

INTERFEROMETRIC EXPERIMENTS WITH THE FIRST ITALIAN AIRBORNE P-BAND RADAR

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ABSTRACT

This work aims to describe the characteristics and the status of development, including the results of a first preliminary testing campaign, of a low frequency airborne imaging radar developed in Italy for the Italian Space Agency.

Index Terms — Synthetic Aperture Radar (SAR), P-Band, SAR undersurface imaging

1. INTRODUCTION

Interferometry has amazingly boosted the application of SAR with many benefits for hazard monitoring and security. Thanks to advantages of the technology over the traditional instruments, global mapping of the Earth elevation with the SRTM and Tandem-X mission has been achieved. Moreover, due to the availability of stacks of SAR data for most of the Earth and to the development of advanced interferometric processing techniques, monitoring of Earth surface deformation has become operative in many contexts related to hazard and security. Persistent Scatterers (PS) method and the Small Baseline Subset (SBAS) developed at Politecnico di Milano and IREA-CNR in Naples are nowadays the most used method for the processing interferometric SAR stacks acquired from spaceborne platforms implemented also in commercial and scientific tools.

SAR Tomography is an advanced method for the coherent processing of multibaseline SAR data that allows implementing a radar scanning in 3D: azimuth, range and elevation. It was first demonstrated with airborne L-Band data in [1]. Developments have been also carried out with spaceborne data with multi-Dimensional SAR imaging, as an extension of classical PS methods, to improve detection and estimation of scatterer motion parameters as well as to resolve the layover effects on vertical buildings [2][3]. Spaceborne SAR Tomography has been implemented with C and X-Band data, i.e., with very limited penetration capabilities, and by using long term multiple passes of sensor. The latter aspect is critical for the imaging of vegetated areas showing losses of coherence over the time. On one hand, the use of low frequency electromagnetic radiation provides SAR system the capability to penetrate the surface [4]. With respect to C and X-Band sensors, this allows extending information extraction from coherent SAR data and significantly increasing the number of applications. Among them it worth certainly to mention first the application to forests mapping [5]: low frequency radiations allow in fact penetrating the canopy, thus revealing the entire vertical structure of the vegetation. The importance of this application is testified by the activities in the planning of dedicated satellite missions: above all, the upcoming ESA-Biomass mission. Another relevant application is the reconstruction of the sub-surface characteristics of glaciers. Other applications regard the mapping detection of mines and crop monitoring in agricultural areas [6]. With regard to all above applications, use of multiple polarizations allows

advanced data processing for improving the performances of the methods for the extraction of the relevant information. On the other hand, the flexibility provided by airborne SAR systems allows very frequent acquisition of multiple pass data thus limiting the problem of temporal decorrelation [7]. For these reasons, the Italian Space Agency (ASI) has promoted and funded the development of an airborne radar sensor operating at VHF and UHF bandwidths. The next Sections are dedicated to describe the characteristics of the system and the status of development with illustration of the results of a first preliminary testing campaign.

2. IMAGING RADAR INSTRUMENT: DESCRIPTION AND DEVELOPMENT

Since 2011 CORISTA has been funded by ASI for the development of a multi-mode, multi frequency airborne radar. Currently the system works in sounder mode with a carrier frequency of 163 MHz, and in the SAR mode at two different P-Band carrier frequencies, namely 450 MHz and 860 MHz. The new contract, signed at the end of 2015 in the frame of a cooperation with different Italian public Research Institutes and Universities, is aimed at further improving the existing system and developing applicative experiments in the areas described in Sect I.

The system is quite compact: its dimensions are 50 cm x 50 cm x 60 cm, for a weight of about 35 kg. Accordingly, it can be easily mounted onboard relatively small airplanes or helicopters.

