An Internal Calibration System Model for the Estimation of SAR Instrument Errors

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Abstract

Two key requirements for a modern spaceborne Synthetic Aperture Radar (SAR) are a high azimuth resolution and a wide swath. This can be achieved by using SAR instruments with multiple digital channels. The Multiple Azimuth Channels (MACs) technique ensures a high azimuth resolution, while in elevation SCan-On-REceive (SCORE) is employed to improve the Signal-to-Noise Ratio (SNR) and suppress range ambiguities.

The influences of the channels on the amplitudes and phases in a multi-channel system are crucial. Differences between the channels lead to a reduced performance due to the degraded antenna pattern. The SNR as well as the resolution are deteriorated. To account for that the system has to be calibrated by correcting the channel differences. The azimuth calibration can be done on ground, but for SCORE it has to be done on-board and in real time. In this paper we focus on the internal calibration. A signal is fed in at transmit receive module (TRM) level and is evaluated in the digital unit. Error sources on Radio Frequency (RF) level are: mutual coupling between the antenna elements, bleed through between the signal paths, temperature drifts, changes to the transfer functions over time and temperature and the analog-to-digital converters synchronization.

The internal calibration concept suggested here allows for a simultaneous calibration while performing the transmit or receive operation. The instrument RF and digital chain is divided into several layers. For the calibration, a single tone calibration signal is sequentially coupled to the echo signal path. It is possible to vary the frequency of the calibration signal. The evaluation is done by using the original calibration signal and the output of the respective layer to get an estimation of the error.
We created a mathematical model and a simulation tool to estimate the errors in such a calibration system and aid in the system design. The calibration signal sequences can be changed to determine the TRMs in which a calibration signal is fed in or alter the frequency of the signal. By varying the frequency we can account for frequency dependencies. We show results with calibration signals outside and inside the SAR echo signal spectrum as well as with a varying frequency over time. We then analyze the effect of different methods to estimate the current drift and make a prediction for the future. Further, the simulation tool allows for an analysis of the estimation errors. A proposal to refine the estimation and reduce the estimation error is included.

Keywords - Calibration methodology and techniques