Large Reflectarray for SAR for Earth Observation: RF Design and Measurement Correlation

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***Abstract*—In this paper the RF design of a large Ka-band reflectarray for Synthetic Antenna Radar (SAR) application and the correlation with the measured data are introduced. The reflectarray is part of a dual-offset antenna system for a high-resolution and wide-swath SAR instrument. The antenna is optimised to work in the high-resolution mode with a directive beam in one linear polarisation, and in a low-resolution mode with a broad beam in the opposite linear polarisation. A dual linear mode sectoral horn is optimised to enable different beam widths for the two orthogonal polarisation. Measurement of the radiation patterns and correlation with the predicted data are presented to validate the design.**

Keywords—Reflectarrays, SAR application, antenna optimisation, measurement correlation, Ka-band

I. Introduction

Single-platform Ka-band interferometric Synthetic Aperture Radar (SAR) instruments are potentially attractive solutions for environmental and security purposes [1], [2]. This has become apparent with the emergence of Along Track Interferometry (ATI) and Ground Moving Target Indication (GMTI) Earth observation missions which require high-resolution and highly sensitive SAR instruments operating on wide swaths.

While in traditional SAR applications, high resolution and a wide swath are difficult to obtain simultaneously, modern digital beam forming (DBF) techniques like Multiple Azimuth Phase Centres SAR (MAPS) and Scan on Receive (SCORE) are promising techniques for achieving both objectives. For MAPS, several azimuthally aligned apertures are needed resulting in a long antenna structure. To enable these instruments to be stowed in available launch vehicles such long antenna structures must necessarily be foldable. Together with additional requirements of high antenna aperture efficiency and low losses, the reflectarray technology is a promising candidate for SAR applications. High aperture efficiencies can be realised on flat substrate structures, which require only a small volume in folded state. In addition, printed circuits on lightweight substrates can be employed, reducing weight and costs.

The inherent ability of polarisation selectivity allows for designs with different beam widths for two orthogonal linear polarisation enabling implementation of two different SAR operational modes with different resolutions and swath widths.

The paper is focused on the RF measurements and correlation with the predicted results while the RF design and antenna architecture are briefly introduced in section II. More information and details on the RF design can be found in [3].

II. Reflectarray Design and Optimisation

A. Antenna Requirements and Architecture

The architecture is a dual-offset antenna system as shown in Fig. 1 and consists of nine reflectarray antennas, each with a panel size of ca. 1.5m x 0.55 m. The dual-offset setup employed in this system is advantageous compared to a single-offset setup: reduced losses associated to the shorter length of the waveguides from the panels to the feed; the use of a sub reflector reduces the amount of necessary hardware which is particularly important in terms of the accommodation into the launch vehicle and in folding/unfolding of the instrument and it allows to have a more compact solution.

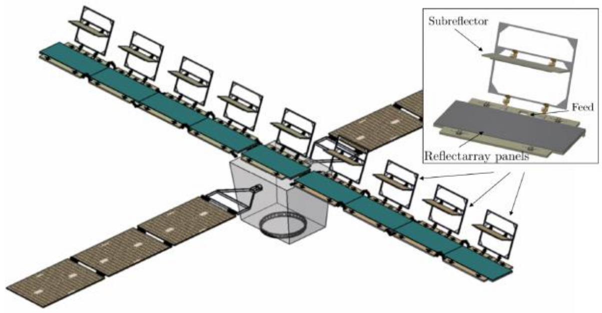

Fig. 1. Antenna system in unfolding configuration.

The reflectarray antenna must operate between 35.5-36.0 GHz in two modes, a high-resolution (HR) mode for one linear polarisation, and a low-resolution (LR) mode in the orthogonal polarisation. The antenna gain must be larger than 46.7 dBi for the HR mode and 45.2 dBi for the LR mode. The Half Power Beamwidth (HPBW) for the azimuth and elevation planes must be 0.33 deg and 1.2 deg respectively for HR mode and 0.33 deg and 2.4 deg for the LR mode. The patterns XPD must be better than 25 dB.

