BISSAT: A Bistatic SAR for Earth Observation

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Abstract—**This paper summarizes scientific rationale and technical approach for a bistatic synthetic aperture radar (SAR) mission (BISSAT). The study has been funded by the Italian Space Agency for a competitive Phase-A study along with other five missions. Its concept consists in flying a passive SAR on board a small satellite, which observes the area illuminated by an active SAR, operating on an already existing large platform.**

I. INTRODUCTION

Bistatic radar operates with separated transmitting and receiving antennas. The proposed configuration is based on a small satellite, equipped with a receiving-only microwave system that catches the echoes of an already existing, main orbiting SAR, without requiring its design modification or additional operating complexities. BISSAT experiment will be the first bistatic SAR implementation in space with two separate platforms, and it will offer unique features:

(a) to conduct original scientific experiments and to exploit novel applications;

(b) to perform a technology demonstration of an original space formation;

(c) to offer to the Italian industry the possibility to design and operate a formation;

(d) to keep cost within a small mission budget.

Bistatic scattering has proven to be of fundamental importance to many branches of earth sciences and several investigations have been conducted, but considering one or both earth-based antennas and targets of limited dimensions [1,2], because bistatic observation requires accurate time synchronization and antenna pointing. As an example, bistatic echoes allows innovative characterization of vegetated and urban surfaces for biomass evaluation, or sea surface waves and currents to be mapped [3,4,5,8,9,10]. Proposed bistatic experiment will allow original scientific activities to be carried out for the first time from space, such as:

(i) evaluation of bistatic radar cross section of natural and man-made targets, by means of multi-angle bistatic SAR observations;

(ii) acquisition of terrain elevation and slope by means of range and bistatic scattering measurements;

(iii) acquisition of velocity measurements, thanks to the simultaneous measurement of two Doppler frequencies;

(iv) stereogrammetric applications [11], thanks to the large antenna separation involved;

(v) improvement of image classification and pattern recognition procedures;

(vi) high-resolution measurements of components of sea wave spectra;

(vii) signal processing of bistatic data;

(viii) across-track and along-track interferometry.

Hence, the program answers to current scientific interests and objectives, and several distinguished Italian and foreign investigators support the proposal, as potential users of bistatic data. As a consequence, ASI could issue an Announcement of Opportunity to exploit bistatic data applications, and an outreach program, to involve students in the activities.

Technical feasibility of the mission has been demonstrated, in particular taking advantage from COSMO/SkyMed X-band SAR2000 experience, which has been selected as main mission. Development of bistatic receiver chain can be carried out with wide reuse of components and instruments already qualified within COSMO project. Furthermore, BISSAT will add value and exploit further scientific applications of COSMO mission.

Ground segment and bistatic SAR processing require novel, although limited, implementations, again founded on well-assessed expertise, that can be integrated within ASI Data Science Center facilities.

Regarding the platform, MITA customization to BISSAT payload can be basically achieved within the architecture envisaged for HypSEO mission, already scheduled by ASI. Furthermore, considering ASI interest in developing a standard platform, BISSAT mission will allow novel experience and potentialities to be fulfilled, such as: propulsion for formation flying and orbit maintenance, and fine attitude and pointing control. It is worth noting that formation flying is an internationally recognized important scenario.

Considering above limitations in new, expensive developments, BISSAT program offers interesting possibilities to participation of small and medium-sized enterprises too.

Finally, a top-level mission management structure has been considered, with components from ASI and universities, to control overall project development. Whereas an operating group, formed by young scientists and engineers carrying out a formation period at proponent universities, would attend all detailed phases of the program.

2. OVERVIEW OF BISSAT PAYLOAD

Development of a light passive antenna is a key point in BISSAT payload design. The main features of antenna beam are reported in Tab. 1. Regarding to azimuth and elevation steering, it must be considered an interesting, but optional feature, not strictly required for fulfilling mission objectives. Therefore, depending on overall cost envelope, it could be considered or not.

