A 3D-Printed Compact Dual-Circularly Polarized Corrugated Horn with Integrated Septum Polarizer

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Abstract **– This paper presents a Compact Dual-Circularly Polarized Corrugated Horn with Integrated Septum Polarizer in the X-band. Usually such a complicated structure would be fabricated in parts and assembled together. However, exploiting the versatility afforded by Metal 3D-printing, a complete prototype is fabricated as a single part, enabling a compact design. Any variation due to mating tolerance of separate parts is eliminated. The prototype is designed to work from 9.5GHz to 10GHz. It has an impedance match of better than |S11|<-15dB and a gain about 13.4dBic at 9.75GHz. The efficiency is better than 95% in the operating band.**

Index Terms **— Metal 3D Printing, Dual-Circular Polarization, Corrugated Horn, Septum Polarizer.**

1. Introduction

Corrugated Horns are usually used feeds to high performance parabolic reflected. They are preferred due their low cross polarization performance and the fact that both gain patterns in the E- and H-plane can be equalized. The working principles, design procedures and other qualities of the corrugated horn are detailed in [1]. Usually, corrugated horns are made via multi-axis CNC machines or via electro-forming [2] which made them costly, restricting their use to the mostly performance critical system. Coupled with the fact that a separate feed or waveguide adaptors are require to make this antenna complete, the use of corrugated horn antennas are not very widespread.

One can easily imagine the complexity in fabrication if Dual Circular Polarization (Dual-CP) is required. To achieve dual-CP, a Septum Polarizer first introduced in [3] is used to feed a Corrugated Horn. A single piece Septum Polarizer not easily fabricated and there are reports that they are fabricated via casting [4]. So to obtain a complete antenna, the Septum Polarizer and the Corrugated Horn are fabricated separately and assembled together; and the inevitable gaps due to fabrication tolerance and assembly process may degrade performance, especially at higher frequencies.

In this paper, a Compact Dual-CP Corrugated Horn Antenna in the X-band that comprise of a Septum Polarizer and a Corrugated Horn presented. The objective is not the maximize the performance but to demonstrate that an integrated Septum-Corrugated Horn previously not amenable to conventional fabrication process can now be designed and fabricated as a single entity. To obtain a compact design, some of the corrugations are folded, increasing the mechanical complexity. As such, the only way to fabricate such a structure is via Metal 3D Printing.

2. Corrugated Horn and Septum Design

The complete design is shown in Figure 1. The dimensions of the corrugation horns are obtained and optimized via an in-house developed mode-matching code. The final modifications like folding of the corrugations, design and integration with the septum and 2×SMA connector feeds are designed with Ansys HFSS. One port gives LHCP and the other RHCP. Note that the folded corrugation allows the prototype to be made as "slim" as possible while choke rings are also included to reduce backlobes. The overall length is 225mm with a diameter of 92mm at its largest span. The prototype, printed via Direct Laser Metal Sintering (DMLS) using Al_2Si_{10} powder is shown in Fig. 2. The weight of the prototype is about 370g including the SMA connectors.

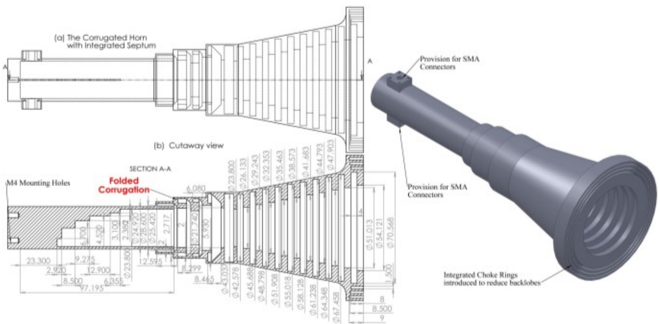


Fig. 1. Design of Corrugated Horn with Septum Polarizer.

Fig. 2. 3D Printed Prototype.

3. Results

As mentioned, the prototype is optimized to work best from 9.5GHz to 10GHz but design performed better than expected. It has an impedance match of |S11| <10dB from 9GHz – 11GHz. Fig. 3 shows the comparison between the simulated and measured impedance match and the isolation between the 2 ports. Note there is an anomaly measured at 10.75GHz which is also predicted by simulation although there is slight frequency shift.

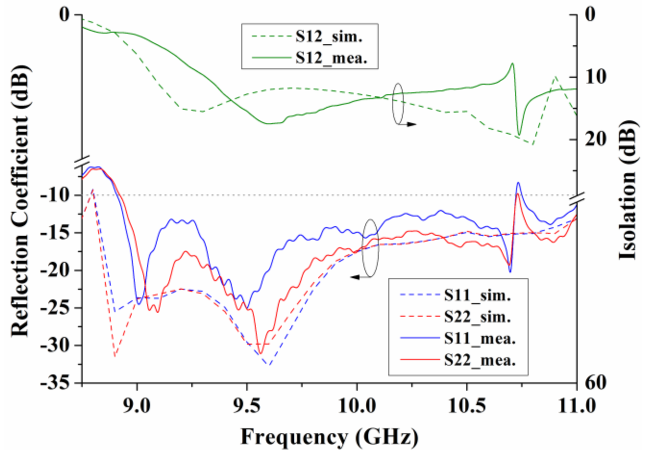


Fig. 3. Comparison of measured and simulated S-parameters.

