3D-printable Perforated Dielectric Reflectarray in Ka-band

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***Abstract*—In this paper, some preliminary results on a 3D-printable dielectric Reflectarray antenna are presented. The unit-cell consists of a single-layer dielectric element perforated with a square hole, whose side is used to control the phase response. It has been adopted to design a 32×32 offset Reflectarray working in Ka-band. The antenna shown a maximum gain of 24.8 dB at 30 GHz and good radiation performances. Moreover, the Reflectarray can be easily printed using Additive Manufacturing techniques.**

I. Introduction

In long distance communication systems, a fundamental antenna requirement is represented by the high gain. Among the wide selection of available antennas with this feature, Reflectarray (RA) antenna has emerged in the last years as one of the most successful solution. Thanks to its favorable features that combines the advantages of printed arrays and reflector antennas, it allows to obtain an high gain antenna with low profile and low cost characteristics [1]. A reflectarray is a quasi-periodic array surface of reflecting elements illuminated by one or several feed sources. The working principle is based on the control of the geometrical parameters of each single cell to obtain a desired radiation pattern. Reflectarrays can be realized in different ways to achieve multiband and broadband performances, to control the polarization or to improve the scanning capabilities. [1]. The most common RA structure consists in single or mutiple metallic elements printed on different dielectric layers [2], or on a single substrate [3]. Another attractive possibility is the implementation of a folded reflectarray, a particular solution that allows to reduce the cross-polarization and the aperture blockage, obtaining a low profile structure as in [4], but usually very complex to design and fabricate. A reflectarray can be also designed on a convex surface, as implemented in [5], where metallic patches were printed on a substrate bent to a cylinder with a given radius of curvature. As an alternative to printed elements, the unit-cell can be also realized using a completly dielectric structure, where the reflection coefficient is typically controlled drilling holes with different size on the dielectric substrate [6]. More recently, novel dielectric Reflectarrays have been realized using Additive Manufacturing (AM) processes [7],[8].

In this paper, the design of a Reflectarray working in Ka-band and based on a perforated dielectric unit-cell is proposed. Firstly the unit-cell is briefly described, then some results on the analysis of its dependence from the incident angles are discussed. Therefore the simulated radiation performances of a small-size RA are presented.

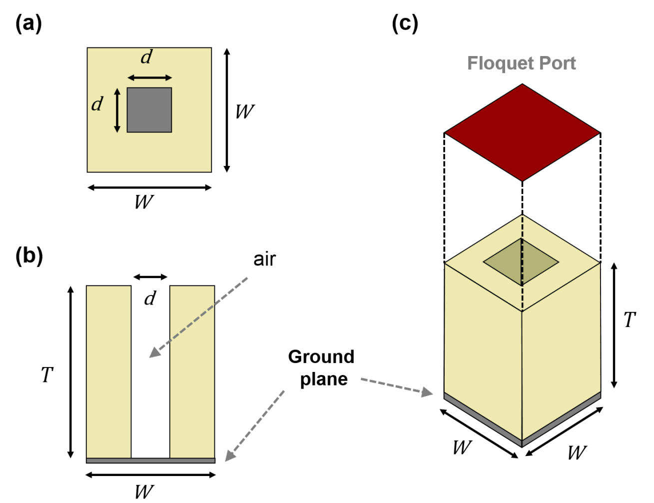

Fig. 1: RA dielectric unit-cell: (a) Top view; (b) Side view; (c) Simulated unit-cell in CST MW Studio.

II. Unit-cell Analysis

The Unit-Cell (UC) is a single-layer dielectric element presenting a square hole, as illustrated in Fig. 1. This UC structure was firstly proposed in [9] for the design of a dielectric Trasnmitarray antenna in Ku-band. The concept behind its working principle is here exploited for the design of a RA antenna. The phase of the reflection coefficient can be controlled through the hole size d, which dertimines the effective dielectric constant of the element. Such a kind of unit-cell could be easily realized with and Additive Manufacturing technique, provided that a proper dielectric material is used as the 3D-printable resin VeroWhite Plus (RGD835 from Stratasys®) has been adopted here ($\varepsilon_r = 2.77$, tan$\delta = 0.021$).

The RA unit-cell is designed to work in Ka-band at the central frequency $f_0 = 30$ GHz. The geomeotrical features have been optimazed to obtain a full phase coverage and taking into account the limitations introduced by the 3D-printing techniques, such as the 3D-printer resolution [10]. These constraints lead to define a structure with a periodicity of $W = 0.3\lambda_0 = 3$ mm and thickness of $T = 1.1\lambda_0 = 11$ mm; the variation of d is restricted in the range 0.5÷2.65 mm, but it is sufficient to have a full phase range of 360°.

