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Alumide as a Nonmagnetic Fresnel Zone Lens at 30 GHz

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Abstract

A nonmagnetic Fresnel Zone Plate Lens (FZPL) antenna with high dielectric plastic porosity controlling is proposed in this paper. Compared to conventional Fresnel plates, the proposed structure has a single homogeneous platform for transmitting mode role, making the gradient refractive index lens antenna a perfect candidate for high gain applications. A non-magnetic plastic has achieved the intended GRIN subzones homogeneously. Each desired permittivity for half-wave plate subzones is estimated with a capacitive estimation on Brakora analysis. Half-wave zone type of FZP is selected to utilize based on optic rules to realize this estimation. A Cos^{41}-like conical horn is used as a central beam-launcher to excite the lens diaphragms and was implemented and measured at 30 GHz. The measured scattering parameters for ZP shows a better than -15 dB return loss and validate our modeling with 5 mm thickness and $3\lambda_0$ lateral dimension.

1 Introduction

Porosity techniques based on additive manufacturing technologies primarily facilitate the design of beam-directional gradient refractive index (GRIN) Maxwell, Fish-eye, Lunenburg, and Fresnel zone plates in more specifically, have aroused many researchers' interest because of their compactness and integrability with a single host medium, which has broad application in communication systems [1]-[11].

Designing homogeneous GRIN mediums based on the host medium's porosity control approach is one of the best solutions for such demands [1], [4]-[7]. However, conventional Fresnel zone plates are limited by the material conditions, where the ZP has identical properties for transmission and reflection states (e.g., high back lobe level, gain, efficiency, input matching, and manufacturing complexity, etc.). Homogeneous platforms, on the other side, have gained a surge for the past couple of years with additive manufacturing technologies developments due to their unique capability for wave engineering, Lens and optical devices, and controlling electromagnetic wave propagation in a particular direction or shape, and as a result, numerous works of literature paid attention to controlling permittivity virtually.

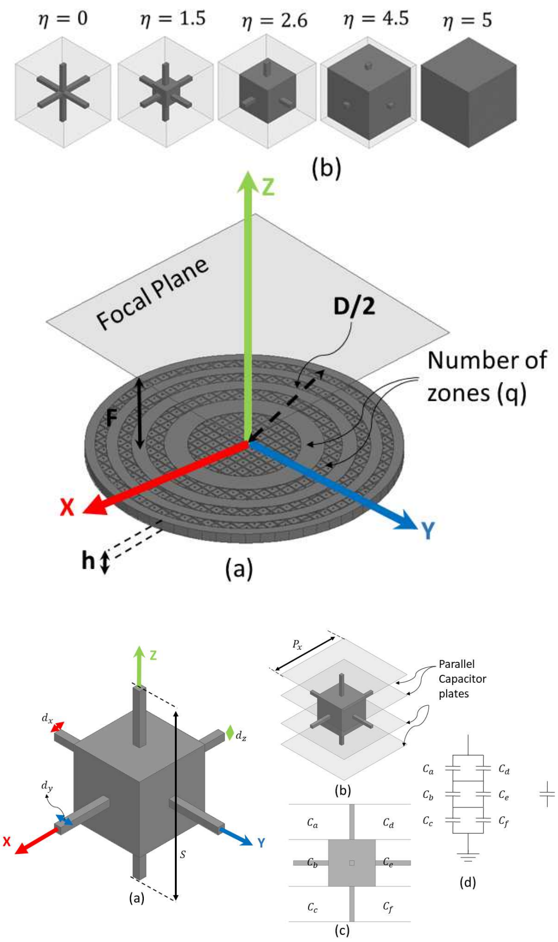

Figure 1. (a) The geometrical principle of the Fresnel zone plate, (b) Brakora static modeling for the proposed porous cell.

A cylindrical air-hole porosity control is reported in [2], which is a perpendicular radiation permittivity control structure. Some porosity control methods based on desired GRIN medium implementations can be found in [1],[6]. Free forming media [1], [6] and full metal [1] structures are other reported GRIN structures.

The cube-shaped or free forming method has several advantages over other porosity control methods to provide virtual permittivity because it needs less manufacturing complexity, ease of composition, and high efficiency [1].

In this paper, to design high efficiency and axially symmetric radiation for lens aperture, a homogeneous ZP with cube-shaped porosity technique in hard and high permittivity host medium using low refractive indices porous cells is investigated. Compared to other reported ZPs [1],[5], which experience earlier drawbacks, the presented topology, and virtual material design provides high efficiency, reduced back lobe level, and efficient beam launcher to produce symmetric radiation beams for transmission states at 30 GHz [6].

