Measurement of a high-gain antenna at 650 GHz in a hologram-based CATR

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Abstract

A hologram-based compact antenna test range (CATR) at 650 GHz was designed, constructed, and used for testing the ADMIRALS RTO antenna of 1.5 m in diameter. The CATR is based on a 3.16-meter computer-generated amplitude hologram. Ordinary floor carpets with good absorbing and scattering properties were used as absorbers in the measurement room.

Introduction

Functional prior-launch end-to-end tests of sub-millimeter wave antennas are vital for reliable satellite missions. However, testing of the electrically large reflector antennas is an extremely challenging task. The required far-field distance becomes easily very large at sub-millimeter wavelenghts. For example, the typical requirement $2D^2/\lambda$ gives about 9.8 km far-field distance for a 1.5 m antenna at 650 GHz. Therefore, far-field measurements are in practice impossible because of the atmospheric effects. Near-field measurements are technically very complicated and expensive requiring a high-accuracy scanner and a very stable RF-measurement system. Conventional compact antenna test range (CATR) measurements, although performed up to 500 GHz [1], are problematic due to high surface accuracy requirement of the reflectors; typical requirement is the surface accuracy better than 0.01λ, corresponding to 4.6 μm at 650 GHz. In the hologram CATR, the needed plane wave is created with the use of a computer-generated binarized amplitude hologram [2]. The hologram pattern can be determined numerically by calculating the structure required to change the known input field (radiation pattern of the feed) into the desired output field (plane wave) [3]. The pattern is realized on a metal layer that is on top of a dielectric substrate. As a transmission type of element, the hologram planarity requirements are less stringent than those of a reflector. Thus, hologram CATR has a great potential in sub-millimeter wave antenna measurements [4,5,6,7].

Design and construction of a hologram-based CATR for 650 GHz

We designed a hologram CATR, Figs. 1 and 2, aiming at 650-GHz tests of the Planck RFQM 1.5-m antenna. However, as the Planck RFQM was not available, we ended up using an alternative test object with the same antenna size, namely the ADMIRALS RTO from EADS Astrium. The hologram was made of three pieces, which were joined by soldering to form the final 3.16 m hologram. A proper illumination of the hologram was facilitated using a dual reflector feed system (DRFS) [8]. For quiet-zone testing, a plane-polar type scanner was designed with a linear stage allowing linear scans of about 2.5 m in four orientations: horizontal, vertical, and two diagonals. The measured peak-to-peak planarity error of the scanner was about 0.3 mm. The scanner planarity was measured using a laser tracker twice during the measurement campaign and the measured quiet-zone phase was corrected accordingly. The antenna positioner was the same that was used during the previous RTO antenna measurements campaign at 322 GHz in 2003 [5,6].

The electrical instrumentation of the hologram CATR at 650 GHz was based on the AB Millimetre MVNA mm-wave network analyzer, and the transmitter and receiver procured from Virginia Diodes Inc. The measured dynamic range was about 27 dB in the quiet-zone field measurements. The measured dynamic range in the RTO antenna tests was about 74 dB with the same integration time as in the quiet-zone tests. A large amount of carpets, ca. 500 square meters, were used as radar absorbing material in the test site to prevent disturbing reflections. The measured reflectivity level was about –50 dB for the selected carpet material, Fig. 3 (please refer to [9,10] for the measurement method).

