FIRST MEASUREMENT RESULTS OF A NEW HIGHLY-ACCURATE ACTIVE SAR CALIBRATION TARGET

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ABSTRACT

The requirements on new spaceborne synthetic aperture radar (SAR) missions are always pushed towards better image quality with respect to signal-to-noise ratio, radiometric accuracy, and spatial resolution. An accurate radiometric calibration of the whole SAR system is crucial to cope with the demand on high image quality. Among other factors, the quality of the calibration depends on the utilized reference targets. Also permanent system monitoring, onboard and by reference targets, is required to guaranty the image quality over the whole mission time. In this paper a new highly-accurate active calibration target (transponder) is presented. The device is currently under development in the DLR-project “Kalibri” [1] and features remote control and alignment as well as an improved internal calibration for stable operation. Furthermore, first representative measurement results could be achieved by acquiring TerraSAR X images.

***Index Terms*—** SAR, calibration, active target, transponder

1. INTRODUCTION

The intention of an imaging synthetic aperture radar (SAR) instrument is to record a high resolution backscattering map of the observed scene. The measured digital values representing the terrain backscatter need to be converted to geophysical units, like the backscattering coefficient of a distributed target or the radar cross section (RCS) of a point target. For this purpose systematic error contributions throughout the complete SAR system have to be estimated and compensated for. This so called radiometric calibration process is performed in two stages: relative and absolute radiometric calibration.

Relative radiometric calibration is based on an accurate internal calibration facility, integrated within the radar instrument for monitoring and compensating for drift effects [2], and on a precise antenna model [3] for providing the antenna patterns, which are required to correct the gain drop across the swath during SAR data processing.

In the final step, these relatively calibrated SAR images are converted to backscatter maps. This so called absolute radiometric calibration is based on an accurate reference target with well-known backscattering characteristics. For typical spaceborne SAR missions like TerraSAR X or TanDEM X this calibration procedure is executed during the commissioning phase [4] and possibly during later recalibrations [5].

In order to keep up with the growing demand for high-quality SAR data products, a new active calibration target (transponder) is currently under development at DLR and is well prepared for future spaceborne SAR systems. The focus of the transponder development is set on a very accurate and stable reference RCS. In order to diminish the clutter and sidelobe effects of other targets nearby, a maximum RCS of 60 dBm2 was defined. Additionally, the transponder operates autonomously and allows remote control and alignment on a two-axis positioner for permanent system monitoring during the whole lifetime of the mission. The paper describes the transponder design and first measurement results derived from images acquired by TerraSAR-X.

2. TRANSPONDER REQUIREMENTS AND DESIGN

To fulfill the needs mentioned above, the requirements for an active transponder with a radar cross section of 60 dBm2 at X-band are challenging. The major parameters for the transponder design are a bandwidth of 600 MHz at 9.65 GHz center frequency with a radiometric stability and accuracy better than 0.2 dB (1□). The transponder should also provide the possibility to record UTC-synchronized azimuth patterns for later analysis as well as record coherently sampled pulses. Furthermore, the transponder can be operated in H, V and 45° polarization on receive and on transmit and is consequently well suitable for polarimetric calibration. And finally, for long-term system monitoring purposes a remote controlled operation and alignment is foreseen.

The high bandwidth and the recording requirement result in a FPGA-based digital design. The basic block diagram of the transponder is shown in Fig. 1. The signal is received by a Potter horn antenna [1] and fed to the receiver chain. The signal is filtered and amplified. A variable attenuator adjusts the power to a suitable level for the subsequent units. The signal is down-converted and lowpass filtered before analog-to-digital conversion. The FPGA allows almost any digital signal processing and storage of sampled pulses of the received signal. In the transmit part the signal is coherently up-converted and adjusted to the desired RCS setting by a second variable attenuator before it is amplified by a high power amplifier (HPA) and re-transmitted via a second Potter horn. An internal calibration loop in conjugation with the digital board and the variable attenuators guarantees a very stable RCS of the transponder, having very few passive and temperature stable components outside the calibration loop that are not compensated for [1].

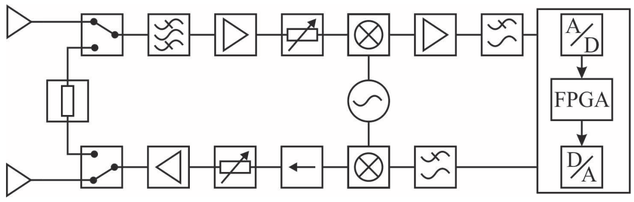

Figure 1 Block diagram of the transponder.

