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Towards E-band Wavelength: 3D Printed Gaussian Corrugated Horn for Cassegrain Antenna Application

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Abstract—Two Gaussian profile conical horn antennas for use within the E-band spectrum are presented. The proposed conical horn antenna is designed in three segments: Mode converter, phasing and profiled sections. These two horns with Cos^n -like radiation patterns as Cassegrain antenna illuminators are analyzed to have high efficiency over the E-band (60-100GHz). Simulations show reasonable results, therefore allowing for reliable predictability. A couple of printing technologies and metal materials to realize proposed designs are analyzed with material characterizations throughout simulations, namely selective laser melting (SLM) using Cu–15Sn material and binder sintering on 316L stainless with 2.79 μm , 12.79 μm surface roughness, respectively. The slot-to-ridge width ratio for both designs is fixed to 4:1 ratio, with a pitch of $\lambda/4$ at 100 GHz. The provided horn antennas' impedance bandwidth ($|S_{11}| < -24$ dB) covers the whole intended operational band for both E- and D spectrum. The realized in-band gain for the E-band antennas is higher than 22.14 and 22, respectively.

I. INTRODUCTION

In the past decades, the fast development of additive manufacturing technologies has provided ease and low-cost fabrication results for high-performance horns [1-7], lens [3-4], [7-9], and detailed profile antennas in commercial applications. Between all candidates, horn antennas with very low sidelobe levels, high polarization purity, low return loss, and Cos^n -like radiation patterns have been found as suitable candidates to fulfill compact feed requirements [7]. Because of the low cross-polarization in both E- and H-planes and low sidelobe levels, Gaussian profile horn antennas, have emerged as the best choice for feeding lens and reflector antennas.

This work describes two prototype gaussian profile corrugated conical horn antennas with gaussian radiation patterns at the frequency bands from 55 GHz to 110GHz. Both of the designed prototypes are similar, with the difference in neck size in long and short types (with a 2 mm difference). The simulation results have been achieved that 30dB return loss, -40 SLL, and -50 X-polarization at the center frequency of bandwidth. Two different metal printing technologies, namely selective laser melting (SLM) on Cu–15Sn conductive material and binder sintering on 316L stainless, are investigated to examine their potential for provided horn structures. The subject of this work is the realization of corrugated horns with a maximum of 52 grooves.

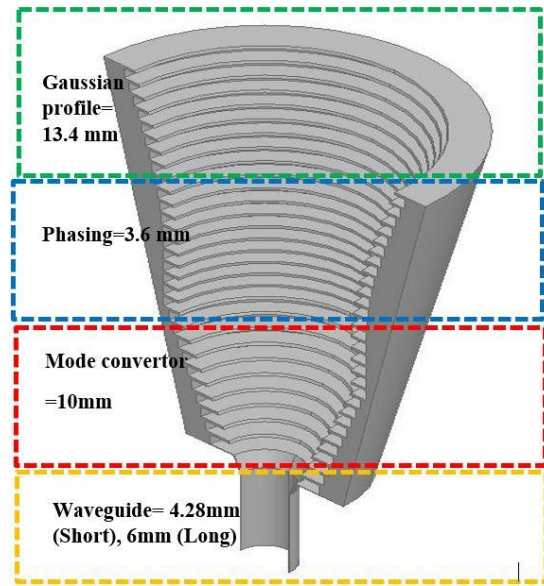


Fig. 1. A cut-away view of the proposed Gaussian profile corrugated horn.

In order to realize the additive manufacturing materials, the material conductivity, surface roughness is determined through simulations.

II. HORN DESIGN AND SIMULATION

The geometry of the proposed corrugated gaussian profile horn antenna has been illustrated in Fig. 1. As it is indicated in the figure, the proposed horn consists of a mode converter, phasing section, and gaussian profile. The Gaussian profile is embedded for aperture with 31 grooves to have high freedom control for our output considering multiple parameters such as SLL, impedance bandwidth, beam diffraction, directivity, and gain. It has 52 grooves entirety, with twenty grooves for two other sections. Two principal features have been incorporated in the phasing section design: first grooves slot depths $\sim 0.5\lambda$ at maximum frequency and last slot depths 0.25λ at the lowest frequency to have a stable phase converter section.

