by small urban areas, forests and agricultural fields. The three SLCs stacks have a resolution of about 4 meters in azimuth and 20 meters in ground range, and are polarimetrically calibrated for channel imbalance and cross-talks Faraday Rotation is assumed to be small. Since the complete scattering matrix is available is possible to generate all the possible polarization combinations.The hybrid-polarimetric solutions generated transmitting circular and receiving linear. This can be derived as in [1]. It has to be pointed out this synthesis does not take in account the 3 dB gain that could derive from transmitting the full power on both channels in case of circular transmission configuration.

## 2 DInSAR Processing

After the co-registration of the of the 8 stacks to the same master acquisition, the PSI processing of each stack [2] have been carried out independently in order to estimate the deformation and topography on the Point Targets. The results of the PSI processing are able to provide a full separation of the interferometric components topography, deformation and atmosphere. In particular the atmosphere is in a first step estimated on the detected point tergets and then under the assumption of low-pass properties in space domain is interpolated using Kriging in order to provide the so called Atmospheric Phase Screen ( APS ) of each interferogram. Exploiting this estimated APS , APS-compensated SLCs have been generated calibrating the phase to the same reference point as in the PSI processing. With this information available it is possible to exploit adaptive multi-looking [3] to estimate the covariance matrix for a reasonable sub-sampled set of the image pixels. The covariance matrix is defined as $\mathbf{C}_{i,j} = \mathbb{E}[\underline{s}_i \underline{s}_j^\dagger]$ where $\underline{s}_i$ is the subset of similar pixels ( of the APS compensated SLCs ) found using adaptive multi-looking and † is the symbol for transpose and complex-conjugate. After the normalization of the matrix for the estimated powers, the amplitude of $C_{i,j}$ will represent the coherences of all the possible interferograms and the phase the multi-looked phase with compensated APS and calibrated to the reference point. The analogously to [4] is possible to estimate the optimum deformation and topography $v, h$ for the multi-looked distributed targets.

$$\arg\min_{v,h} \left\{ \underline{t} \mathbf{C}^{-1} \underline{t}^\dagger \right\} \tag{1}$$

where $\underline{t} = [0, .., e^{j\frac{4\pi}{\lambda}(\Delta t^i v + B_n^i h)}, ....]$ is a row vector containing the phase modeling for the $i^{th}$ SLC and the $v, h$ pair being $\Delta t^i$ the temporal baseline of the $i^{th}$ SLC and $B_n^i$ the geometric baseline. The estimation is therefore performed exploiting all the possible interferometric combinations in order to get rid of the de-correlation problems that characterize the distributed targets. It is worth to notice that for the PSI processing the estimation has been done using only one possible interferometric stack. However as far as the Point targets do not decorrelate in time this estimation is theoretically equivalent to the one in Equation 1.

## 3 Analysis of the Results

The aim of this section is to experimentally find out if the different polarization configurations are providing different properties for PSs and DSs. Therefore the results of PS processing and DS processing are first analyzed in the different polarizations and then compared.

## 3.1 Detected PSs and DSs

The first analysis that has been carried out is about the number of detected measure points (PSs or DSs). In a first step is in fact interesting to take a look at how many points have been detected in the different polarizations bases.

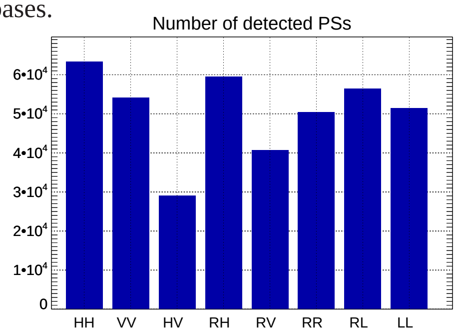


**Figure 1:** Histogram of the detected PSs.

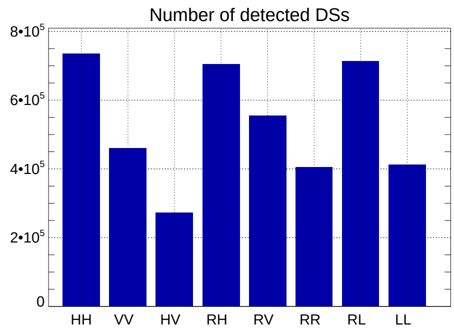


**Figure 2:** Histogram of the detected DSs.

Then how and how many of these detected points are shared between the different polarization configurations is considered. In order to do that the approach of the incidence matrix has been used. The polarization configurations are shown on the two axis and the color-coded number shows the number of common points between the two configurations. The detection has been done setting a coherence threshold of 0.8 for the point targets and 0.3 for the distributed targets.

