BISTATIC SAR ALONG TRACK INTERFEROMETRY WITH MULTIPLE FIXED RECEIVERS

Sergi Duque(1), *Paco López-Dekker*(1)(2), *Juan C. Merlano*(1), *and Jordi J. Mallorquí*(1)

(1)Remote Sensing Laboratory (RSLab) - UPC, Spain
(2)DLR, Germany

1. INTRODUCTION

Although Bistatic SAR (BSAR) systems have been studied for the first time more than 25 years ago, they have become popular over the last decade. The scientific interest about BSAR has been focused on the image formation and on system aspects, such as phase synchronization between transmitter and receiver [1]. Anyway, the interest in BSAR should be moved to the applications side. It has to be highlighted that in a BSAR or in a Multistatic SAR (MSAR) configuration, only one transmitter is needed and multiple transmitters can be freely deployed allowing to observe the scene from different points of view. In addition, the receivers are cheaper then their monostatic counterparts that have to include also a transmitter.

The Remote Sensing Lab (RSLab) at the Universitat Politècnica de Catalunya is studying interferometric applications of fixed-receiver BSAR systems [2]. This configuration presents two important advantages in interferometric and tomographic applications. The first one, is that due to the relative proximity of the receiver to the region of interest, good interferometric results can be produed with short baselines on the receive end. The other is that the acquisition can be done in a single-pass configuration, elliminating the temporal decorrelation.

This paper studies BSAR Along-Track Interferometry (ATI) using multiple fixed-receivers an a satellite as a transmitter.

2. BSAR ATI THEORY

2.1. Monostatic equivalent

Figure 1 illustrates the BSAR ATI geometry considered in this work. A single transmitter moves at an effective velocity v_x illuminating the target. The scattered signal is received by two (or more) antennas separated by an along-track baseline, B_a. The geometry can be considered as an equivalent monostatic system with a set of antennas placed along the bisectors of the angles formed by the transmitter antenna, the target, and the receivers. These bisectors rotate as the transmitter follows its trajectory with an angular velocity that is half that of the monostatic one, $\omega_t' = \omega_t/2$, being the monostatic $\omega_t = v_x/R_t$. Thus, the monostatic equivalent effective velocity is

$$v_x' = \frac{v_x}{2}. \tag{1}$$

The ATI phase can be expressed as

$$\Psi_{ATI,0} = \arg(V_2 \cdot V_1^*) = k_0 B_a \sin\phi. \tag{2}$$

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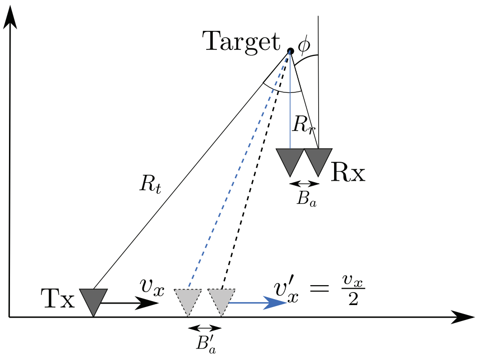


Fig. 1. ATI bistatic geometry. The figure shows a single moving transmitter, two fixed receivers with an along-track baseline, and the equivalent *monostatic* phase-centers forming a moving along-track pair.

This phase is deterministic, and it can be removed from the interferometric data using an external DEM, the transmitter trajectory and the receivers positions.

2.2. Moving target

If a target is moving at a constant velocity during the SAR integration time, it produces a bistatic range derivative, $\dot{R}_b$, which is constant. The resulting linear phase term will result in a shift of the apparent azimuth position of the target. If the theoretical ATI phase related to the angular position is substracted to the ATI phase, the residual phase will be

$$\Psi_{res} = 2k_0 v_b \tau_{ATI}, \quad (3)$$

being τ_{ATI} the temporal lag due to the ATI baseline and v_b the velocity of the target in the bistatic range direction taking into account that transmitter and receiver are on the same side of the observed scene. It has to be noticed that the formulation employed assumes that all the resolution cell is moving. This can be a valid assumption for a sea surface or if there is only one moving target with a high Signal to Clutter Ratio (SCR), thus the clutter can be ignored. In order to estimate more than one contribution, multiple baselines and spectral estimation algorithms have to be used.

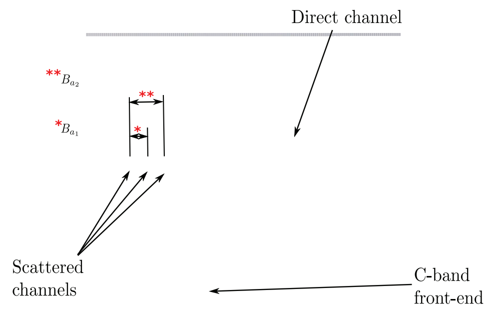
2.3. Multi Along Track Baseline Implementation

If multiple receivers performing a set of baselines are available, it is possible to estimate more than one moving contribution for each resolution cell.The first step is to remove the deterministic ATI phase with respect a master image. Once, this systematic phase component has been removed, it is possible to establish a signal multi along track baseline model analogous to the one used in SAR Tomography. The multibaseline approach for Bistatic ATI will be discussed in detail in the full paper.

3. EXPERIMENTAL RESULTS

3.1. Experimental set-up

Experiments have been carried out using UPC's C-band SABRINA system and ESA's ENVISAT satellite. A description and discussion of an earlier 2-channel version of the system can be found in [2]. Now, the system has 4 channels. The absence of a dedicated link between the transmitter and the receiver local oscillators results in the necessity of using a direct signal for PRF recovery and phase synchronization [1]. This direct signal is obtained using one dedicated channel, with an antenna pointing directly to the satellite. The other 3 channels are placed performing two independent along-track baselines, B_{a_1} and B_{a_2} of 18 and 37 cm respectively. Figure 2(a) shows the set-up of the acquisition system for this experiments. SABRINA was placed at the top of a 54 meter tall building at UPC's campus.



