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3D-printed Dielectric Wideband Transmitarray in Ku-band

A. Massaccesi*, P. Pirinoli*, S. Zhang †, J. C. Vardaxoglou †

**Department of Electronics and Telecommunications, Politecnico di Torino, Turin, Italy,*
{andrea.massaccesi, paola.pirinoli}@polito.it
†Wolfson School of Mechanical, Electrical and Manufacturing Engineering, Loughborough University, Loughborough, UK,
{S.Zhang, J.C.Vardaxoglou}@lboro.ac.uk

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Abstract

In this paper, we propose a novel three-layer perforated dielectric unit-cell for Transmitarray antennas. Starting from a configuration with a central square hole, two additional layers with linear tapered sections have been added on top and bottom of the element. The resulting unit-cell is made-up by the same dielectric, that, in the case considered here, it is a 3D-printable material with a dielectric constant of 4.4. A 30x30 elements dielectric Transmitarray, using the proposed unit-cell and working in Ku-band, has been designed and numerically analyzed using a commercial tool. The structure has been manufactured using an FDM (Fused Deposition Modeling) technique and its performances have been experimentally characterized in the anechoic chamber. The experimental results shown notable performances: the measured 1-dB Gain bandwidth is equal to the 29.5% parallel to an aperture efficiency greater than 40%.

1 Introduction

In the recent years, the interest in Transmitarray (TA) antennas has grown rapidly, since they represent a good solution in satellite or radar applications for obtaining high gain, high efficiency and beam steering antennas [1]. Transmitarrays are multi-layer array of cells illuminated by one or several feed sources. Exploiting the concept of lenses and planar arrays, they are able to produce a desired radiation pattern just varying one or more parameter of each unit-cell. However, transmitarrays have typically a limited bandwidth, due to the frequency-selective behavior of each single cell [2], [3]. Among the different possible technological solution adopted for the realization of a Transmitarray, a particularly convenient could be adopting a single or multiple layers of perforated dielectric material [4, 5], instead of a stack of metallic elements printed on several dielectric substrate layers [3]. The resulting antenna structure is characterized by ease of manufacturing using 3D Additive Manufacturing (AM) techniques.

The idea behind the realization of a perforated dielectric TA is that of locally control the phase of the transmission coefficient properly changing the hole size in the dielectric. Through this operation, it is possible to modify the effective dielectric constant of the substrate, maintaining the S_{21} amplitude as close as possible to 1. Different solutions have been presented in literature, aimed to improve the performances of the transmitting layer, playing with the shape and the number of holes in each unit-cell and/or the number of dielectric layers.

2 Unit-cell design

The proposed unit-cell is composed by three layers of the same dielectric material. The central layer has a uniform square hole, while the two external elements are matching layers characterized by linearly tapered holes, as described in [6]. The transmission coefficient phase can be controlled changing the hole size *d*. The unit-cell has been designed to work in Ku band. The used material is PREPERM® TP20280, that is a commercial 3D-printable dielectric (ε_r = 4.4, tan = 0.004). The three-layer structure is shown in Fig. 1.

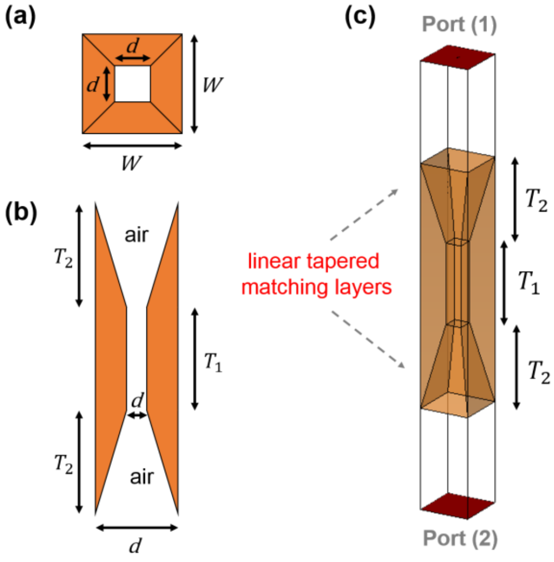

Figure 1: Proposed dielectric perforated unit-cell: (a) 3D view. (b) Top view. (c) Side view.