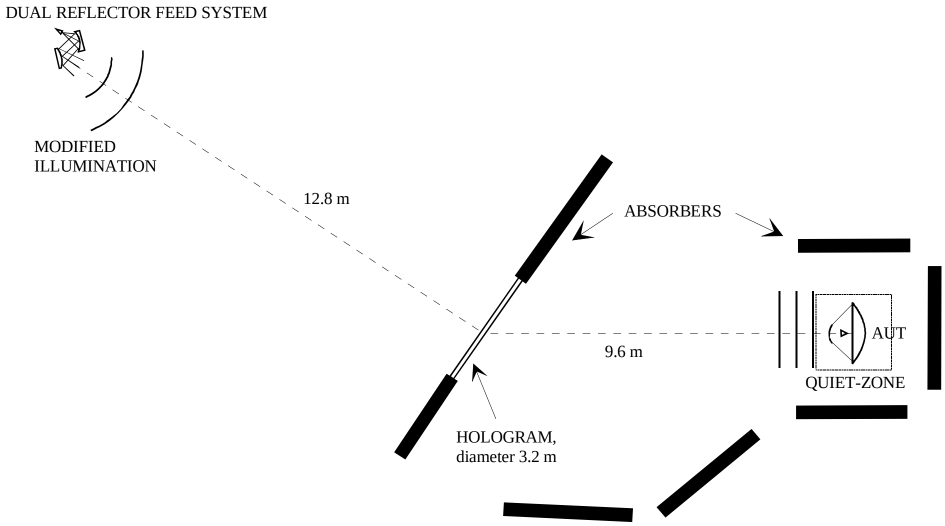

Figure 1 – Layout of the hologram CATR. The dual reflector feed system is enlarged for clarity.

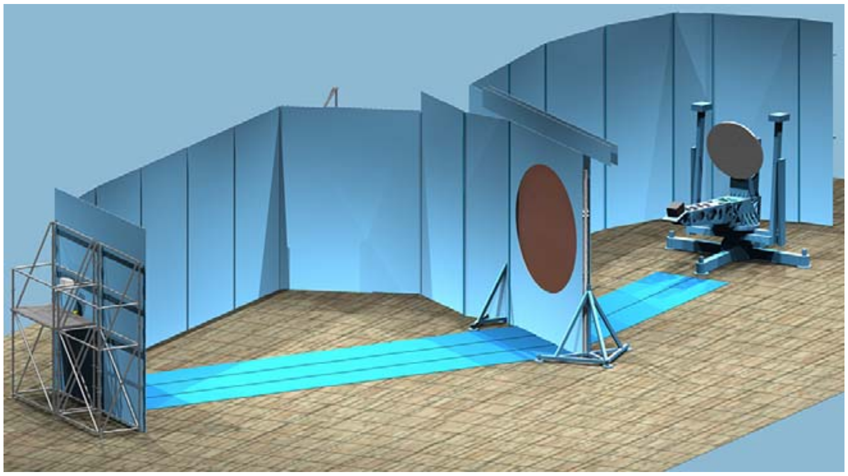

Figure 2 – Artistic view of the 650 GHz hologram-based compact antenna test range.

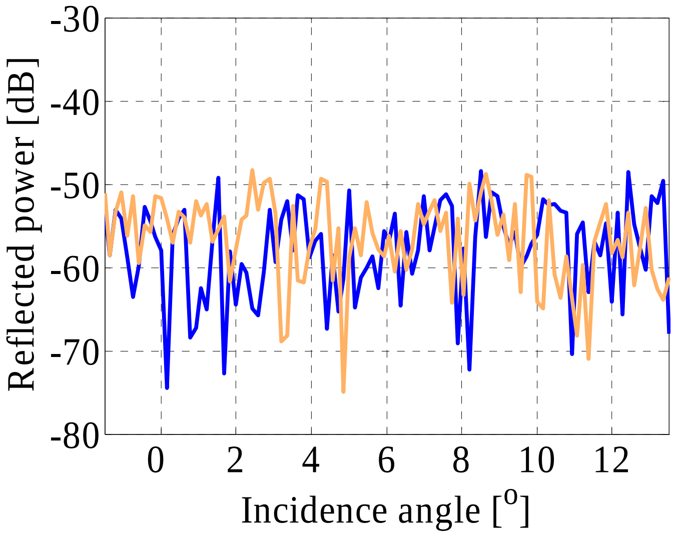

Figure 3 – Measured radar reflectivity of a synthetic carpet at 650 GHz.

