MANUFACTURING OF LARGE-SIZED AMPLITUDE HOLOGRAMS FOR A SUBMM-WAVE CATR

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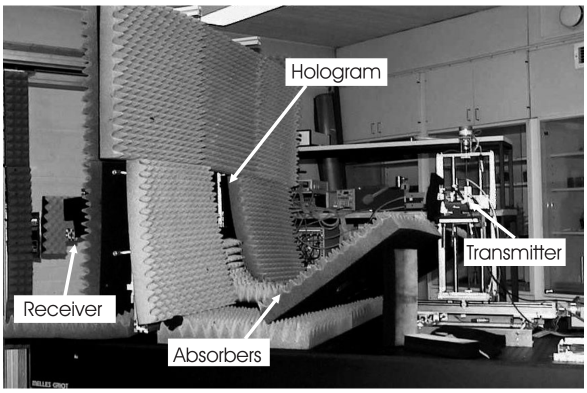
ABSTRACT

An amplitude hologram is a novel alternative as the focusing element in a CATR at submm-wavelengths. The amplitude hologram can be manufactured using printed circuit board technology. However, for tests of high-gain antennas, the required size of the hologram may be several square meters. In this paper, details concerning manufacturing of the holograms and the following tests are discussed. Potential methods for manufacturing and joining of holograms are identified and measured results at 310 GHz are shown.

1 COMPACT ANTENNA TEST RANGE BASED ON A HOLOGRAM

Testing of electrically large antennas operating in the submillimeter wave region is difficult with the traditional antenna testing methods. The compact antenna test range (CATR) based on a hologram is one possible way to solve the problem [1]. A hologram is an interference pattern of two wavefronts. When it is illuminated with a spherical wave, a planar wavefront comes out. In the hologram CATR, a computer-generated binary amplitude hologram is used. An example of a hologram pattern and a photograph of the hologram CATR test setup are presented in Figure 1. The absorbers are surrounding the hologram to prevent reflections and direct radiation from the feed to the quiet-zone (QZ).



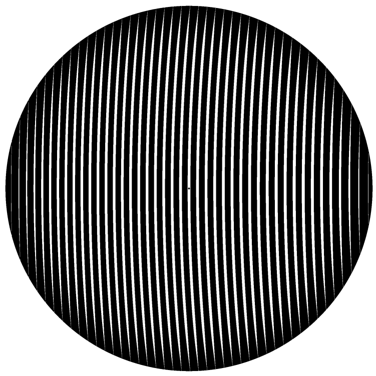


Figure 1. Measurement setup (left) and a binary amplitude hologram (right).

The hologram pattern is generated and optimized with computer simulations. The simulations are done using the finite-difference time-domain (FDTD) and physical optics (PO) methods. Both phase and amplitude can be modified in the iterative optimization process. To avoid disturbances caused by the unwanted wavemodes which propagate straight through the structure, the hologram is designed so that the plane wave propagates in to an angle of 33° relative to the hologram normal. The volume where the amplitude and phase ripples are optimized is called the quiet-zone (QZ). Before starting to use the hologram CATR for measuring antennas, the quality of the QZ has to be verified using a scanning probe antenna. Measurement setups like in Figure 1 have been used for the quality verification and to compare the quiet-zones generated by different holograms.

The largest QZ demonstrated with a hologram CATR so far at 310 GHz is about 0.25 m in diameter [2]. In order to measure antennas for real applications, a QZ of several square metres is needed. Small holograms are relatively easy to manufacture but there does not exist large enough facilities to manufacture large holograms in one piece. A hologram of 3 x 3 m^2 at 322 GHz is planned to be manufactured in three pieces. The designed QZ size is about 1.8 m in diameter. This means that in addition to studying different kinds of manufacturing methods research also has to be done on different ways of joining the hologram pieces.

2 MANUFACTURING

Hologram is manufactured by patterning a metallized mylar (polyester) film. Manufacturing can be done using a conventional printed circuit board (PCB) process. Wet etching with laser exposure, laser etching and laser-assisted chemical liquid phase deposition (LCLD) have been studied as possible alternative methods for the hologram manufacturing. In these tests a 75 µm thick Mylar film was used. In the first two methods there was 17 µm copper coating glued on the Mylar.

