BISTATIC SAR BASED ON TERRASAR-X AND GROUND BASED RECEIVERS

Antoni Broquetas, Mario Fortes, Juan Carlos Merlano,

Sergi Duque, Paco Lopez-Dekker(*), Jordi J. Mallorqui, Albert Aguasca,

RSLab, Universitat Politècnica de Catalunya, Campus Nord UPC - D3, 08034 Barcelona, Spain

(*) Now with DLR, HR Institute, Wessling, Germany

1. INTRODUCTION

As Synthetic Aperture Radar (SAR) and associated research areas such as InSAR or Pol-SAR are developing into maturity, bistatic systems are emerging as a new research field. Bistatic systems open the possibility to explore alternative geometries and different scattering mechanisms. Some of the upcoming systems, such as the future Tandem-X mission, can be described as quasi-monostatic, with the receiver and the transmitter close to each other in almost parallel orbits. While these systems present important technological challenges, but the geometry of observation is similar to the monostatic case. In contrast, if the receiver and the transmitter follow independent trajectories or are located far apart completely, new scenarios arise. Besides the geometry-related issues in the design of bistatic systems, there are a number of synchronization-related challenges. For example, the need for independent reference oscillators on transmit and receive increases the impact of oscillator phase noise. The Remote Sensing Laboratory (RSlab) of the Universitat Politècnica de Catalunya (UPC) has been developing a C-band receiver for a ground-based bistatic-SAR system using the European Space Agency's (ESA) ERS-2 and ENVISAT as transmitters of opportunity that has been named SABRINA (SAR Bistatic Receiver for INterferometric Applications) [1]. Experimental studies are being carried out to study some specific aspects of bistatic SAR systems, including scattering phenomena, raw data processing, hardware related aspects with a particular emphasis on those linked to synchronization , interferometry and polarimetry [2]. This activity is being extended to X-Band using TerraSAR-X as a transmitter of opportunity which allows obtaining images with a higher spatial resolution. This paper presents the SABRINA-X, a multichannel bistatic receiver, its main design parameters and the preliminary results obtained. Full version of the paper will present a bistatic SAR image quality assessment and first metric resolution bistatic interferometric products obtained in both across and along track baselines. The intended applications are stability control or urban areas with differential interferometry and MTI multichannel research using multiple receiving antennas.

2 SABRINA-X BISTATIC RECEIVER

SABRINA-X is a coherent 4 channel homodyne receiver tuned at TerraSAR-X 9.65 GHz carrier. To obtain a low phase noise the local oscillator signal is obtained from a ultra-low noise crystal reference oscillator and a subharmonic low noise PLL followed by an active x4 frequency multiplier. The resulting LO signal is amplified by a driver stage to reach the recommended levels (+13 dBm) of each channel I/Q mixers.

I/Q operation is convenient in the case of TerraSAR-X given the 150 MHz nominal signal bandwidth which allows acquisition below 100 Ms/s speed with a commercial dual input acquisition board per received channel. Low noise amplifiers with a typical gain of 19 dB are used in the receivers front-ends in order to keep the noise figure below 3 dB. The received signal is bandpass filtered in order to reject possible intereferences. A microstrip coupled lines filter with 3 resonators has been designed for this purpose having an insertion loss of 3 dB and 300 MHz bandwidth suitable for both nominal and extended bandwidth TerraSAR-X operation. To compensate for filter insertion loss and increase the chain RF gain a second amplifier with a gain of 14 dB is used between the filter output and I/Q mixer input.

After I/Q detection both base-band I,Q signals are low-pass filtered with 70 MHz commercial components and amplified with a low-noise wide band DC-1GHz amplifier with 16.5 dB gain. After amplification the output receiver ports allow to digitise the base-band signals with a commercial PXI-based system with 12 bit of resolution. The onboard memory allows 2.5 seconds of continuous signal acquisition which is sufficient for bistatic close to ground applications if precise orbital data is used. Fig. 1 shows the developed receiver with the first 2 homodyne I/Q channels, intended for direct and reflected signal simultaneous acquisitions using synchronous digitising boards.