Results

The measured peak-to-peak amplitude deviations in the quiet-zone field were about 3 dB at each scanner orientation. The quiet-zone area in the vertical cut corresponding to the upper seam of the hologram had a slightly larger deviation. The typical measured amplitude ripple in the 2-meter diameter quiet-zone was of the order of 1.5–2 dB peak-to-peak. The peak-to-peak phase deviation was about 270 degrees in the whole quiet-zone area. The measured cross-polar level in the quiet-zone was below –20 dB compared to the co-polar level in the quiet-zone area. After evaluation of the quiet-zone field, its quality was concluded to be sufficient for antenna tests.

The ADMIRALS RTO test antenna was tested in the quiet zone described above. The horizontal (*H*-plane) pattern cut was measured in the angular range of –85°…+85° and the vertical (*E*-plane) cut in the range of –12.5°…+12.5°. Some results are shown in Fig. 4. The pattern cuts do not reveal any far-side lobes above the noise floor. The antenna pattern of the ADMIRALS RTO was simulated with GRASP software. The simulation model consisted of a physically measured reflector surface shape and an electrically measured feed pattern. The simulated antenna pattern corresponds well to the measured pattern. The range reflections were studied with the feed scanning APC [11] and spurious side lobes due to reflections were observed at around –6.3°, –3.7°, +3.9°, and +6.6° in the horizontal direction. The effect of the quiet-zone field on the measured antenna pattern was estimated with simulations. It was found that the realized quiet-zone field may cause 2 – 4 dB errors to the measured main beam.

Conclusions

A CATR based on a computer-generated hologram operating at 650 GHz designed, constructed, and used for testing a 1.5 m diameter reflector antenna. Ordinary floor carpets with good absorbing and scattering properties were used as absorbers in the measurement room. The quiet-zone field was measured and optimized – the typical measured amplitude ripple in the 2-meter diameter quiet-zone was of the order of 1.5–2 dB peak-to-peak. Both horizontal (*H*-plane) and vertical (*E*-plane) cuts of the antenna pattern were measured.

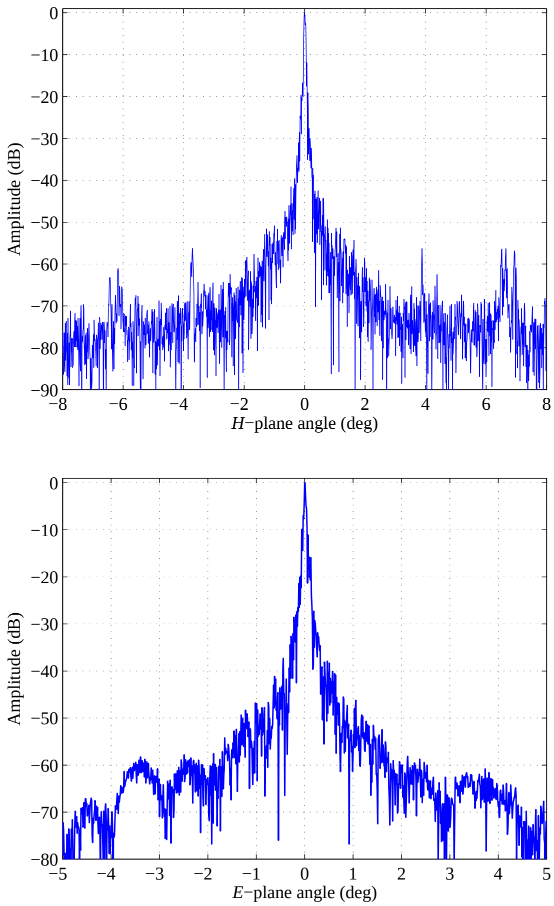

Figure 4 – Measured antenna patterns at 650 GHz: horizontal pattern (upper), vertical pattern (lower).

Acknowledgments

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