In laser etching, the pattern is done by evaporating the metal from the slots using a laser beam. Adjusting the process parameters proved to be difficult and manufacturing takes a lot of time. In LCLD, the film is metallized selectively [3]. It has been noticed that by using LCLD, sharper patterns can be fabricated than by using the PCB process, but the metallization is too thin for the desired hologram operation. In Figure 2 the comparison of simulations (FDTD+PO) and measurement results of the QZ of the PCB and LCLD processed holograms at 310 GHz is presented. The hologram diameter is 20 cm. LCLD has a better phase pattern but the amplitude pattern is not good enough mostly due to the field penetrating through the thin layer of copper.

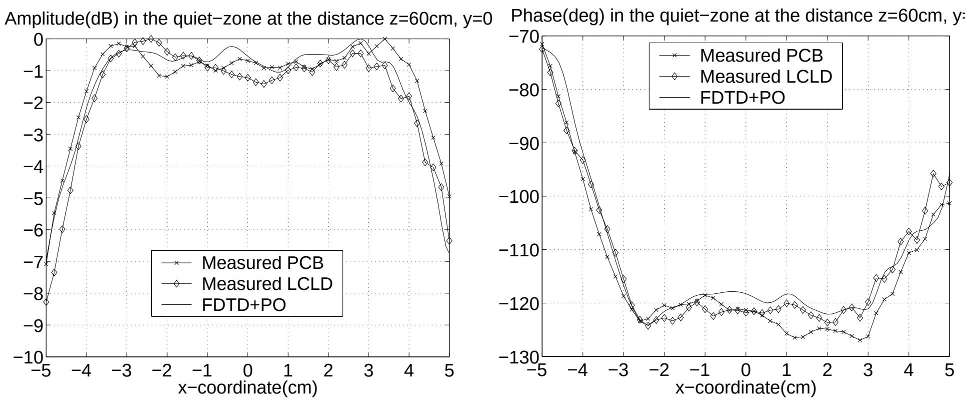


Figure 2. Horizontal cut of the QZ, 60 cm away from the hologram at 310 GHz.

Wet etching with direct laser exposure is a potentially better method than the standard PCB process, since the selective exposure is done by using a laser and no masks are needed. Tests with laser exposure are still going on. It has been noticed that the material issues are very important for accurate etching results. So far Mylar laminated with copper has been used but since it is quite hard material tests with Mylar with electroplated copper have been started. The new material is also thinner but as before, it has a layer of glue between the dielectric film and the copper. Glue causes uncertainty to the thickness and the relative permittivity of the effective substrate. This complicates the hologram design. Therefore, materials without glue are also studied. However, using laser exposure 1.35 x 3 m^2 hologram pieces can be manufactured and the facilities are already available.

3 JOINING

In the previous tests it was found out that a horizontal joint (perpendicular to the electric field) causes less disturbance to the QZ than a vertical joint [4], so only horizontal joints are studied here. At lower frequencies tape splicing was used for joining the pieces and successful measurements were made for the Odin telescope at 119 GHz [5]. Now other methods like glueing and soldering were also studied. The joining tests were done with 30 cm holograms.

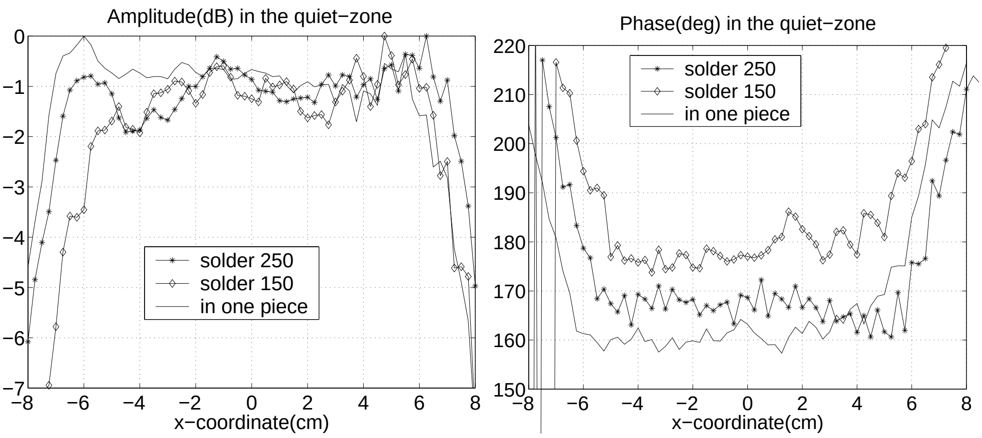


Figure 3. QZ results with and without a soldered joint. Melting points in the legend.