The system exploits the stepped chirp technology, which allows combining different chirp pulses of 10 MHz bandwidth at different carrier frequencies. With reference to the SAR mode, this allows obtaining a bandwidth of 40 MHz at 450 MHz, and a bandwidth of 80 MHz at 860 MHz. Accordingly, the (slant) range resolution achievable with the SAR system is 3.75 m at 450 MHz, and 1.88 m at 860 MHz. To this regard, it is worth stressing that, according to the system upgrade planned in the frame of the third contract, the system will be able to transmit chirp pulses characterized by a wider bandwidth (namely 40 MHz). Accordingly, to reach the 80 MHz bandwidth at 860 MHz. Similarly, the 40 MHz bandwidth at 450 MHz will be reached with just one pulse.

Currently, the system operates in single polarization (HH). However, according to the system upgrade mentioned above, the radar will become full-polarimetric.

The SAR antennas at 450 MHz and 860 MHz, although based on the same technology, are different. In particular, for the 450 MHz case, it is exploited a linear array of 4 patch antennas. The half power beamwidth is equal to 75° in the range direction and 20° in the azimuth one. The gain is equal to 17 dB. The antenna is single-polarized. However, the system upgrade mentioned above will involve the realization of a new, dual-polarized antenna capable of operating at the 450 MHz carrier frequency. For the 860 MHz case, it is exploited a planar array of 8x2 patch

antennas. In this case, the half power beamwidth is scaled by a factor two (in both the directions) with respect to the antenna exploited in the 450 MHz case. This leads to an increase of the gain, which in this case is equal to 19 dB. Moreover, in this case, the antenna is dual-polarized. More details on the systems and antennas can be found in [8] and in [9].

3. EXPERIMENTAL RESULTS

The imaging radar instruments at 450 MHz has been used in a campaign aimed at testing SAR capabilities of the imaging sensor. The campaign was carried out in October 2013 with the instrument placed onboard a helicopter (AB212) of the Aeronautica Militare Italiana (AMI). Figure 1 shows the performed accommodation of the radar that is composed by the blue rack inside the helicopter fastened on the floor and by the side-looking antenna fixed with a dedicated mechanical framework.

The whole installation has been performed by a joint team formed by CORISTA and Reparto Sperimentale di Volo (RSV) of AMI.

During the two days of campaign, several passes (more than ten per day) have been performed over a hilly area located in Sannio region, South Italy.

Two trihedral corner reflectors were placed on ground for calibration purpose. Corner reflector have been designed and realized by CORISTA following a modular approach that allows different sizes. In this case the two corner reflectors have a 2.8 m side length that assures a nominal RCS of 32.5 dB at 450 MHz and 38.5 dB at 860 MHz.

The data were processed by IREA-CNR implementing motion compensation based on the measurements provided by the IMU. An additional autofocus was implemented to correct the forward velocity.



Figure 1 – Radar system on board of AB212 platform of AMI during 2013 flight campaign



Figure 2 – Corner Reflector used for 2013 flight campaign

The images corresponding to two Scan after geocoding are shown in Figure 3 – images generated by the scans 13 (left) and 19 (right). The two tracks were not perfectly parallels. It is evident how the image is able to map ground features present in the Google Map image. A general agreement with the location of vegetated areas as well as with ground slopes is visible in both the images.

Interferometric data processing was also carried out. The coherence and interferometric images generated by the Politecnico di Milano are shown in Figure 4 confirming the coherent acquisition capabilities of the developed system. In this case data focusing was carried out with a 3D back-projection algorithm.

3. CONCLUSIONS AND FUTURE DEVELOPMENTS

An overview of the activities carried out with reference to the development of an airborne P-Band imaging systems for application to subsurface imaging have been described. The system is currently undergoing an upgrade that mainly foreseen a significant enlargement of the sounder bandwidth (up to 40 MHz) and the doubling of receiving channels for allowing implementation of full polarization mode.