This principle design with two linear polarized rotatable antennas, one for receiving and one for re-transmitting the radar signal allows a very flexible operation of a reference target with adjustable scattering matrix. Consequently this constellation is well suitable for polarimetric calibration. The required stability of the transponder results in design with rotatable antennas located within in a temperature-stabilized housing.

3. FIRST MESASUREMENT RESULTS

As a first milestone to test the transponder parameters and the framework like power supply, the thermal concept, and the positioning under realistic conditions, the transponder was operated within a scene imaged by TerraSAR X. To provide the necessary environment (power supply and LAN access) the transponder was mounted on the roof of the institute's building for this first measurement, as shown in Fig. 2.

The first radar image of the transponder was acquired by TerraSAR-X on December 15, 2011 in an autonomies mode and is shown in Fig. 3. As expected the impulse response (cross) appears very bright and is shifted about 400 m in ground-range direction due to the configured digital delay. A detailed analysis of the radar image with the DLR software CALIX [4] results in a RCS of 57 dBm2. As expected a 3 dB safety margin was adjusted for the first test measurement. Hence, the first experiment demonstrates the functionality of the transponder even for bad weather conditions.

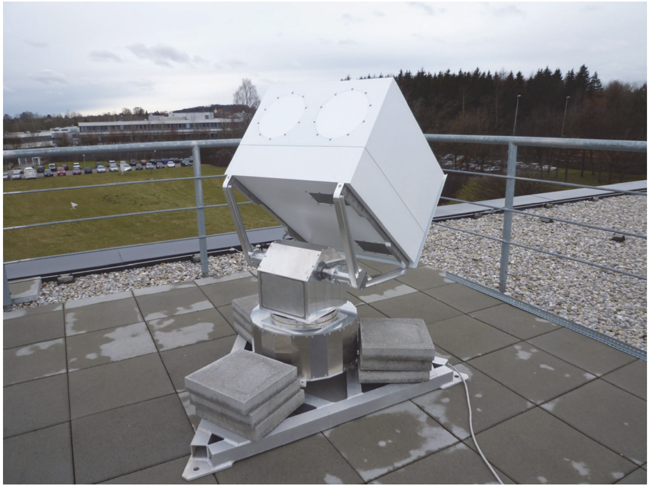

Figure 2 DLR Kalibri transponder and its positioner mounted on the roof of the institute's building for the first measurement acquired by TerraSAR-X.

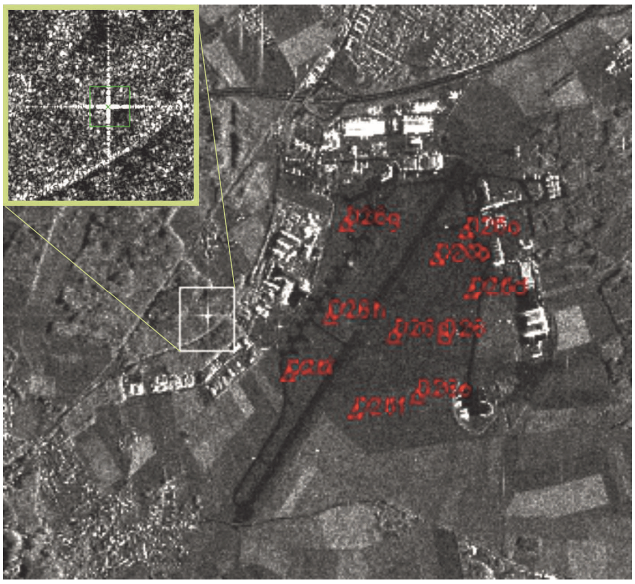

Figure 3 First radar image of the transponder (12-15-2011, Wessling, Germany)

4. CONCLUSION

The development of a highly accurate active calibration target in X-band for calibrating and long-term system monitoring of current and future SAR systems could be successfully demonstrated by a first measurement in a realistic scenario with TerraSAR X. Considering the expected shift due to the internal delay, the analysis of the impulse response shows the expected RCS and the correct position of the transponder within the SAR image.

5. REFERENCES

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