Soldering was studied as one possibility for joining. The measurement results of the QZ at 310 GHz are presented in Figure 3. Two soldering pastes with different melting points were used. The melting point of basic soldering wire is so high that the polyester film starts to melt. The test showed that this is not the main cause of disturbances in QZ. The QZ of a whole hologram was measured with and without the solder and there was no considerable difference between the measurement results. This would suggest that with solder joints the main problem is the misalignment of the hologram pieces.

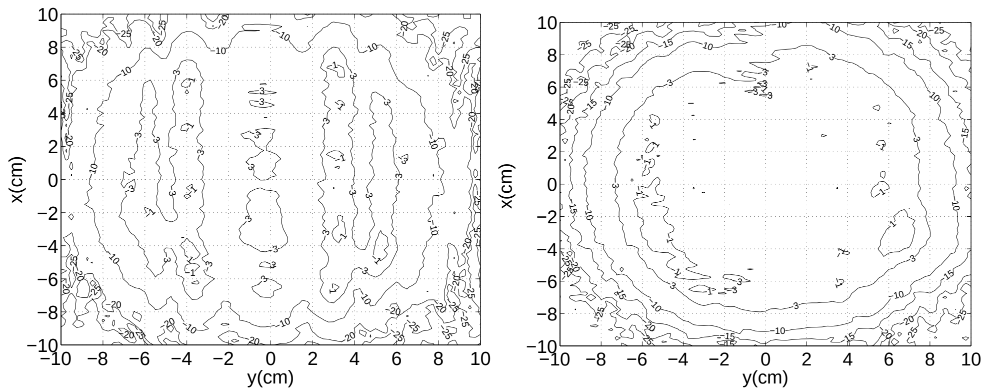


Figure 4. QZ amplitude contour (dB) plots of measured results: Overlapping glue seam (left) and solder joint after the second test (right).

The joining test was repeated with more careful alignment of the pieces. The hologram pieces were first carefully taped together and then the seam was soldered using regular solder paste. The soldering was done on a specially made vacuum table, which takes away some of the heat and also keeps the hologram pieces in place. The measurement results are shown in Figure 4 (right). The requirements for the QZ amplitude and phase ripples (1 dB and 10°) are met in the expected area.

Joining by glueing and tape splicing was also studied. A seam using glue can be done either as a push edge seam or as an overlapping seam. Multilayer structures can cause disturbances to the QZ field both locally and in the whole QZ. The misalignment causes problems in the whole QZ. In the tests it was found out that seams done either by taping or glueing cause a lot of disturbance all over the QZ. The measurement results are presented in Figure 4 (left). The location of the seam and a clear interference pattern due to the diffraction from the seam can be observed in the QZ field. Using a thinner glue layer helps but after a certain point the seam does not hold the tension anymore.

Based on a series of experiments, it seems that soldering is the most promising method to be used in joining the 3 x 3 m^2 hologram. Soldering is a technique, which requires lots of laborious work and certainly is not the easiest method to use but the results are much better than with the other techniques investigated. Accurate alignment of the pieces is an important issue regardless of the technique used for joining. The measurements at 322 GHz using the large hologram will be carried out during the fall 2002.

4 CONCLUSIONS

Manufacturing possibilities of holograms and joining of hologram pieces have been studied. After analysing the results of the tests, a decision about the manufacturing and joining methods will be made. Currently, based on the tests and measurements at 310 GHz, it seems that the manufacturing will be done by using wet etching with direct laser exposure and the pieces will be joined together by soldering.

ACKNOWLEDGEMENTS

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