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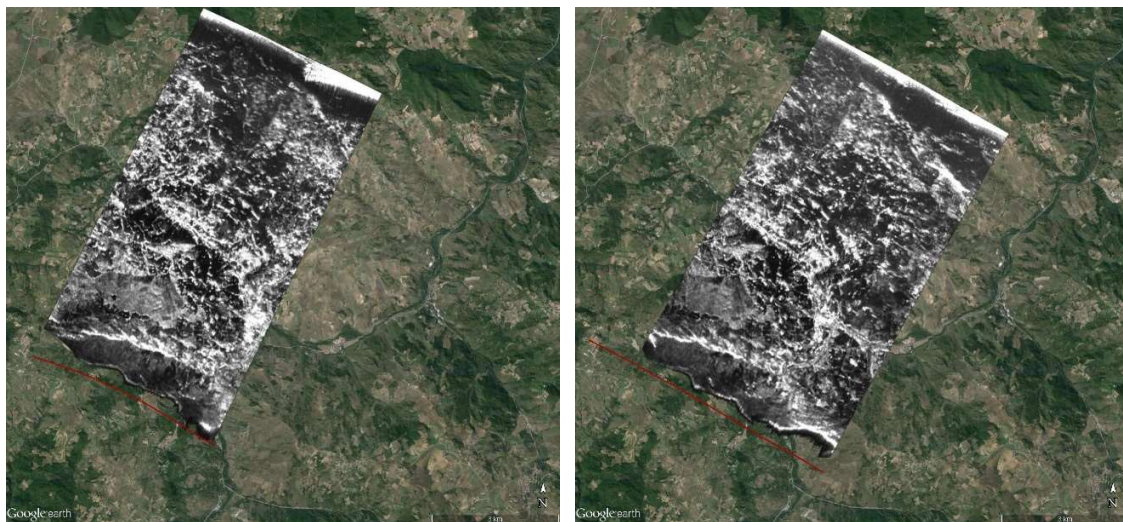


Figure 3 – images generated by the scans 13 (left) and 19 (right).

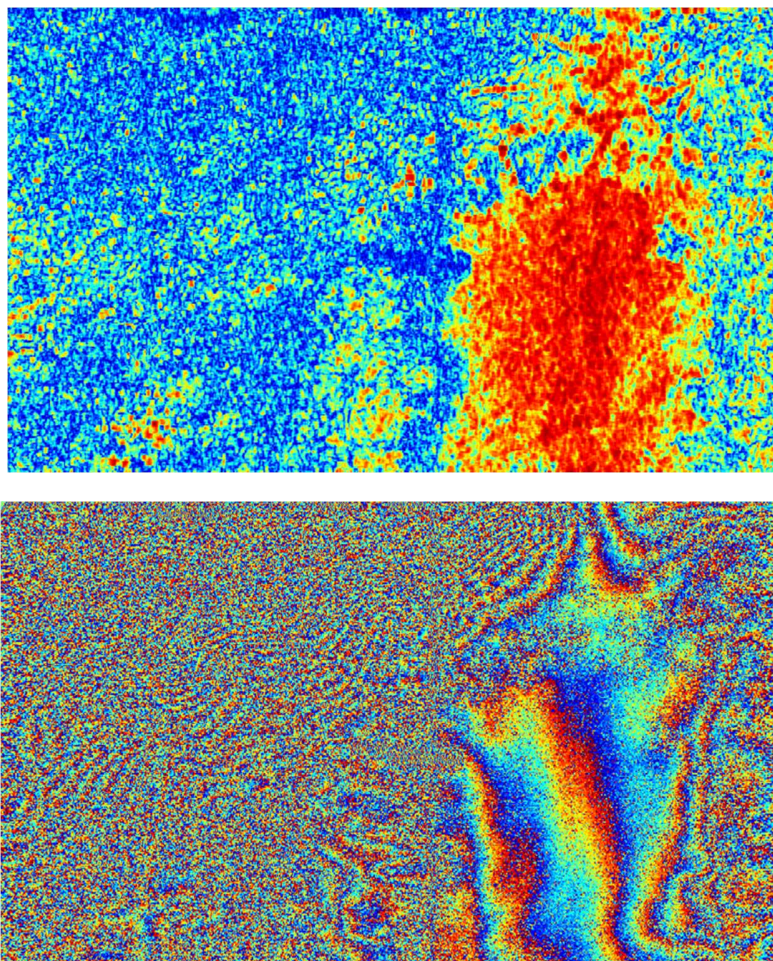


Figure 4 – Coherence map (top) and interferometric fringes (bottom) derived from the scans 13 and 19.