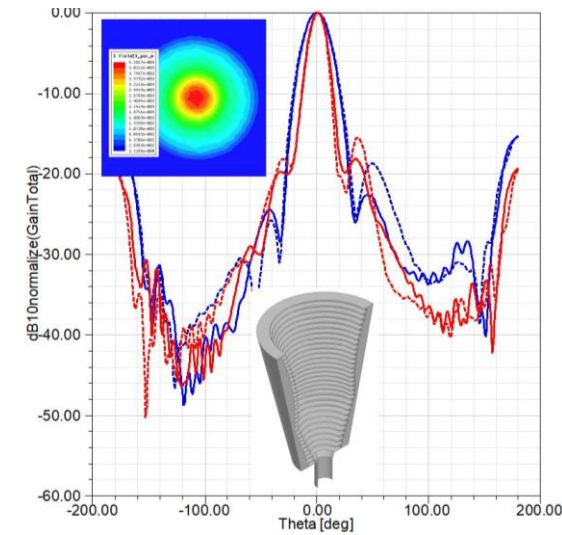


Fig. 2. Simulated radiation patterns in $\phi = 90^\circ$ (solid-line), and $\phi = 0^\circ$ (dash-line) for horn at 66 GHz (red), 80 GHz (blue), Transversal $|E|$ -field $\phi = 0^\circ$ outputs for horn aperture surface at 80 GHz for short waveguide Gaussian profile corrugated horn (top corner).

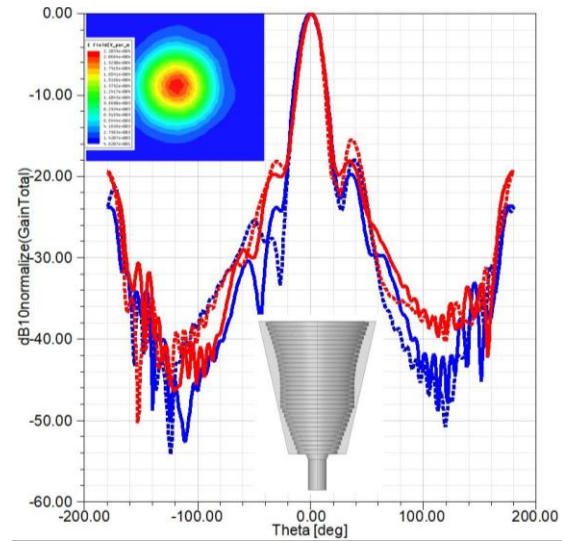


Fig. 3. Simulated radiation patterns in $\phi = 90^\circ$ (solid-line), and $\phi = 0^\circ$ (dash-line) for FZP2 at 66 GHz (red), 80 GHz (blue), and Transversal $|E|$ -field $\phi = 0^\circ$ outputs for longhorn aperture surface at 80 GHz for long waveguide Gaussian profile corrugated horn (top corner).

As we know, both TM_{11} and TE_{11} , when passing the different depth slots due to discontinuity and eventually arrive into horn aperture with different phase planes [1], [5]. Therefore, designing a high stability phase section can produce equal phase velocities, so total mode fields will quickly decrease to zero in the horn aperture edge [5]. So, the combination of these modes will form the hybrid HE_{11} mode [1]. The phasing section of the gaussian-profiles corrugated conical horn contains ten grooves

with a depth of 1 mm. The mode converter section consists of ten grooves with a depth of 1.71 mm and a width of 0.7 mm. The simulation results show that increasing the flare length (mode converter + phasing) can increase the antenna's gain with the expense of moderate beamwidth. The total length of the design horn antenna is 32mm, and its aperture area is 520 mm². The simulated radiation patterns in $\phi = 90^\circ$ (solid line), and $\phi = 0^\circ$ (dash-line) for short and long Gaussian horns at 66 GHz (red) and 80 GHz (blue) are shown in Figs. 2, and 3, respectively. The simulated S_{11} is better than -25 dB in E-band. Simulated Transversal $|E|$ -field $\phi = 0^\circ$ outputs for horn aperture surface at 80 GHz for both corrugated horns plotted on the top corner of Figs. 2 and 3.

III. CONCLUSION

The simulation studies have confirmed Gaussian profile corrugated horn design with perfect and axial symmetrical gaussian radiation patterns in both E- and H-planes. We choose variable pitch to width slot dimensions to produce the balance hybrid mode radiation in horn aperture. A phasing section is embedded within the gaussian profile section and mode converter section to make a stable phase in the proposed horn apertures, as shown in Fig.1. The radiation pattern for both long and short waveguide feed conical horns confirms the gaussian design. The proposed Gaussian-profiled horn can work from 60 to 110 GHz with low SLL and cross-polarization isolation as low as 58 dB. Interestingly, the phase of the main lobe for the gaussian profiled on the center frequency produced translation upward. Hence, it is a desirable candidate for the E-band reflector antennas.

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