Satellite antenna measurement at 322 GHz using a computer-generated hologram as the focusing element

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Summary

Computer-generated holograms [1] can be applied in space terahertz technology; they are particularly suitable as focusing elements in compact test ranges, for example, in testing of high-gain antennas [2,3,4] and measuring radar cross section (RCS) of scaled models [5]. Radio holograms have also been demonstrated in other millimeter- and submillimeter-wave beam-shaping applications, such as the creation of non-diffracting mm-wave Bessel beams, mm-wave vortices, and custom-designed beam patterns [6,7,8].

During summer 2003 we built a temporary measuring facility, Figures 1 and 2, at the High Voltage Institute of the Helsinki University of Technology to test the ADMIRALS antenna, shown in Figure 3, built by EADS Astrium. Astrium manufactured the ADMIRALS representative test object (RTO) for demonstrating the current satellite antenna technology and for comparing the potential antenna testing methods at mm- and sub-mm wavelengths. The diameter of the offset-fed reflector of the ADMIRALS RTO is 1.5 m and the total weight of the RTO is about 400 kg. The feed and related quasioptics are placed 3 m away from the center of the main reflector. Astrium has tested the ADMIRALS RTO in a compact antenna test range (CATR) based on reflectors at the frequencies 203, 322, and 503 GHz [9].

Because the diameter of the quiet-zone of the compact antenna test range (CATR) must be larger than the diameter of the antenna under study, a quiet zone of the required size was produced with a 3-m-size circular amplitude-hologram pattern. The pattern was exposed with a laser on the photosensitive resist on top of the copper layer of the hologram material (17-μm copper on 50-μm Mylar film). Chemical wet etching was used for processing the slots to the copper layer. The hologram was made from three 1m × 3m pieces, which were joined by soldering the metal stripes of the hologram together to form the final 3m × 3m hologram structure.

A dedicated transmit module constructed for the ADMIRALS antenna tests was used as the transmitter both in the quiet-zone probing and in the antenna measurements. In the quiet-zone measurements, the ABmillimètre MVNA-8-350 millimeter-wave network analyzer with its receiver extension ESA-2 was used. This configuration gave a sufficient dynamic range of about 50 dB and also allowed a phase measurement of the quiet-zone field. Phase errors due to the cable flexing during the probe movement were corrected with a phase-correction system based on the use of a pilot signal [10]. In the measurements of the high-gain antenna the dynamic range was about 80 dB when the dedicated receiver module of the ADMIRALS antenna was used.

The measurement results obtained at 322 GHz (Figure 4) are so promising that we are currently proposing a hologram CATR test for the Planck telescope at 500 GHz.

Discussion

Computer-generated holograms (diffractive elements) can be used for shaping mm-wave beams, e.g. for producing a plane wave in a compact space. So far, the most useful application found for the mm- and submm-wave holograms is testing of antennas at these short wavelengths where traditional test methods are useless. A computer-generated amplitude hologram has been successfully used as a focusing element in a compact antenna test range (CATR) in 1998 at 119 GHz for the Odin satellite antenna tests, and more recently at 322 GHz for the ADMIRALS RTO tests.

The need to find a good solution for submm-wave antenna testing is urgent, as the aim of several ongoing space research projects is to launch satellites equipped with scientific or remote sensing instruments to probe space or the atmosphere at sub-mm wavelengths. These satellites will have on board electrically large reflector antennas, which should be tested before the launch.

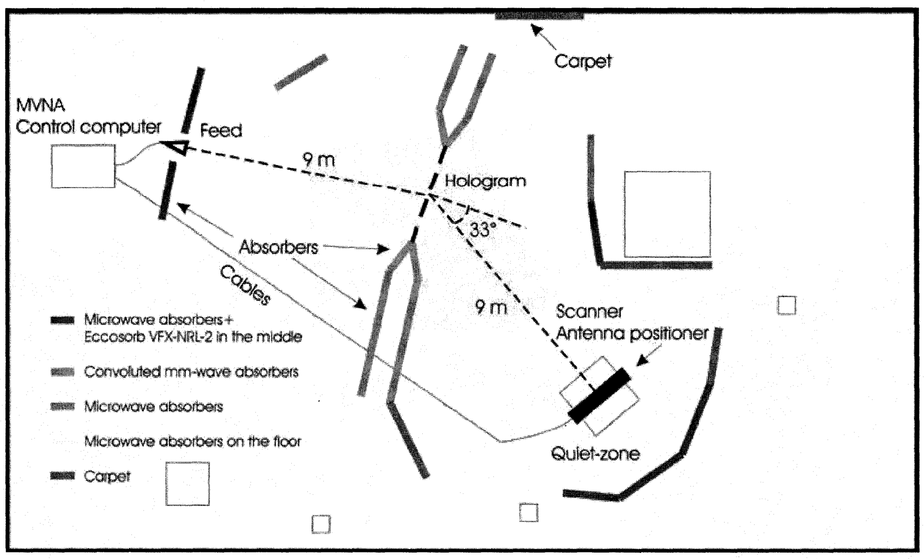


Figure 1 Schematic top view of the hologram CATR set-up for the ADMIRALS RTO tests at 322 GHz.

