Calibration Concepts of Multi-Channel Spaceborne SAR

Tobias Rommel, Felipe Queiroz de Almeida, Sigurd Huber, Marc Jäger, Gerhard Krieger, Christopher Laux, Michele Martone, Michelangelo Villano, Steffen Wollstadt, and Marwan Younis
German Aerospace Center (DLR), Oberpfaffenhofen, Germany

Abstract

Future synthetic aperture radar (SAR) systems will incorporate multi-channel Digital Beam-Forming (DBF) capabilities and operate in new modes. These SAR instruments offer new opportunities but also challenges for calibration. For example on-board real time channel adjustment is unavoidable, but then the on-board digital signal processing capabilities are also readily available in DBF SAR. In any case, current instrument calibration concepts can not be extrapolated to future multi-channel SAR. Thus a new approach is requires required here. This paper reviews the calibration functionality of state-of-the-art spaceborne SAR and then suggest a calibration concept for future SAR.

Spaceborne SAR Calibration

Current SAR systems have reached a high maturity in exploiting calibration. Instrument deviation from the ideal operation, long and short time drifts, mismatch and coupling between the RF paths are measured. In addition, external effects such as atmospheric and ionospheric disturbances are characterized. The purpose of calibration is to minimize the impact of the known errors. This is achieved by *i)* tuning the instrument in real-time to compensate the errors; *ii)* subsequently modifying the instrument settings to remove errors based on the analysis of the calibration data on ground; and *iii)* mitigating the effect of known errors (without removing the error source) by considering it within the SAR data processing.

Internal Instrument Calibration

Dedicated calibration pulses are injected into the signal paths using elaborate cal-networks. To guarantee the required accuracies in the order of fractions of a dB, the cal-networks are characterized on ground to minimize the measurement uncertainty. Various calibration loops are implemented to measure the transmit and receive paths as well as the central electronics. This enables constructing a replica, i.e. a reference signal, affected by the characteristics of the SAR signal path. A typical Transmit/Receive Module (TRM) architecture is shown in **Fig. 1** where the numbers are associated to the different functionality of the respective hardware blocks.

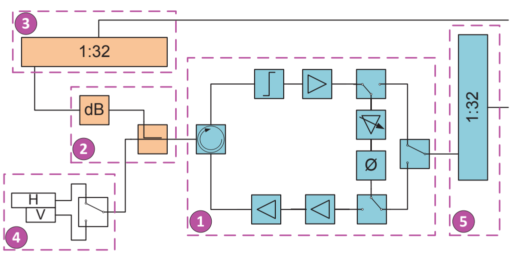

Figure 1: An example Tx/Rx-Module (TRM) architecture including the blocks for calibration.

Data Driven Calibration

The application of a data driven calibration algorithm based on the correlation between antenna elements is considered worth investigating [1]. These techniques are suitable for calibrating slowly varying errors, because of the computational load and the number of independent measurements needed. A method is developed by ATTIA & STEINBERG in [2] which basically shows that the correlation between the signals of any two antenna elements (spatial correlation) depends only on the separation between the two elements. The underlying model assumes the signals to originate from non-coherent scatterers.
An assessment of the calibration accuracy is shown in **Fig. 2** which represents the residual phase errors matrix in a logarithmic scale. The value on the abscissa represents the distance between the antenna elements; A quantitative analysis of the residual error shows that its value is below 1° for separations up to six elements.

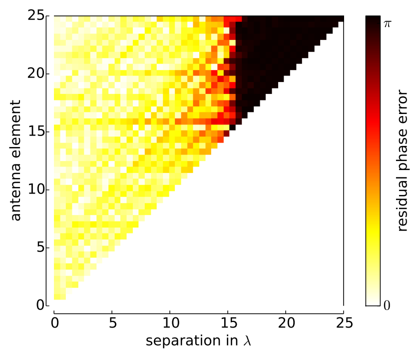

Figure 2: Residual error matrix where the color coding corresponds to a logarithmic measure of the phase error.

References

[1] G. Farquharson, P. López-Dekker, and S. J. Fraiser, "Contrast-based phase calibration for remote sensing systems with digital beamforming antennas," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 51, pp. 1744–1754, Mar. 2013.

[2] E. H. Attia and B. D. Steinberg, "Self-cohering large antenna arrays using the spatial correlation properties of radar clutter," *IEEE Transactions on Antennas and Propagation*, vol. 37, pp. 30–38, Jan. 1989.