Estimation and Correction of Ionospheric and Atmospheric Induced Phase Errors in SAR Images Using Coherent Scatterers

Rafael Zandona-Schneider

German Aerospace Center (DLR)
Microwaves and Radar Institute (DLR-HR)
PO BOX 1116, 82230 Wessling, Germany
Rafael.zschneider@dlr.de

When propagating from spaceborne platforms to the earth, electromagnetic waves may be influenced by propagation effects caused by the ionosphere or atmosphere. Such effects may change the amplitude, phase and polarization state of the waves. In Synthetic Aperture Radar (SAR) systems, the phase is of crucial importance in the formation of SAR images (SAR image focusing). SAR interferometry and differential interferometry are two examples of SAR images applications, for the estimation of the earth surface topography, and surface displacement monitoring, rescpectively. Both techniques use the phase information of the SAR images for its evaluation, making the phase the main parameter concerning their accuracy. The phase errors induced by the ionosphere or atmosphere generate SAR image defocusing and biases in SAR interfeormetry as well as differential interferometry.

Examples of correction means of atmospheric phase errors have been proposed on the basis of the well know Permanent Scatterers (PSs) in SAR interferometry [1]. PSs are scatterers with relative constant scattering properties over time and can be used to filter atmospheric phase screens [1]. However, PSs are detected when at least about 30 acquisitions are performed over the same scene, making the application of atmospheric phase screen filtering not possible on the basis of a single SAR image.

In this work we use the so-called Coherent Scatterers (CSs) for the estimation and compensation of propagation phase errors induced by the atmosphere and/or ionosphere. CSs are scatterers showing a point-like scattering behavior and can be detected on the basis of a single SAR image when enough bandwidth is available [2].

The work is divided into two main parts. The first one concerns the proposal of an alternative detection procedure of CSs. The procedure is based on the phase behavior of such scatterers as a function of the frequency. Being point-like scatterers, CSs need to have a linear phase variation as a function of frequency, in contradiction to distributed scatterers, whose phase has random variation. This property is thus exploited for their detection leading to some advantages over the standard method [2] in the context of less loss in spatial resolution. The detection procedure is also extended to the case when polarimetric data are available, by performing a polarimetric optimized detection, what dramatic increase the number of CSs in the scene.

The second part of the paper concerns the use of CSs for phase error estimation and correction. For that, an autofocus procedure is implemented in the azimuth direction. The autofocus uses the set of detected CSs as reference points, and is based on the

Phase Curvature Autofocus (PCA) [3], which is the stripmap version of the spotlight Phase Gradient Autofocus (PGA) [4]. Autofocus algorithms estimate and correct one dimensional phase errors. As the phase error originated by ionospheric or atmospheric effects may be two dimensional, the autofocus procedure is further extended to allow estimation of two dimensional phase errors (a phase screen). The algorithm is shown to perform well when a reliable number of CSs is present in the imaged scene. However, the accuracy of the phase error estimation is shown to be related not only to the number of CSs within the scene but also to their Signal to Clutter Ratio (SCR).

The detection of CSs and their utilization for phase error estimation and correction are applied to airborne and spaceborne SAR data. In both cases, the images are contaminated with simulated one or two dimensional phase error screens under different ionospheric/atmospheric conditions. The airborne data are full polarimetric at L-band, from the E-SAR system of the German Aerospace Center (DLR). The spaceborne data are from the recently launched TerraSAR-X sensor.

[1] Ferretti, A.; Prati, C.; Rocca, F., "Permanent Scatterers in SAR Interferometry", *IEEE Trans. Geoscience and Remote Sensing*, vol. 39, No. 1, pp. 8-20, April 2001.

[2] Zandona-Schneider, R., Papathanassiou, K. P., Hajnsek, I., Moreira, A., "Polarimetric and Interferometric Characterization of Coherent Scatterers in Urban Areas", *IEEE Trans. Geoscience and Remote Sensing*, vol. 44, No. 4, pp. 971-984, April 2006.

[3] Wahl, D. E., Jakowatz, Jr., C. V.; Thompson, P. A. and Ghiglia, D. C. "New approach to strip-map SAR autofocus", Digital Signal Processing Workshop, pp. 53-56, 2-5 October 1994.

[4] Eichel, P. H., Ghiglia, D. C. and Jakowatz, Jr., C. V. "Speckle processing method for synthetic-aperture-radar phase correction", Optics Letters, vol. 14, No. 1, pp. 1-3, January 1989.