Fig. 4 and 5 compares the measured and simulated RHCP and LHCP patterns at 9GHz, 10GHz and 11GHz. The pattern at 10GHz is representative of the performance in the operating band of 9.5GHz – 10GHz, with good cross-polarization performance. Although the antenna is working at 9GHz and 11GHz, the cross-polarization performance is somewhat degraded.

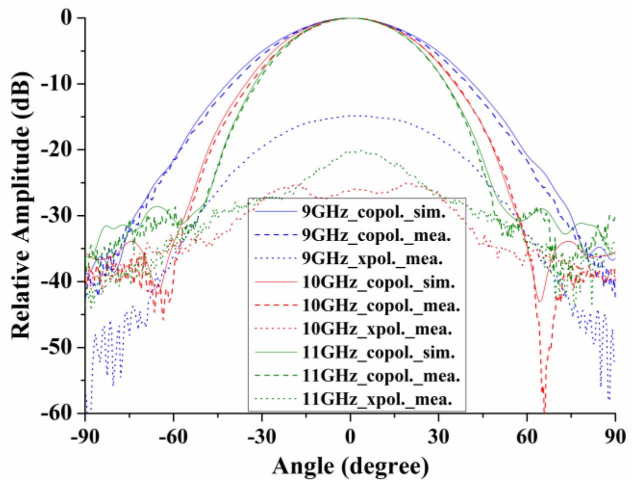


Fig. 4. Comparison of Measured and Simulated Pattern at Port 1; Co-pol is RHCP, X-pol is LHCP.

Fig. 6 plots the simulated and measured Axial Ratio (AR) and the Swept Gain from 9GHz – 11GHz. The measured AR is < 2dB at the optimized frequencies (9.5GHz – 10GHz) although the simulated results are better. In this band, the measured gain tracks simulated results closely and the efficiency is better than 95%. At frequencies outside the optimized band, there are dips and spikes in gain and efficiency which needs to be investigated in future work.

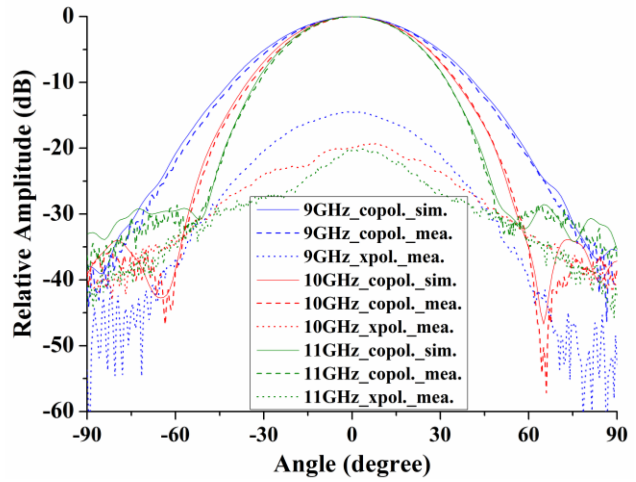
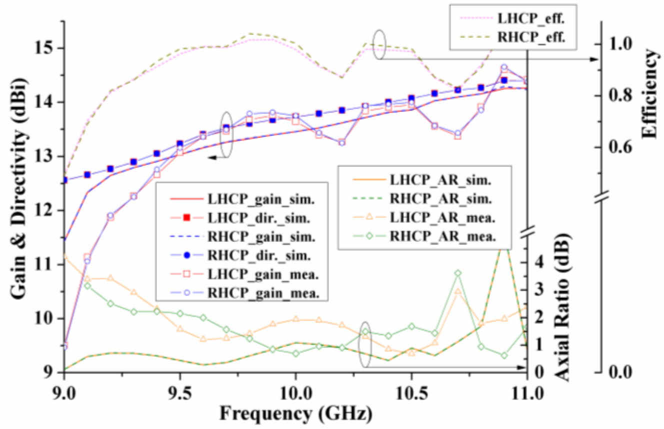


Fig. 5. Comparison of Measured and Simulated Pattern at Port 2; Co-pol is LHCP, X-pol is RHCP.



4. Discussion and Conclusion

In this paper, a Compact Dual-Circularly Polarized Corrugated Horn with Integrated Septum Polarizer in the X-band is designed especially to be fabricated as a single part with Metal 3-D printing. The first article prototype showed that the antenna performed remarkably well and agrees well with simulated results. It is demonstrate the versatility of 3D printing to antenna design. Through deliberate design, those that are previously not tractable can now be easily fabricated.

References

[1] C.Granet and G.L.James, "Design of Corrugated Horns: A Primer," *IEEE Antennas and Progation Magazine*, Vol. 47, No. 2, pp. 76-84, April 2005.

[2] J.Teniete-Vallinas, "Modern Corrugated Horn Antennas". PhD Thesis, Department of Electrical and Electronic Engineering, Universidad Pública de Navarra, July 2003.

[3] M.H.Chen and G.N. Tsandoulas, "A wideband square waveguide array polarizer", *IEEE Trans. Antennas Progat.,* Vol-21, pp. 389-391, May 1973

[4] J. Bornemann and S. Amari, "Septum polarizer design for antenna feeds produced by casting," *Antennas and Propagation Society International Symposium, 1997. IEEE., 1997 Digest*, Montreal, Quebec, Canada, 1997, pp. 1422-1425 vol.2.