Development of W-band horn antennas using 3D printing technologies

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Abstract—We report on the performance of a W-band multi-flare angle horn antenna manufactured with 3-D printing technology. The paper highlights the fabrication challenges for high frequency operations including the surface roughness of the 3-D technology and the metallization of the polymer.

Keywords—3D printing technology, multi-flare angle horn, corrugated horn, W-band.

I. INTRODUCTION

3-D printing is an emerging technology enabling the fabrication of complex three dimensional objects directly from a computer-aided design (CAD) digital model [1]. The additive process used in 3-D printing technology differs from traditional computer numerical control (CNC) metal machining where the metal is removed from bulk material. Recently, progress in 3-D printing, has enabled application of this technique to Ku-band (12-15 GHz) horn antenna [2] using electron beam melting (EBM). In this paper we report on a W-band horn antenna fabricated using the same technology.

II. MULTI-FLARE ANGLE HORN ANTENNA

A. Design and simulation

The design and dimensions of the horn shown in Fig. 1 was first optimized using a mode matching [3] method then simulated using the 3D EM solver CST. Fig. 2 shows the simulated beam pattern at 99 GHz. The maximum simulated gain is 22.4 dBi and 3 dB beam width is 12.1°. A metal conductivity of $10^4$ S/m was used in the simulated model.

B. Measurements

It was found after fabrication that the metallization was not uniform along the inside sidewall of the horn. The plating process is challenging due to the required high aspect ratio. This significantly affects the performance of the horn. The measurements of the reflection coefficient and the gain of the antenna are carried out using a network analyzer HP8510C with WR-10 extenders. Fig. 3 presents the measured reflection coefficients as a function of frequency and is compared to the simulation results achieved using CST. The discrepancies between the measurement and the simulated data are due to the non-uniformity metallization issue of the 3D printing polymer and fabrication tolerances. For instance, the output diameter measured is 21.69 mm and originally designed to be 21.73 mm. In addition, the input diameter was designed to be 2.84 mm but...
after fabrication it is found to be 2.82 mm. After carefully inspecting the horn under a microscope, we observed that some small areas are not metallized. The metal conductivity ($\sigma=10^4$ S/m) is adjusted in the simulation to match the measured gain leading to an antenna efficiency of 71%. The frequency dependence of the measured and simulated gain of the antenna is shown in Fig. 4. The beam pattern is measured using a W-band harmonic mixer connected to a 24 dB standard gain antenna. The antenna to be measured is connected to a 99 GHz synthesizer. A chopper and lock-in amplifier are used between the two horns to maximize signal-to-noise ratio and obtain accurate data. The standard gain antenna is mounted on a moving platform to measure the elevation and azimuthal pattern over a 40 degrees angle aperture. The normalized gain measured and simulated beam pattern function of the azimuthal and elevation angles are shown in Fig. 5. The pattern angle is limited to the sensitivity of the harmonic mixer as presented in Fig. 5. Due to the lack of sensitivity above 0 degree angle the measured normalized gain becomes flat. In addition, it should be noted that the measured beamwidth following the elevation angle is wider than predicted due to multiple reflection from the measurement test bench table.

CONCLUSION

Although the 3D printing multi-flare angle horn antenna measured performances are lower than the horn traditionally manufactured in a metal block [4], it is encouraging. The progress in 3D printing technology and the tremendous amount of research on this topic should allow in the near future to obtain 3D printing components competing with the performance of machined metal horns. The additive technology compared to CNC machining will allow manufacturing even more complicated microwave parts that are not feasible in micro-machining. It should also reduce the manufacturing cost.

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REFERENCES