The total thickness is $T = T_1 + 2T_2 = 1.8\lambda_0 = 36$ mm, while the UC lattice is $W = 0.3\ \lambda_0 = 6$ mm. The hole size d is varied from 0.1 to 5.9 mm to obtain a full phase range of 360°. Moreover, the tapered matching layers guarantee a value of the transmission coefficient module never lower than -0.5 dB in the whole parameter variation range (d).

3 Wideband Dielectric Transmitarray

A reduced size dielectric Transmitarray, working in Ku-band, has been designed using the proposed unit-cell. The structure is center-fed with F/D = 0.91, being F the distance between the feed and the transmitarray having size D. It consists in a square array of 30x30 elements with D = 9λ = 180 mm. The feed is a pyramidal horn providing a gain of 13.3 dB at 15 GHz, while its pattern can be modelled as $cos^q(\theta)$, with q = 5.9. The TA performances have been analyzed using CST Microwave Studio. In order to validate experimentally the effectiveness of the introduced tapered matching layers, a 3D-printed TA prototype has been realized through an FDM-based technique. The manufactured transmitarray has been printed in 5 parts, subsequently connected together with a specific glue. The 3D-printed model is shown in Fig. 2.

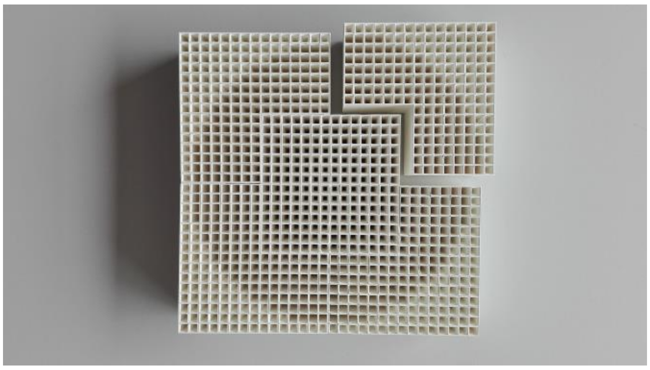

Figure 2: 3D-Printed prototype of the dielectric transmitarray using FDM technique.

The simulated and measured radiation pattern in E-plane is shown in Fig. 3. The simulated and measured HPBW is 6.4°, while the measured Side-Lobe-Level (SLL) is -17.5 dB. The gain achieved at 15 GHz is 26.16 dB, corresponding to an aperture efficiency of 40.6%. The antenna provides a measured 1-dB Gain bandwidth of 29.5 %.

4 Conclusion

In this work, a novel perforated dielectric unit-cell has been exploited to design and fabricate a 30x30 Transmitarray. The fabrication has been performed through an Additive Manufacturing process based on FDM technique. The experimental results confirm the improvements in terms of bandwidth, achieving a measured 1-dB Gain bandwidth of 29.5% and demonstrate the potentiality of the proposed solution.

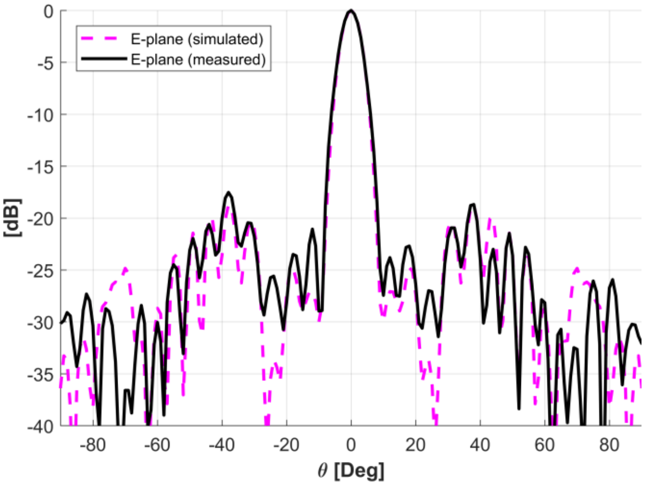

Figure 3: Measured and simulated E-plane radiation pattern at 15 GHz of the 3D-printed Transmitarray antenna.

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