B. Feed and Antenna Panel Optimisation

The rectangular shape of the reflectarray panels needs an elliptical feed pattern and for this reason sectoral horn with the dimensions of 55mm x 14mm and a flare length of 200 mm was designed. The feed can be fed by two orthogonal polarisations through WR-28 rectangular waveguide ports to accommodate the need for two different operational modes. The horn was optimised to provide the best panel illumination and for this scope the software ESTEAM, which is a product in the TICRA Tools software framework [4] was used. The reflectarray panel consists of roughly 82.500 elements printed on a Rogers 6002 substrate with thickness of 0.762 mm. The unit cell is a Jerusalem Cross with an open quadratic loop each confined in a unit cell of

3.15mm x 3.15 mm, see Fig. 2. This element provides a near-linear phase curve with low mutual coupling between two orthogonal linear polarisations which is suitable for dual polarisation applications. Several geometrical parameters of the unit cell have been subject to optimisation using the software tool QUPES, which is a product in the TICRA Tools software framework [4].

Fig. 2. Reflectarray panel and unit cell model used in the optimisation.

III. Measurement and RF Correlation

The test campaign of the antenna breadboard was focused on the measurement of the radiation patterns at the selected frequencies and for the two operative modes. A preliminary measurement session on the feed subassembly was done to validate the feed design [5] before the integration in the antenna system. The manufacturing, assembly and test activities were performed by AIRBUS Defence and Space SAU in its facilities of Madrid, see Fig. 3.

Fig. 3. Reflectarray breadboard in the AIRBUS Madrid anechoic chamber.

The antenna model built by TICRA was updated to take in account the effects on the radiation patterns of the MGSE and manufacturing and assembly tolerances. Fig. 4 shows the induced currents on the MGSE and sub reflector when the feed works in the two modes at the frequency of 35.75 GHz. As expected, the MGSE is more illuminated when the antenna works in the HR mode.

Fig. 5 reports the correlation of the measured patterns (coloured dotted curves) and the predicted patterns (black solid curve) for the HR and LR mode at 35.75 GHz. The plot dynamic is 30 dB. Inspecting the correlation, it can be noticed a good agreement between the predicted and the measured data. In addition, the measured data in the HR mode exhibits some noise contribution, lower than -27 dB, which is under investigation. The good agreement is also for the antenna directivity where the measured values are 46.15 dBi and 47.65 dBi for HR and LR modes and the predicted values are 46.23 dBi and 47.7 dBi for HR and LR case. Please note that the antenna directivity is calculated and measured considering an uv-grid of (±0.183, ±0.183).

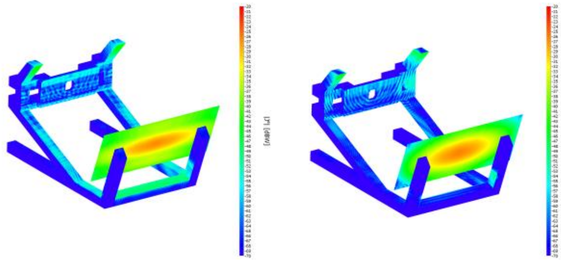

Fig. 4. Induced currents in the MGSE and on the sub reflector: HR mode on the left and LR mode on the right.

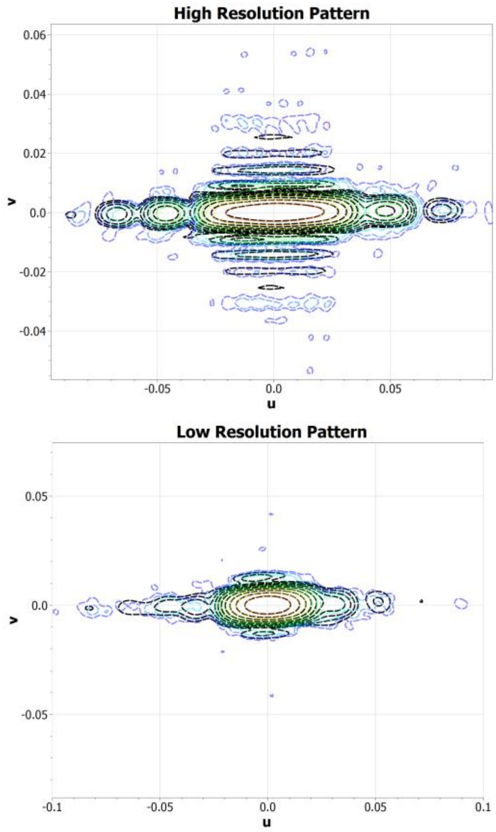

Fig. 5. Correlation of the measured (coloured dotted curves) and predicted (black solid curves) co-polar patterns at 35.75 GHz. The HR mode is on the top and LR is on the bottom.

Acknowledgment

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