The unit-cell reflection coefficient has been computed using CST MW Studio. Fig. 2 shows both the variation of the re-

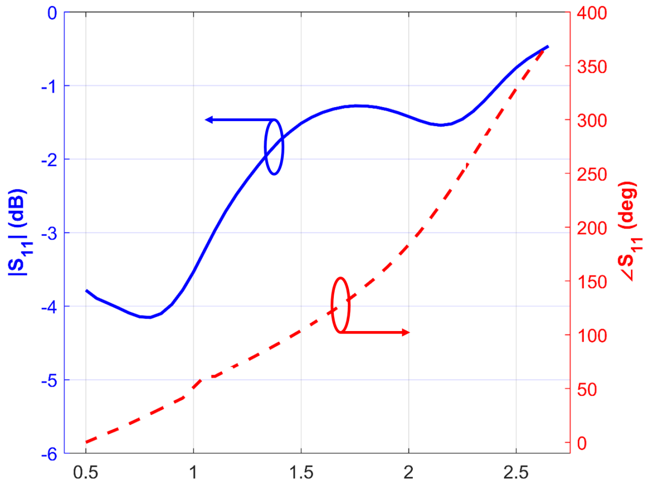

Fig. 2: Variation of the simulated reflection coefficient S_{11} (amplitude and phase) with d computed at 30 GHz.

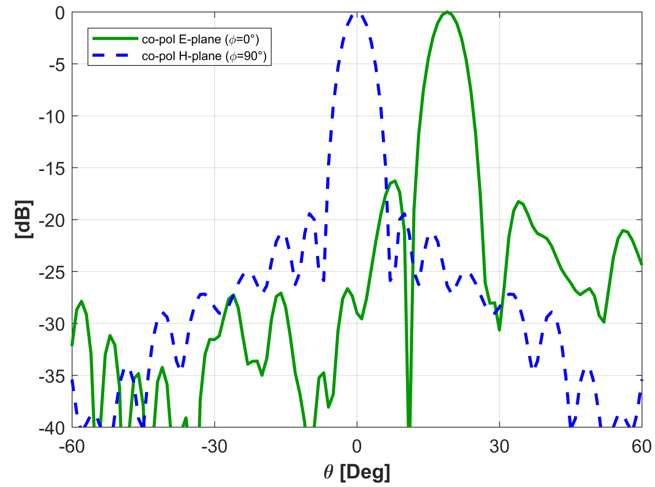

Fig. 3: Comparison of the simulated radiation patterns in E-plane and H-plane at 30 GHz.

flection coefficient amplitude ($|S_{11}|$) and phase ($\angle S_{11}$) with d, evaluated at 30 GHz and considering a normal incidence. The value of $|S_{11}|$ remains high for larger holes and has a reduction when d decreases; this is due to the not negligible losses of the dielectric material. The phase curves provide a full phase coverage for all the considered angles of incidence, and they do not present discontinuities or significant distortions.

III. Reflectarray Design

Using the unit-cell prensented in the previous section, a square 32×32 offset Reflectarray having a size $D = 9.6\lambda_0 =$ 96 mm has been designed. The offset feed is a linearly polarized pyramidal horn designed in Ka-band and located at 86 mm ($F/D = 0.9$) from the RA surface with an offset angle of 20° for blockage minimization. The feed presents a gain of 14.4 dB at 30 GHz and half-power beamwidths (HPBW) in E-plane and H-plane of 32.3° and 33.2°, respectively. The complete structure has been simulated with CST MW Studio.

The computed gain at 30 GHz resulting from the simulations is 24.8 dB, corresposnding to an aperture efficiency of 26.3%. The obtained 1-dB Gain bandwidth is 13.2%. The simulated radiation patterns in E-plane and H-plane are shown in Fig. 3. The HPBW in E-plane is 6.5°, while in H-plane is about 6.1°. The Side-Lobe-Level (SLL) is -16.3 dB and -19.4 dB, for E-plane and H-plane, respectively.

IV. Conclusion

In this work, a dielectric perforated unit-cell has been exploited to design a small-size Reflectarray. Some preliminary results on the unit-cell analysis and the RA perfomances have been presented. Further details and the experimental validation of a 3D-printed prototype will be shown at the Conference.

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