Use of more panels constituted by 12-patch arrays, spaced $\approx 0.7\lambda$, will be adopted to develop BISSAT antenna. Electronic steering will be achieved by means of the feeding network. Antenna dimensions are: 2.2 m as azimuth length, 0.4 m as elevation length, 40 mm as overall mechanical thickness, 12 mm of which are devoted to electrical circuitry. The mass of the antenna is estimated in 31 kg. Antenna boresight direction forms an angle of 4° with respect to the local vertical, towards the right side of the ground track.

TABLE 1
MAIN CHARACTERISTICS AND REQUIREMENTS OF ANTENNA BEAM

Azimuth beamwidth	0.7 deg
Azimuth side lobe level	< 14 dB
Azimuth steering angle (passive)	± 3 deg
Azimuth steering resolution (step)	<0.03 deg
Elevation beamwidth	4 deg
Elevation side lobe level	< 20 dB
Elevation steering angle (passive)	± 3 deg
Elevation steering resolution (step)	<0.3 deg
Elevation main beam gain flatness	< 2 dB
Antenna pointing error (azimuth and elevation planes)	± 0.1 deg
Polarization	HH or VV

Antenna will be composed by three elements, a central one corresponding to half-length and two wings folded during launch, and will be thermally autonomous and insulated from satellite. It is worth noting that, besides mass reduction, a BISSAT smaller antenna with respect to main SAR makes beam overlapping easier.

A GPS receiver will be on-board BISSAT, to generate a time reference necessary for synchronizing the satellites [6] and to determine spacecraft position necessary for applications and orbital maneuvers.

3. OVERVIEW OF PAYLOAD PERFORMANCE

Performance of the designed bistatic mission are analyzed in terms of Doppler parameters (centroid frequency and bandwidth). They have been computed considering the motion of both the transmitting/receiving (T/R) and the receiving-only (R/o) SARs [7]. With regards to bistatic Doppler centroid frequency, in the range of latitudes of feasibility of bistatic acquisitions (-65.2°÷66.2°), it varies from -8000Hz (65.2°S) to –18000Hz (66.2°N), going through 0 Doppler (equator) (Fig. 1). Doppler bandwidth can be estimated by computing for any given target of the Earth surface its Doppler frequency as a function of the azimuth position of the radar (considered as a time co-ordinate) and the resulting gain from the T/R and the R/o antenna patterns. The Doppler bandwidth is computed considering the 6dB apertures of the resulting pattern and for different values of the elevation angle. As an example, Doppler frequency is plotted for a point at the near, mid, and far range

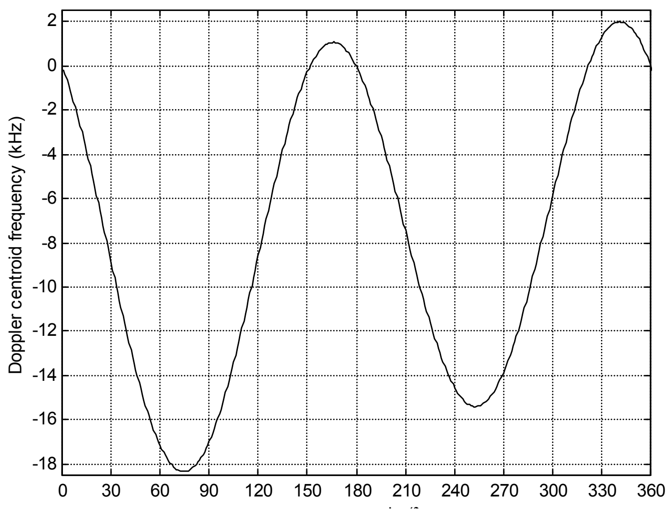

Fig. 1. Bistatic Doppler centroid frequency as a function of BISSAT anomaly.