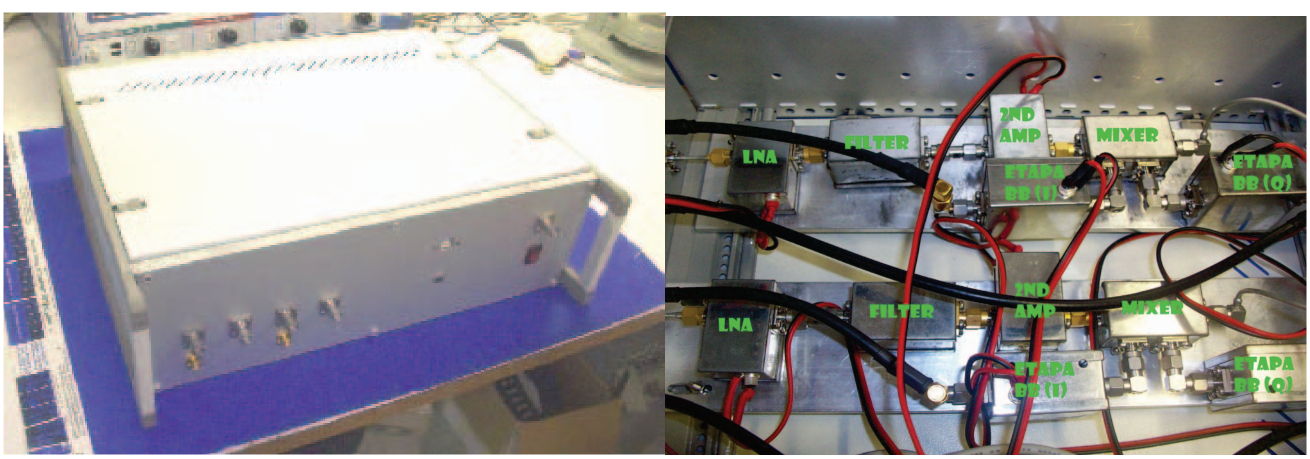

Figure 1 SABRINA-X bistatic receiver

Using simple rectangular horn antennas with a gain of 18 dB, the direct signal is acquired with a signal to noise ratio close to 40 dB in the center of the TerraSAR-X beam. In the case of the reflected channel the Noise

Equivalent σ^0 is -25 dB for an observed area at around 1 km distance from the receiver. It must be pointed out that bistatic radar scattering coefficients are expected to be different from monostatic values depending on the detailed scene surface. For example in urban areas the strong monostatic returns corresponding to trihedrals and dihedrals formed by buiding walls and underlying flat surfaces should not be present in a bistatic geometry, however other strong scatterers related to single or multiple surfaces can appear. More bistatic radar observations are needed in combination monostatic images and ground truth analysis to understand the dominant bistatic scattering mechanisms in both natural and man-made surfaces.

3 FIRST RESULTS

A first direct and reflected data acquisition corresponding to a TerraSAR-X ascending orbit observing the city of Barcelona has been obtained using the described SABRINA-X receiver. Fig.2 shows the experimental set-up mounted on top of the highest building of UPC University Campus. Both forward and backward scattering geometries can be acquired depending on the orientation of the antenna corresponding to the reflected echoes as shown in [4]. In order to obtain the best spatial resolution, in the first experiment the reflected channel antenna was pointed in the backscattering direction approximately orthogonal to the satellite track.

Figure 2 SABRINA-X first experiment

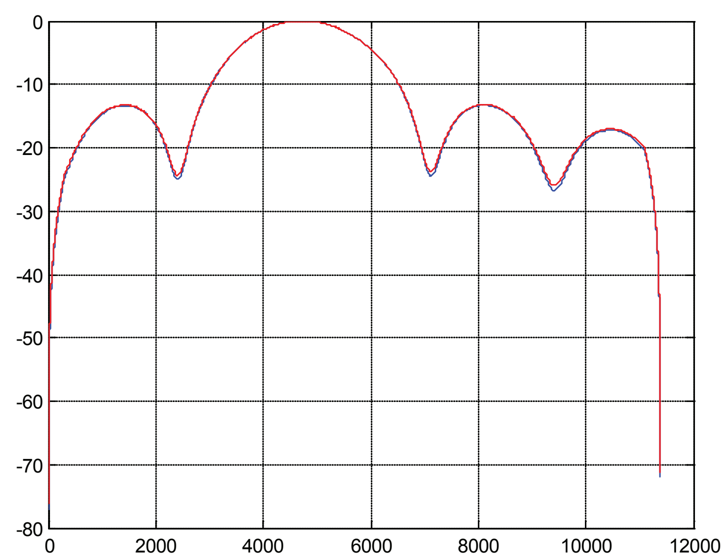

Figure 3 Received TerraSAR-X direct signal envelope

The direct path data inspection revealed a correct acquisition timing showing the main lobe of TerraSAR-X close to the center of the observation time window (Fig.3). Since the receiving antenna has a much wider beamwidth, the pattern shown in Fig.3 corresponds basically to the azimuth cut of TerraSAR-X operating beam. Since no tapering is used in transmission the captured pattern shows the expected sinc shape.