(a) (b)

Fig. 2. (a) SABRINA set-up for a bistatic multibaseline along-track acquisition. (b) Controlled moving target consisting on a BARC attached to a linear unit.

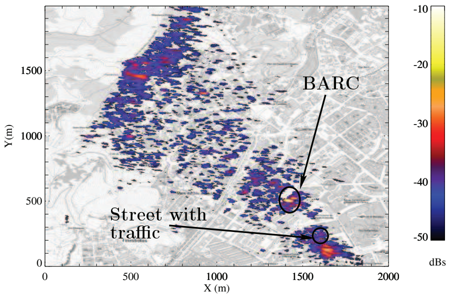
In order to have a controlled moving target, a Bistatic Active Radar Calibrator (BARC) has been used. The BARC consists in an antenna pointed to the satellite, an amplification chain and a transmitter antenna pointed where SABRINA is located. The BARC was attached to a linear unit and its motion was synchronized with the satellite pass. The BARC was moving at a constant velocity of 20 cm/sec towards the receiver. The velocity vector projected over the bistatic range where the BARC was placed was $v_b = 15.1cm/s$. Figure 2(b) shows a picture of the BARC attached to the linear unit.

3.2. Results

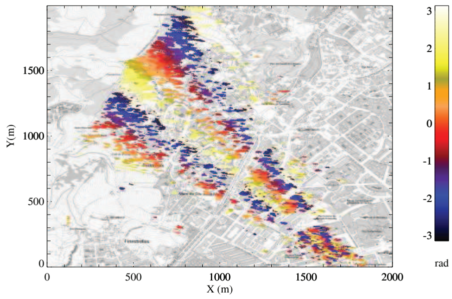
This section shows the geocoded results using the 18cm baseline for the points with a SNR higher than 15dB and the MB results. For the latter, the obtained amplitude versus velocity profile for two different resolution cells with different inversion methods is presented. Figure 3(a) shows the geocoded received power, the BARC can be easily identified as it presents a high SCR. In addition, its high SCR allows to estimate its velocity with a single baseline. The ATI phase is illustrated in Figure 3(b), it presents fringes in the ortogonal direction to the receiver range. Once the deterministic term of the phase has been removed, the phase can be converted to velocity.

As it can be seen in Figure 3(c), the major part of the selected points are static, they are represented in green. There is a red spot where the BARC is located related. The measured velocity in the bistatic range direction for the BARC is $v_b = 15.0cm/s$, very close to the expected value, $15.1cm/s$.

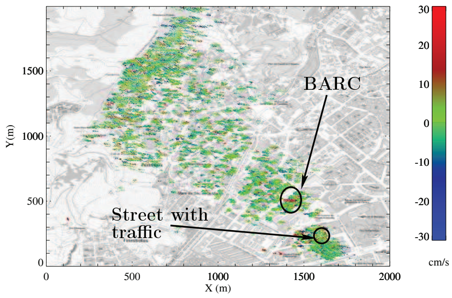
Capon, MUSIC, BF and NLS have been used as inversion methods to retrieve the velocities with the multibaseline approach. Figure 4 shows the results from the multibaseline approach for the BARC, 4(a), and a street with some traffic, 4(b), using Capon, MUSIC assuming 1, $N_s = 1$, and 2, $N_s = 2$, targets, BF and NLS as inversion methods. Taking a look to Figure 4(a), it can be said that BF finds the solution, but it presents high sidelobes, due to the irregular baseline sampling. Capon also gives the correct solution wit no secondary lobes. MUSIC performance is good if the assumption of number of targets is correct. Finally, the NLS method retrieve the velocity with high precission. Focusing in the results for the pixel with some traffic, the expected behaviour is to observe two main velocity contributions, the static clutter and a moving target. It is extremely likely that the velocity of the car is over the non-ambiguous one, thus the system can be only used for GMTI. In this case, BF shows a bad performance, it only retrieves one contribution due to the car. Capon retrieves both of them but with poor precission. MUSIC with $N_s = 2$ and NLS produce similar results, retrieving both contributions, clutter and moving target, wiht good precission. Finally, MUSIC assuming only onet target finds a single contribution with a velocity different to the previous ones.



(a)



(b)



(c)

Fig. 3. Experimental geocoded results using only the 18 cm baseline. (a) Received power. (b) Raw interferometric phase. Finally, (d) shows v_b.

4. REFERENCES

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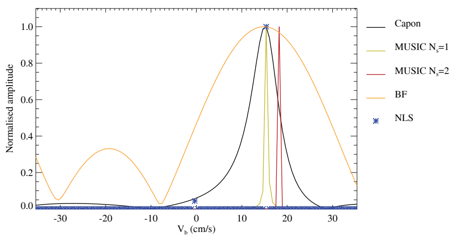
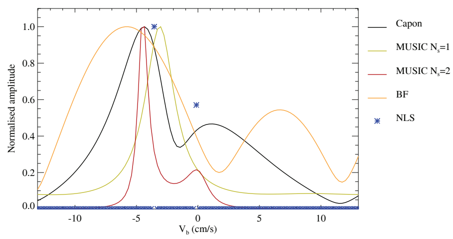


(a)



(b)

Fig. 4. Results from the MB approach for the BARC, Figure 4(a), and a street with some traffic, 4(b), using different inversion methods.