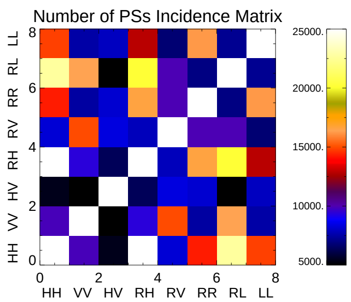


**Figure 3:** PSs incidence matrix.

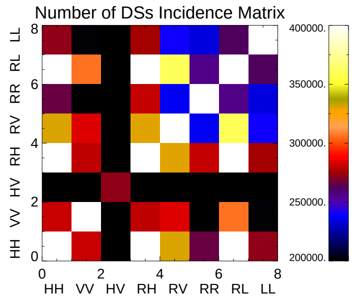


**Figure 4:** DSs incidence matrix.

## 3.2 Coherence

In [1] an analysis of the temporal evolution of the distributed targets coherence was carried out. The idea was to identify the polarization configurations that can provide better level of coherence on the long period in order to grant a better precision in deformation measurements. The observed behavior showed a better performance for co-pol configurations (HH,VV and RL). Observing the temporal coherence derived from the estimator in Equation 1 this behavior is in general maintained with the exception of the VV polarization that seem to perform slightly worse than the hybrid RH (Figure 5).

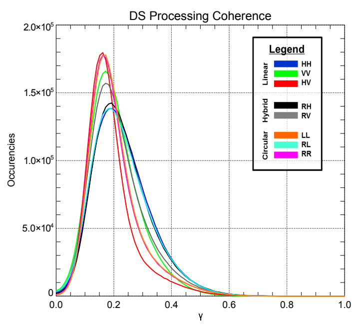


**Figure 5:** Estimation coherence at the different polarizations

According to the incidence matrices generated it is now possible to have all the possible subsets of points shared between the different polarimetric configurations. This allows to perform an accuracy analysis comparing the coherences achieved at different polarizations. Of particular interest is to have a comparison between the circular and the linear polarizations. The comparison between the HH configuration and the RR and RL are shown in Figures 6 and 7 in order to asses the performance in the different polarimetric bases.

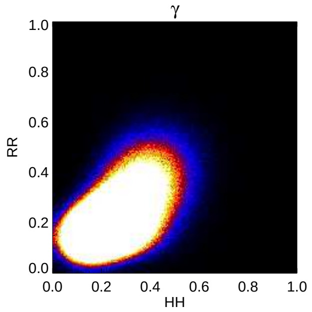


**Figure 6:** Estimation coherence comparison for the common DSs. HH vs RR.

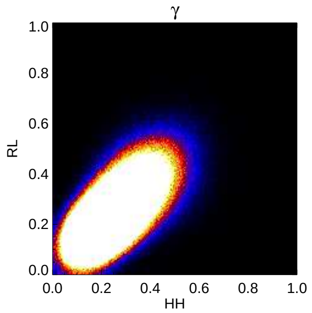


**Figure 7:** Estimation coherence comparison for the common DSs. HH vs RL.

# 4 Conclusions

According to the previously presented results some preliminary conclusions can be derived as follows:

- Point targets and distributed targets show similar distribution through the different polarizations. The polarizations having more co-polar content (HH,VV,RL) present the best performance both in term of detection and accuracy
- The configurations having more cross-polar content (HV,RR,LL) perform worse both for point and distributed targets. However this gap results to be more evident in the distributed targets probably because of the bigger impact that the $SNR$ can provide on the final results.

# 5 Acknowledgments

This work has been funded by the Helmoltz Gemeinschaft under the project HGF Earth Dynamic Alliance (EDA). PALSAR data were provided by JAXA under the ALOS RA-4 proposal PI1118.

# References

[1] Alessandro Parizzi, Kostantinos Papathanassiou, and Michael Eineder: *Study of the impact of polarizations for dinsar displacement measures* Proceedings of EUSAR 2014 10th European Conference on Synthetic Aperture Radar, 2014.

[2] A. Ferretti, C. Prati, and F. Rocca: *Permanent scatterers in sar interferometry*, IEEE, Geoscience and Remote Sensing Transactions on, 2001.

[3] A. Parizzi and R. Brcic: *Adaptive insar stack multilooking exploiting amplitude statistics: A comparison between different techniques and practical results*, IEEE, Geoscience and Remote Sensing Letters, 2011.

[4] F. De Zan and F. Rocca: *Coherent processing of long series of sar images*, IEEE, Geoscience and Remote Sensing Symposium, 2005.