ANTENNA CHARACTERIZATION APPROACH FOR HIGH ACCURACY OF ACTIVE PHASED ARRAY ANTENNAS ON SPACEBORNE SAR SYSTEMS

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1. INTRODUCTION

Normally the radar instrument of a spaceborne SAR system hosts an active phased array antenna consisting of a large number of sub radiation elements each controlled by an individual transmit/receiver module. Thus, adaptive beam forming is available allowing a multitude of different operation modes for antenna beam steering and shaping (like StripMap, ScanSAR, Spotlight, etc.).

As the demand on high quality of SAR data products of all these operation modes is of paramount importance, an accurate characterization of the antenna is a major task, i.e. the thousands of different antenna beams being operated have to be determined precisely for compensating the antenna impact on the SAR data. Only then, a spaceborne SAR system based on an active phased array antenna can be successfully commissioned.

On this, a novel antenna characterization approach has been developed and established based on a precise antenna model and the so called PN gating method [1]. By this approach, precise measurements of antenna patterns in orbit down to an accuracy of 0.2dB have been achieved, see fig 1, as well as an antenna pointing knowledge of only a few millidegree, see fig 2. But also the excitation coefficients of each individual transmit/receiver module have been derived in operation/orbit down to an accuracy of 0.2dB in amplitude and 2deg in phase. This information of the coefficients is fed into the antenna model providing precise antenna patterns.

In example of TerraSAR-X [2], a highly flexible X-band SAR system operated in space since June 2007, the paper will describe the approach and results derived from different measurements for characterizing an active phased array antenna in flight.

2. ANTENNA CHARACTERIZATION

The characterization of the antenna is based on a precise antenna model. The verification of this antenna model is performed with a few selected beams really measured in-flight and can be divided into three main tasks:

- measurements across the rainforest to verify the elevation pattern shape,
- ScanSAR measurements over rainforest to verify the calculated vs. simulated peak-to-peak gain offset between different beams and
- measurements using ground receivers to verify azimuth pattern shape.

However, the success of verifying the antenna model precisely is essentially dependent on the knowledge of the beam pointing.

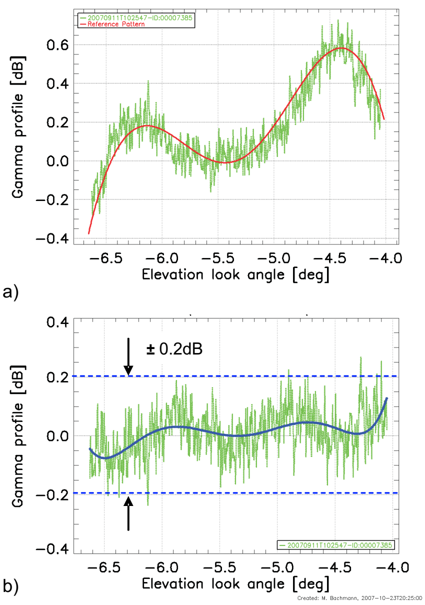

Fig. 1. a) Comparison of the gamma profile (green) derived from a rain forest scene and the reference elevation pattern (red), b) difference between reference pattern and gamma profile, the blue line is a fit of this difference.

2.1. Antenna Model Verification

The verification in flight is performed by a comparison between reference pattern derived from the antenna model with those patterns really measured in flight for both the shape within the main-beam and the gain-offset between different beams.

One example of verifying the shape of the elevation pattern in flight is shown in Fig. 1 performed for TerraSAR-X. The slight noisy green curve in a) is the gamma profile derived by SAR data acquired over Amazon rainforest and the red line is the corresponding reference pattern (red line) derived by the antenna model. The maximum deviation between both is less than $\pm$ 0.2dB.

By these excellent results verifying a precise antenna model the effort for calibrating and consequently commissioning a complex SAR system can be reduced extremely because only a few selected beams have to be really measured in-flight.

2.2. Antenna Pointing

An important task is the determination of beam pointing errors coming from mechanical and electrical antenna miss-pointing as well as attitude control offsets of the satellite.

One example of measuring the beam pointing in elevation is shown in Fig. 2 performed for TerraSAR-X. Applying a so called notch pattern in elevation, by a comparison to the reference pattern derived from the antenna model, the offset of the notch and consequently the actual pointing of the antenna in elevation can be determined, in case of TerraSAR-X down to an accuracy of 0.008 deg, as shown in Fig 2.

The beam pointing in flight direction is likewise determined by notch patterns, but then operated in azimuth direction and measured by deployed ground receivers. By this method, for TerraSAR-X a pointing knowledge better than 0.002deg has been achieved in flight direction.

Hence, even small miss-pointing of the antenna can be detected and consequently compensated for by applying a method based on notch patterns.

3. CONCLUSION

In example of measurements performed in space with TerraSAR-X [2] the suitability of the antenna characterization approach will be described in this paper. This approach contributes not only to the tight performance of SAR systems with high accuracy but also to an efficient way of commissioning such complex SAR systems like TanDEM-X or Sentinel-1.

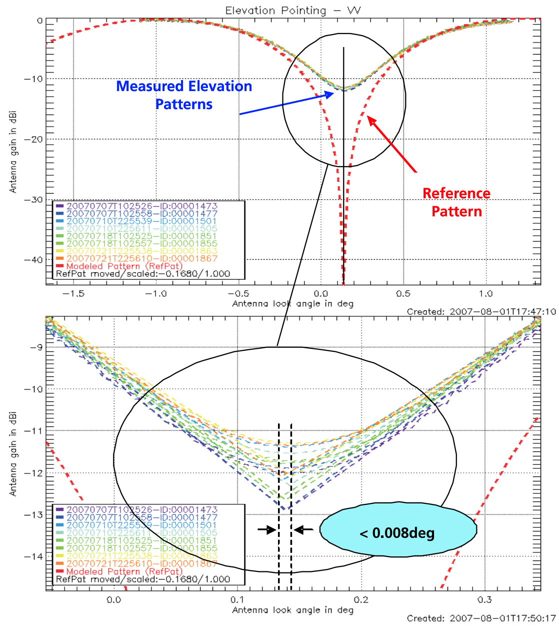

Fig. 2. Beam pointing in elevation of TerraSAR-X determined by measured notch patterns across the rainforest.

4. REFERENCES

[1] Benjamin Bräutigam, Jaime Hueso Gonzalez, Marco Schwerdt, and Markus Bachmann, "Radar Instrument Calibration of TerraSAR-X," in *7th European Conference on Synthetic Aperture Radar*, Friedrichshafen, Germany, 2008.

[2] Stefan Buckreuss, Rolf Werninghaus, and Wolfgang Pitz, "German Satellite Mission TerraSAR-X," in *2008 IEEE Radar Confrerence*, Rome, Italy, 2008.