Validation of S-band data performance for future spaceborne SAR missions

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Abstract

Most of the SAR missions of the latest years presented sensors working in X-band (like in the TerraSAR-X and Cosmo-SkyMed missions). Today new SAR missions, working at alternative frequencies like S-band, are under planning/design and will be launched in the upcoming years. In addition, full polarimetry is likely to be implemented in some of those missions. This is the case of the UK sensor NovaSAR-S to be launched by 2013. In order to validate the performance of S-band, especially in comparison with the better known and tested X-band, an airborne demonstrator has been set up to contemporaneously acquire fully polarimetric SAR data in both bands. In this paper we present, compare and discuss results deriving from the application of the $H/\alpha$ and the Pauli decompositions to the fully polarimetric datasets in both bands to understand possible advantages of S-band in specific applications.

1 Introduction

In the last decade we have witnessed the launch of many new spaceborne SAR missions presenting new capabilities, high performance and an interesting wide range of fields of applications. These features are often accompanied by high costs typical of SAR missions which, finally, result always much more expensive than the traditional optical ones.

A new generation of low-cost spaceborne SAR missions is under planning. Among these the UK NovaSAR-S [1], developed by SSTL Ltd. in collaboration with EADS Astrium, will present a cost significantly lower than that presented by any other current spaceborne SAR platform with still competitive performance. This is made possible by the adoption of an efficient S-band solid state technology. A very few works can be found in literature on the capability of the S-band (3.1-3.3GHz) because of the poor availability of data at this frequency. In this study, many S-band datasets acquired by an airborne SAR demonstrator have been analyzed in order to start a deep investigation of the band performance in conjunction with the technical specifications that the corresponding spaceborne mission will present (spatial resolution in the order of 6m and full polarimetry). More precisely, in this paper we compare the performance of S- and X-band by analyzing polarimetric data acquired simultaneously on the same area in both bands. The methodology and the current results are explained and discussed in the next sections. Central conclusions are then summarized.

2 Methodology

Datasets coming from the airborne demonstrator campaign [2] have been extensively used in this study. All these data present the same initial values of spatial resolution and same acquisition features except for the band. Indeed, the demonstrator simultaneously acquired fully polarimetric SAR images in S- and X-band over the same areas in the South England and these data have all been multi-looked and calibrated in order to get comparable sets of data. The original processed images presented a spatial resolution of 0.35m and 0.835m respectively in azimuth and slant range. Then a multilook 20x4 has been applied to get 7m x 3.34m resolution in the azimuth/slant range plane and a final 7m x 6.7m resolution on the azimuth/ground range plane when considering an average incidence angle of 30°. These final values are consistent with those considered in the design of NovaSAR-S [1] which performance is under investigation.

The calibration instead has been performed for all datasets according to the van Zyl calibration method.
[3] using just one trihedral corner reflector and natural targets.

Finally, with the purpose of comparing the S- and X-band in their fully polarimetric performance, classic polarimetric decompositions [4-5] have been applied, an example of which is presented and discussed in the next section.

3 Discussion of results

In [2] first results related to performance of fully polarimetric S-band data were discussed. Here we present some of the results of a synoptic study in which the same polarimetric analysis, previously applied to the dataset in S-band, is now applied also to the X-band dataset acquired by the demonstrator exactly at the same acquisition time.

In particular we present some of the outcomes deriving from a combination of the entropy $H$ and the mean angle $\alpha$ based on the well known eigenvector-eigenvalue decomposition [4].

In Figure 1 the $H/\alpha$ decomposition is applied to both datasets, relevant to the same area of Baginton in Southern England, respectively in X-band, Fig.1(a), and S-band, Fig.1(b). A colour code map based on [5] is also shown in Fig.1(c).

Comparing the outcomes we see that the decomposition applied to the S-band dataset brings about a finer separation of the vegetated areas in terms of contours while the same applied to the X-band produces a quite noisy map where only some targets can be distinguished.

Moreover, according to [5] and Fig.1(c), a better classification of forested areas is also possible with the S-band data, an example of which is given by the large red area in the white frame in the bottom of Fig.1(b). That area is relevant to a forest site and is better detected in this map than in the corresponding in X-band, Fig1(a). Indeed, as known from [5], the scattering from forest canopies lies in the region $Z2$ of the colour code map, see Fig.1(c), and is relevant to high values of entropy and values of angle $\alpha$ close to 45°. If we look at the scatter plots representing the angle $\alpha$ against the entropy $H$, see Figure 2, from which the colour maps have been derived, it is apparent how the above property is better reflected in the S-band dataset. In correspondence of the mentioned forested area the mean values of the couple ($H, \alpha$) are (0.94, 48.9°) for the S-band and (0.88, 52.6°) for the X-band thus proving a better adherence of the S-band dataset to the theory in [5].

Applying another typical polarimetric decomposition, the Pauli one, to the same spotted area, we find a further validation of the S-band better performance. Figure 3 shows a particular of the colour maps derived by applying the Pauli decomposition to the same area.

Figure 1. $H/\alpha$ polarimetric decompositions applied to the quad-pol X-band dataset (a) and S-band dataset (b) with corresponding color code map (c).

The volume, the surface and the double bounce scatterings have been evaluated and represented together with the colour palette in Fig.3 to give two different composite colour maps respectively for the S-(Fig.3(a)) and the X-band (Fig.3(b)).
Figure 2. Scatter plot of the angle $\alpha$ against the entropy $H$ for, respectively, the S-band dataset (a) and the X-band dataset (b) of the forested area framed in Fig.1.

From the Pauli decomposition we understand that in the S-band the electromagnetic return from the forest presents a contribution of volume scattering larger than the one due to the surrounding flat background, see Fig.3(a). In the X-band image, instead, because of the smaller wavelength, the overall contribution of volume scattering is very large, also from other vegetated areas, which makes the forest signature in X-band less distinguishable from that of other vegetation features.

Similar results have been found also from the application of the same decompositions to other datasets, thus revealing an advantage in the adoption of fully polarimetric S-band data when some vegetated areas are to be monitored.

4 Conclusions

In this paper, fully polarimetric airborne SAR data in S- and X-band have been processed and compared. The $H/\alpha$ and the Pauli decompositions have been applied to both datasets with the purpose of investigating possible fields of application for the S-band which will be available from spaceborne SAR platform in the upcoming years.

It has been observed that the lower frequency of the S-band presents a high potential in classification and monitoring of forested areas when a fully polarimetric dataset is considered.

The authors have analyzed several datasets in both frequencies and it appears a general conclusion that vegetated areas are much better separated in this band than in X when polarimetry is exploited.

The complete study will be presented and discussed at the conference in order to validate the outcomes here introduced.

References


