Combined Estimation of Ionospheric Scintillations in SAR images exploiting Faraday Rotation and Autofocus

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Ionospheric scintillations occur due to electron density irregularities in the ionospheric plasma, predominantly in low and high latitude regions. They can cause severe distortions to radio waves at lower carrier frequencies which are transmitted and received by a spaceborne SAR system resulting in impulse response degradation at imge level. The degradation can strongly impair the image quality and prevent accurate retrivals from the intensity.
ESA's Earth Explorer Biomass mission will be the first spaceborne SAR mission to operate in P-band. Previous studies have shown that for this system disturbances in SAR images are expected due to ionospheric scintillations [1]. The ground processor of the biomass mission will include an ionospheric mitigation step for single SAR images [2], where the ionosphere is estimated from the Faraday rotation using the Bickel & Bates algorithm [3]. Additionally, autofocus will be optionally performed to correct defocusing of SAR images due to scintillations. This work focuses on combining both techniques to improve the estimation of ionospheric scintillations. This work proposes a new approach based on the combination of both methods to improve the estimation of ionospheric scintillations. The combination approach is similar to the one propsed in [4], but developed for SAR not INSAR products and the methods which are combined are different. By performing the correction at image level, the image quality is guaranteed, which, in the frame of the BIOMASS mission, is required by the inversion algorithms based on the image intensity in order to estimate the biomass.

To analyze different estimation methods, phase screens were simulated as Gaussian random processes with the commonly used power spectral density, which was derived in [5]. To emulate the estimated phase screen from Faraday rotation, zero mean Gaussian phase noise with single look Faraday rotation estimate variance was added to the phase screens. Afterwards a Gaussian filter was applied to reduce this noise. This technique was analyzed in [6]. To evaluate the estimation of ionospheric scintillations with autofocus, simulations of raw SAR images with point targets at different locations were performed. Each point target was focussed to the height of the ionosphere, where the simulated phase screen was added to the phase of the signal. Then the simulated data was focussed to ground level and a map-drift autofocus algorithm was applied to estimate the misregistration between two azimuth looks due to defocussing. An inversion filter was developed to retrieve the phase screen from the measured Doppler rate error. For the combined estimation a filter matrix was derived to minimize the squared error between the phase screen and its estimation in dependence of the filters of each method and the spatial statistical properties of the phase screen. It was found that the combined estimation technique outperformes estimations which only use the Faraday rotaion or autofocus. In the final presentation, not only point target simulations will be presented, but also real airborne P-band data, which was acquired in the frame of the BIOSAR-I campaign by the DLR's E-SAR system to emulate BIOMASS data.

References

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