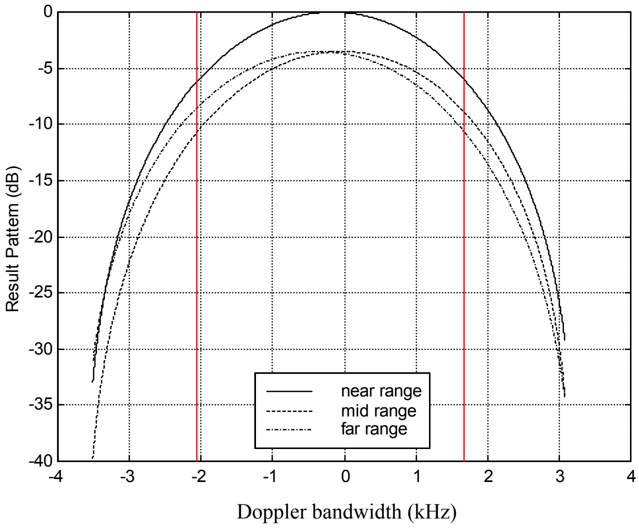

Fig. 2. Bistatic pattern along the azimuth aperture as a function of Doppler frequency at near, mid and far range (on the equator).

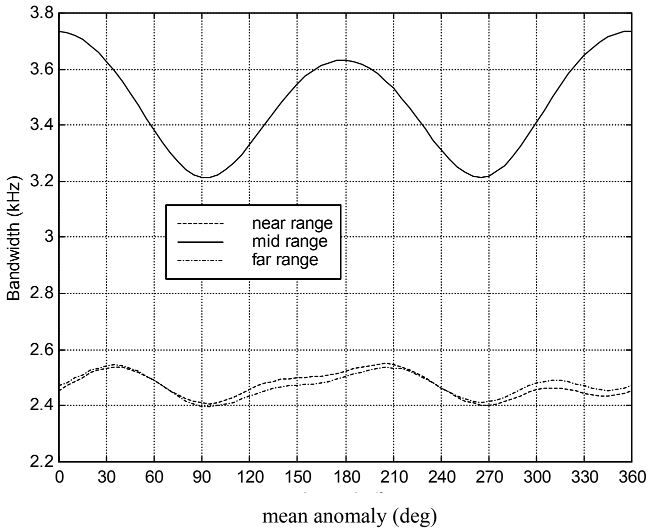

Fig. 3. Bistatic Doppler bandwidth as a function of BISSAT anomaly.

(Fig. 2), when BISSAT is on the equator. Finally, Doppler bandwidth is plotted (Fig. 3) for a whole orbit.

Integration time is an important parameter to evaluate the azimuth resolution. For monostatic radars it can be defined as the time interval within which a target is within the 3dB antenna pattern. For bistatic radars this definition can be generalized considering the time interval within which a target is within the 6dB aperture of the pattern obtained multiplying the T/R and the R/o antenna patterns. The resulting bistatic gain varies from near to far range, because at mid-range the antenna main lobes are larger. Finally, integration time at near, mid, and far range is plotted in Fig. 4 for a whole orbit.

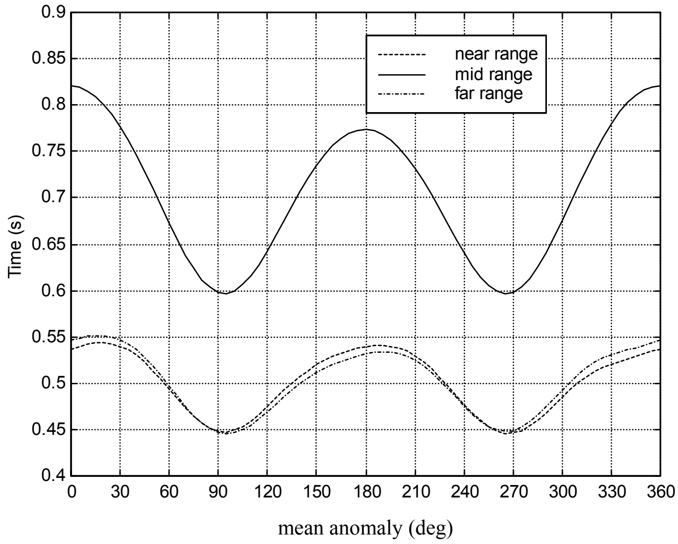

Fig. 4. Bistatic integration time as a function of BISSAT anomaly.

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