A first simplified bistatic SAR processing has been carried out on the scattered channel data. First the linear complex data take has to be converted in the usual SAR 2D matrix. This can be done easily once the direct channel data is range compressed and the resulting peak positions are used as time reference of the scattered signal. The direct data signal is used both for range and azimuth compression of the scattered data since the phase history of the direct channel is very similar to the phase history of scatterers close to the receiver antennas. Fig.4 shows a the first bistatic image obtained with SABRINA-X acquired data showing the most reflective nearby targets. This data set will be reprocessed using a more accurate backprojection bistatic SAR algorithm and duly georeferenced for ground truth comparison and reflectivity analysis. Additional data sets will be acquired and analyzed in the final version of the paper.

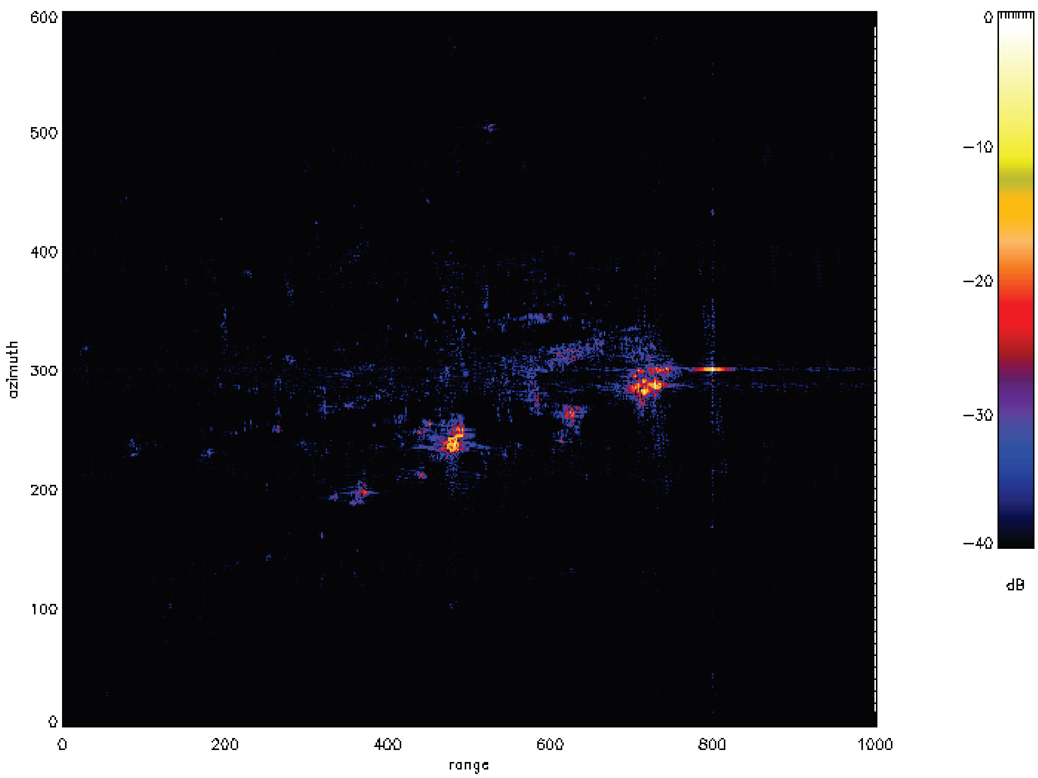

Figure 4 First Bistatic image with SABRINA-X

REFERENCES

[1] J. Sanz-Marcos, P. Lopez-Dekker, J.J. Mallorqui, A. Aguasca, P. Prats, "SABRINA: A SAR Bistatic Receiver for Interferometric Applications", IEEE Geoscience and Rem.Sens. Letters, Volume 4, Issue 2, April 2007, Page(s):307 – 311

[2] P. Lopez-Dekker, J.J. Mallorqui, P. Serra-Morales, J. Sanz-Marcos, "Phase Synchronization and Doppler Centroid Estimation in Fixed Receiver Bistatic SAR Systems", IEEE Transactions on Geoscience and Remote Sensing, Volume 46, Issue 11, Part 1, Nov. 2008 Page(s):3459 – 3471