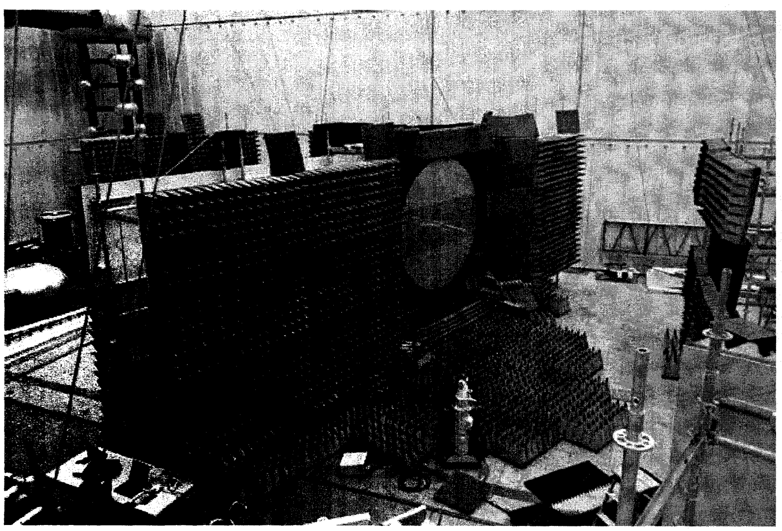


Figure 2 Hologram-based CATR under construction in the high-voltage test hall of HUT.

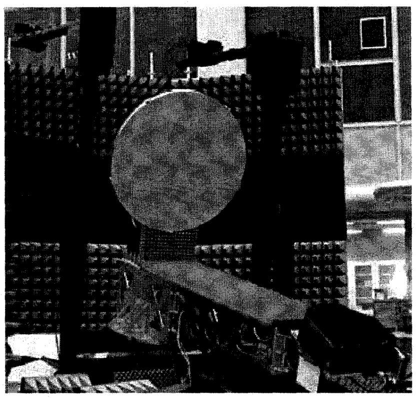
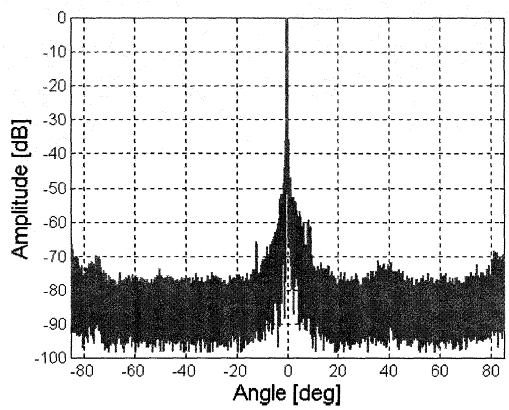


Figure 3 ADMIRALS RTO under test.



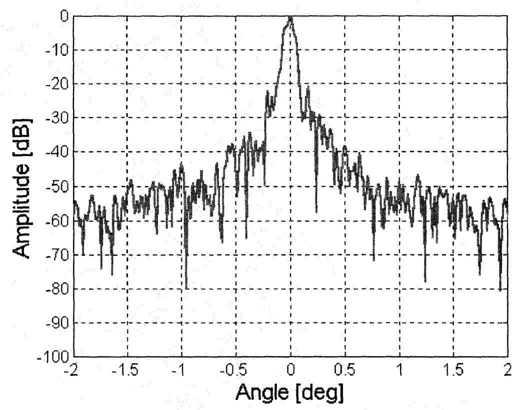


Figure 4 Azimuth pattern of the ADMIRALS RTO at 322 GHz.

Acknowledgements

This work has been partially funded by ESA/ESTEC, the Academy of Finland and Tekes (National Technology Agency of Finland) through the Center-of-Excellence program, and the Graduate School in Electronics, Telecommunication and Automation, GETA. The authors would like to thank CSC – the Finnish IT Center for Science for providing computer resources. The authors would also like to thank Mr. Eino Kahra, Mr. Lauri Laakso, and Mr. Lorenz Schmuckli for valuable help in these studies.

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