Additively Manufactured Profiled Conical Horn Antenna with Dielectric Loading

Shiyu Zhang, Darren Cadman, Will Whittow and J(Yiannis) Vardaxoglou
Wolfson School of Mechanical, Electrical and Manufacturing Engineering, Loughborough University,
Loughborough, Leicestershire, United Kingdom, LE11 3TU
s.zhang@lboro.ac.uk

***Abstract*—A dielectric loaded profiled conical horn antenna is shown in this paper. With the smooth profiled flare and two loaded dielectric core materials, this horn offers wideband gain and low side-lobe level. Additive manufacturing and metal plating have been used to address the fabrication challenges. The cost of the manufacturing has been significantly reduced.**

Keywords—additive manufacturing; 3D-print; artificial dielectric; smooth profiled horn antenna; dielectric loading

I. INTRODUCTION

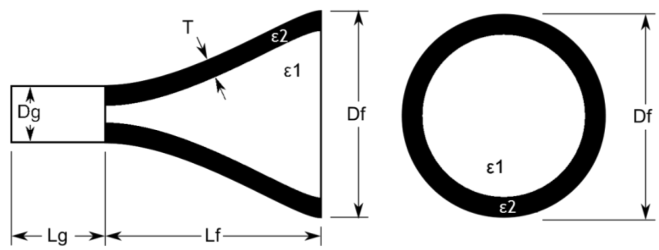
Additive manufacturing (AM) technology constructs successive layers of materials to create three-dimensional (3D) objects. It has garnered immense attention from many applications including biology, aerospace, electronics, and electromagnetics [1]–[4]. AM allows arbitrary geometries and internal structures that are difficult to realize using traditional machining techniques. Composite structures with the desired set of properties over a wide range of frequencies can be constructed [5], [6]. These structures could be viewed as artificial dielectrics and provide a means of altering the electromagnetic (EM) properties that offers extra freedom in choosing of materials for radio frequency (RF) designs.

This paper presents an additively manufactured and metal plated conical horn antenna. The conical horn has smooth sinusoidal profile with two dielectric materials loaded in the core to realize low side-lobes and low cross-polarization over the frequency range [7], [8]. The two dielectric cores are concentric with the outermost metal shell and both of them have the same profiles. It is challenging to fabricate this horn with a heterogeneous dielectric by using the traditional manufacturing techniques, particularly for the outer dielectric shell due to the thin thickness. Furthermore, the required dielectric materials may not be available off-the-shelf. With the advent of AM, and assisted by metal plating, this profile horn antenna can be rapidly but inexpensively prototyped in-house. This turns the design from a concept to a finished product in days instead of many months.

II. PROFILED HORN DESIGN

The sketch of the dielectric loaded profiled horn is shown in Fig.1. The sinusoidal profiles with $p = 2$ and $A = 0.8$ can be described as Equation (1):

$$a(z) = \frac{D_g}{2} + \left(\frac{D_f}{2} - \frac{D_g}{2}\right)\left[(1-A)\frac{z}{L_f} + A\sin^p\left(\frac{\pi z}{4L_f}\right)\right] \quad (1)$$



a b

Fig.1. Sketches of proposed smooth profiled conical horn antenna, (a) side view, (b) front view.

TABLE 1. DESIGN PARAMETERS OF THE PROFILED HORN ANTENNA

Name	Description	Value
Dg	Waveguide diameter	20.27 mm
Lg	Waveguide length	29.98 mm
Df	Flare diameter	87.61 mm
Lf	Length of the flare	138.30 mm
T	Thickness of the outer dielectric layer	4.00 mm
ε1	Relative permittivity of the core material	1.60
ε2	Relative permittivity of the outer dielectric layer	1.06

The design parameters are shown in Table 1. The outer dielectric is covered with a metal shell layer and the horn is fed by a circular waveguide.

Simulation results by using CST indicate that this profiled horn antenna offers 17.0 to 20.1 dBi gain over the frequency range from 9 to 15 GHz - shown in Fig.2. Fig.3 shows the radiation patterns of the horn. It can be seen that the profiled horn produced symmetrical patterns around the boresight axis and low side-lobe level (less than -33 dB) were obtained.

III. MANUFACTURING AND MEASUREMENT RESULTS

The entire horn has been additively manufactured in a single-process by using the same material (polylactic acid) which had dielectric constant of 2.78. The desired dielectric constants for the dielectric cores were realized by creating non-solid internal structures with air inclusions [5]. After the

This work is supported by UK's EPSRC Grand challenge SYMETA (www.symeta.co.uk).

