Improved cross-range resolution in SAR imaging using a bistatic configuration

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Abstract *Modern Synthetic Aperture Radar (SAR) systems usually operate over land in complex scanning modes such as ScanSAR or TOPSAR that illuminate a wide area and result in a low cross-range resolution. In this work, a novel SAR image synthesis method is proposed to exploit those complex radar modes in a bistatic configuration to produce radar images with a 5-fold increase in cross-range resolution. The proposed method is demonstrated using real measurements from the European Space Agency's satellite Sentinel-1A.*

Introduction

In monostatic SAR, the elevation antenna pattern is shaped to substantially attenuate echoes at angles that correspond to ambiguous ranges when the main beam is directed towards the scene of interest. This two-way attenuation of signals originating from sidelobe illumination yields a non-continuous illumination of the ground in the case of a burst-mode illumination such as ScanSAR or TOPSAR.

However, in a bistatic configuration with a receiver constantly pointing to the scene of interest, the returns originating from the elevation sidelobes of the transmit antenna may enter the mainlobe of the receiver with a sufficient SNR. This continuous illumination of the scene of interest may be used to increase the integration time and thus improve the cross-range resolution compared to the traditional monostatic SAR image. The considered bistatic space-ground geometry of the experiments is shown in Fig. 1. In that configuration, a stationary receiver located on the roof of a building opportunistically exploits the illumination of a spaceborne SAR transmitter.

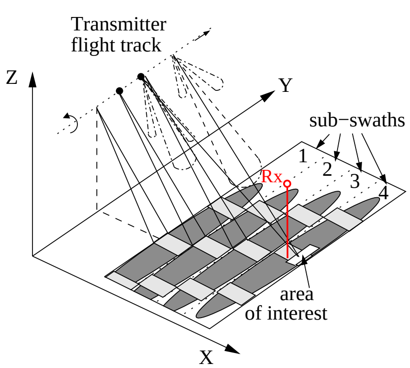

Figure 1: *Bistatic acquisition geometry in the ScanSAR mode.*

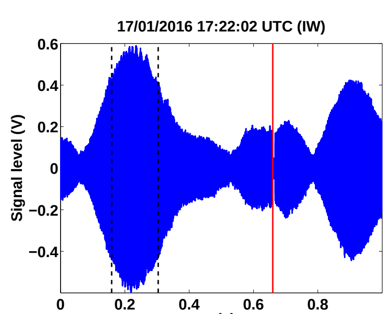

Figure 2: *Direct signal acquired during an overpass of Sentinel-1A.*

Figure 2 represents the direct signal acquired during an overpass of Sentinel-1A operating in TOPSAR mode over the ground-based receiving system. During this acquisition, the receiver and the scene to be imaged are first illuminated by the elevation beam illuminating sub-swath 2, from 0 to 0.66 s (IW2) in Fig. 2 followed by the elevation sidelobe of the elevation beam illuminating sub-swath 3, from 0.66 to 1 s (IW3).

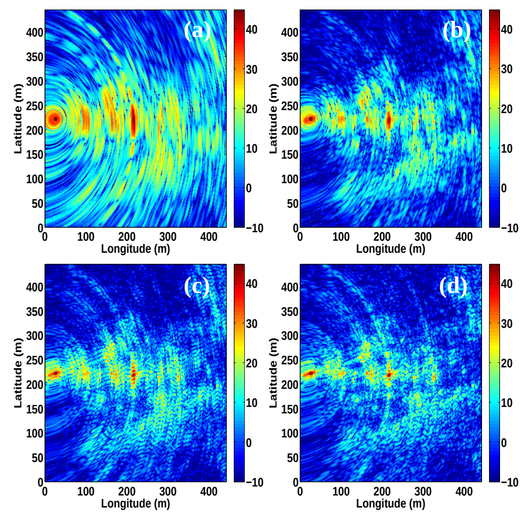

Figure 3: *Zoom near the receiver in the bistatic SAR image.*

Results and conclusion

To illustrate the performance in terms of cross-range resolution, a SAR image has been computed with the traditional integration time of classical monostatic processing, i.e. 3 dB mainlobe width of the transmit antenna, and is illustrated in Fig. 3 (a): the pulses between the dashed black lines in Fig. 2 are considered to build the SAR image. The measured cross-range resolution is equal to 22 m and corresponds to the theoretical monostatic value. This poor cross-range resolution can be enhanced by integrating the pulses transmitted in the azimuth sidelobes of beam IW2, i.e. from 0 to 0.66 s in Fig. 2 using the conventional Matched Filter (MF). The resulting bistatic SAR image is represented in Fig. 3 (b). The cross-range resolution can be further enhanced if the elevation antenna diagram sidelobes of beam IW3 are also exploited, corresponding to the pulses from 0.66 s to 1 s in Fig. 2. The SAR focussed image represented in Fig. 3 (c) shows a high energy in the sidelobes which can be noticed around patches with a large reflectivity. In Fig. 3 (d), the sidelobes are reduced after application of the method and the patches can be easily distinguished. The achieved cross-range resolution is five times better than that of the monostatic SAR image produced by the transmitter at the same time.

The exploitation of wide-swath SAR illuminations considerably increases the number of opportunities to produce high cross-range resolution images over the area of interest as there are many more passes in the wide-swath mode than in the conventional Stripmap mode.