SAR Pointing Calibration for Ocean Surface Radial Velocity Estimation: Challenges and Alternatives

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Abstract

This paper discusses, for the case of the Sentinal-1 mission, the challenges for SAR system pointing calibration that is especially required for ocean surface radial velocity estimation based upon the Doppler Centroid Anomaly (DCA) approach.
In view of the Sentinel-1 Next Generation (NG) mission, the paper addresses Along-Track Interferometry (ATI) as an alternative technique.

The Sentinel-1A/-1B cross-InSAR performance is ensured through a stable antenna pointing on both spacecraft, as well as due to the highly accurate time synchronization between corresponding Interferometric Wide Swath mode (TOPS) image bursts, acquired from repeat-pass orbits. This enables an instantaneous InSAR mapping of wide-area (250 km) surface deformation.

While for InSAR, a stable SAR antenna pointing is sufficient (i.e. small Doppler centroid difference), the estimation of ocean surface radial velocity based upon the Doppler Centroid Anomaly (DCA) approach, requires the knowledge of the pointing related geometric Doppler centroid contribution of better than 2Hz. This translates to a very accurate knowledge of the spacecraft attitude to an accuracy of better than 0.5mdeg. However, this is very difficult to achieve even with state-of-the art spacecraft attitude and orbit control systems (AOCS), including CMOS-based SSTs. These type of SSTs are implemented on the Sentinel-1C/-D spacecraft.

In the case of Sentinel-1A/-1B, we have observed jumps in the Doppler centroid when changing the in orbit star-tracker STT configuration during operations, indicating an issue with the STTs inter-alignment. To avoid such Doppler jumps, it requires an accurate measurement of the inter-alignment during on-ground spacecraft assembling and integration (AIT). In addition, the SST measurements have been corrected for the relativistic light aberration effect by applying a patch to the SST software on board Sentinel-1A/-1B.

In addition, the Sentinel-1A/-1B Doppler measurements, as derived from the SAR data, are affected by electronic antenna pointing uncertainties and beam tapering effects, causing different Doppler slopes (ramps) and discontinuities in and between sub-swaths, across range. Furthermore, there have been Doppler ramps within the TOPS bursts along azimuth

observed, indicating that the actual antenna beam steering rate is different to the theoretical/commanded one. However, the later is used for the de-ramping of the range-compressed data prior to the Doppler estimation using the Madsen approach.

For the Sentinel-1 Next Generation (NG) mission, it is envisioned that it provides High Resolution Wide Swath (HRWS) mapping capability based upon a multi-channel SAR system using ScanSAR beam modes. One of the potential implementation options is to use a phased-array antenna configuration with multiple azimuth phase centers (i.e. channels). Such an antenna configuration provides the capability for single-platform ATI. In fact, it has been demonstrated, using the single-platform DRA mode on TerraSAR-X, that ATI provides the possibility for accurately measuring strong ocean surface and tidal currents. As such, ATI provides an alternative to the Doppler Centroid Anomaly (DCA) approach.

The ATI performance depends highly on SAR system parameters, such as the ATI baseline length (to some extent also on its orientation (pitch and yaw)), the coherence time, the SNR (NESZ) and the spatial resolution (i.e. number of looks). As outlined in the literature, in general ATI provides a higher sensitivity than DCA. However, in the case of a single platform implementation with a short ATI baseline, both methods could provide similar or complementary results. As such, the combination of both methods may enable the cross-calibration of ocean surface radial velocity estimates.

We have recently initiated a study using Canada's RADARSAT-2 MODEX ScanSAR data to study the performance (i.e. sensitivity and accuracy) of both methods, ATI and DCA, for measuring ocean surface radial velocity, using the same C-band ScanSAR data. Results will be validated using in-situ reference ocean current velocity data (e.g. buoy and drifter data), and applicable ocean current models, and as far as possible, TerraSAR-X/TanDEM-X ATI acquisitions.

Keywords - Calibration of future missions