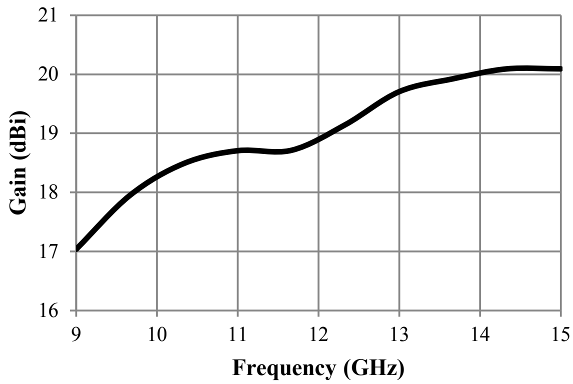


Fig.2. Simulated gain of the profiled horn antenna

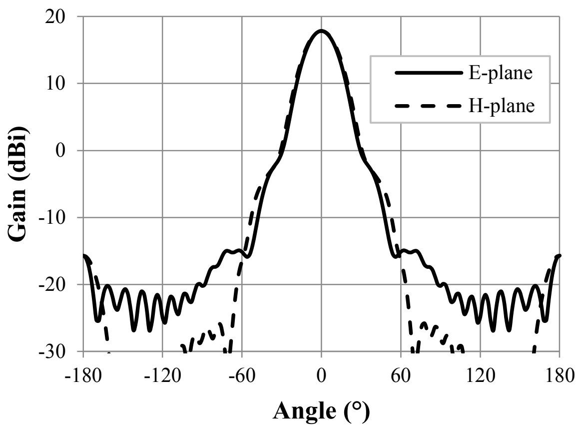


Fig.3. Simulated gain patterns of the profiled horn antenna at 10 GHz

two dielectric cores were created, the outer surface was metal-plated by using conductive spray. A circular X-band waveguide flange was also fabricated and metalized to connect this horn to a standard circular waveguide feed. The fabricated horn with the flange is shown in Fig.4. The measured radiation patterns are shown in Fig.5.

IV. Conclusions

This paper has presented the design and fabrication of a smooth profiled conical horn antenna loaded with two dielectric materials by using advanced AM technique. The two different dielectric loaded materials have been additively manufactured with the desired sinusoidal profiles in a single process. The dielectric loaded profiled horn antenna offers wideband gain and small side-lobe values. Manufacturing details, in-depth analysis of the horn antenna performance will be presented at the conference.

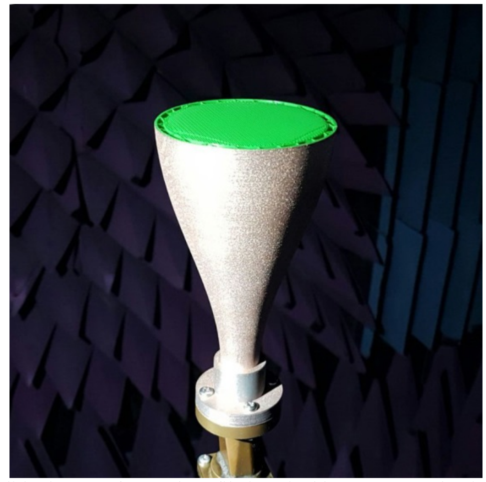


Fig.4. Additively manufactured profiled conical horn antenna that is fed by a circular X-band waveguide

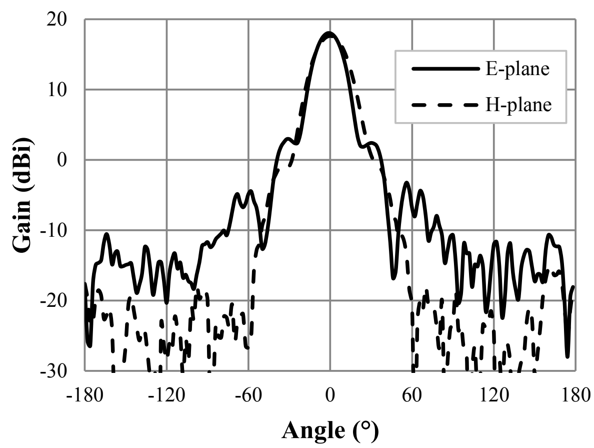


Fig.5. Measured radiation patterns of the additively manufactured profiled horn antenna at 10 GHz

References

[1] A. Bisognin, D. Titz, F. Ferrero, R. Pilard, C. A. Fernandes, J. R. Costa, C. Corre, P. Calascibetta, J. Riviere, A. Poulain, C. Badard, F. Gianesello, C. Luxey, P. Busson, D. Gloria, and D. Belot, “3D printed plastic 60 GHz lens: Enabling innovative millimeter wave antenna solution and system,” in 2014 IEEE MTT-S International Microwave Symposium (IMS), 2014, pp. 1–4.

[2] C. Garcia and J. Correa, “3D printing of anisotropic metamaterials,” in Progress In Electromagnetics Research Letters, 2012, vol. 34, no. July, pp. 75–82.

[3] G. P. Le Sage, “3D Printed Waveguide Slot Array Antennas,” IEEE Access, vol. 4, pp. 1258–1265, 2016.

[4] G. Du, M. Liang, R. A. Sabory-Garcia, C. Liu, and H. Xin, “3D Printing Implementation of an X-band Eaton Lens for Beam Deflection,” IEEE Antennas and Wireless Propagation Letters, vol. 1225, pp. 1–1, 2016.

[5] S. Zhang, C. C. Njoku, W. G. Whittow, and J. C. Vardaxoglou, “Novel 3D printed synthetic dielectric substrates,” Microwave and Optical Technology Letters, vol. 57, no. 10, pp. 2344–2346, Oct. 2015.

[6] B. Biemacki, S. Zhang, and W. Whittow, “3D printed substrates with graded dielectric properties and their application to patch antennas,” in 2016 Loughborough Antennas & Propagation Conference (LAPC), 2016, pp. 1–5.

[7] B. Philips and A. D. Olver, “Design and performance of profiled dielectric loaded horns,” IEE Proceedings - Microwaves, Antennas and Propagation, vol. 141, no. 5, p. 337, 1994.

[8] C. Granet, R. Bolton, and G. Moorey, “A smooth-walled spline-profile horn as an alternative to the corrugated horn for wide band millimeter-wave applications,” IEEE Transactions on Antennas and Propagation, vol. 52, no. 3, pp. 848–854, 2004.