2 Fresnel Zone

Figure 1 shows the geometrical principle of the Fresnel zone plate [6]. The lens diaphragm receives the signal from the focal point for the transmission mode and transmits it to the other side perpendicularly. The lens gets the maximum gain with Cos^{41}-like conical before more focusing. Each focusing device's essential concept is similar in two parts: a lens device and a beam launcher to ignite the lens diaphragm. Here, we consider two subzones for the proposed half-wave zone plate. Each zone introduces a phase shift for the radiated ways on the lens surface. Figure 1(b) shows a schematic representation of the Brakora approximation with the capacitive modeling method [1], [7].

In this modeling, an effective dielectric tensor of a cub-shaped porous structure to produce virtual permittivity can be determined accurately by managing the total volume of host media by reducing the entire host volume linearly. Figure 1(b) shows a capacitive estimation of effective permittivity. The Brakora permittivity control approach gives precise controlling levels in our design to change the host media's natural permittivity using static physics rules to the intended range.

As we know, in all periodic structures with dielectric mixing, permittivity estimation is relevant to the linear assessment in material theory to estimate dielectric properties virtually [1]. Accordingly, the cell sizes are small compared to wavelengths in the operating frequency at 30 GHz. Thus, the electrical behavior for porous cells' can be estimated with the Brakora method applying static physics rules with constant E-field. The total estimated capacitance for the proposed cube-shaped cell is achievable with reliable estimations using diverse host mediums such as ABS, Alumide, ceramic, and printable polymers.

Figure 2 depicts the implemented alumide based half zone plate, which is manufactured using powder-based additive manufacturing (ADM). The presented half-wave FZP is built and experimentally analyzed in the laboratory.

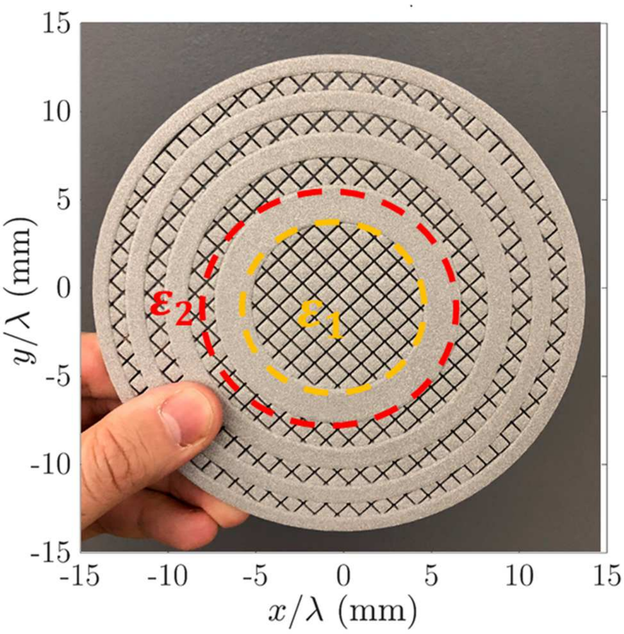

Figure 2. Fabricated alumide based half-wave zone plate.

3 Results

The fabricated FZPLs are analyzed and measured for 28 to 40 GHz frequency bandwidth. Three progressive modeling phases for the proposed lens are done to provide a reliable physical model. Various mathematical estimation using Brakora modeling for host medium permittivity are applied to meet the ZP equation requirements. The FZPL is designed and fabricated at 30 GHz. A commercial conical horn antenna (A390-17) is employed as a feed to ignite this zone plate.

The results in figure 3(a) and 3(b) show an E-Plane, and H-plane normalized radiation patterns achieved for the the horn antenna and the provided half-wave zone plate [1]. The zone plate cells are designed at the measured permittivity of alumide using WR-28 spacer for Ka-band. The results are confirmed that the realized porous ZP provides a maximum gain of 34 dB with a difference of lower than 4 dB over the desired frequency band. In the proposed lens diaphragms, the phase corrector rings produced by four constraints. These crucial values involve the number of phase corrector rings with virtual permittivity, the lens diaphragm diameter *D*, the intended subzones permittivity depend on Fresnel zone geometrical rules, and the natural permittivity of the alumide as a host medium [1].

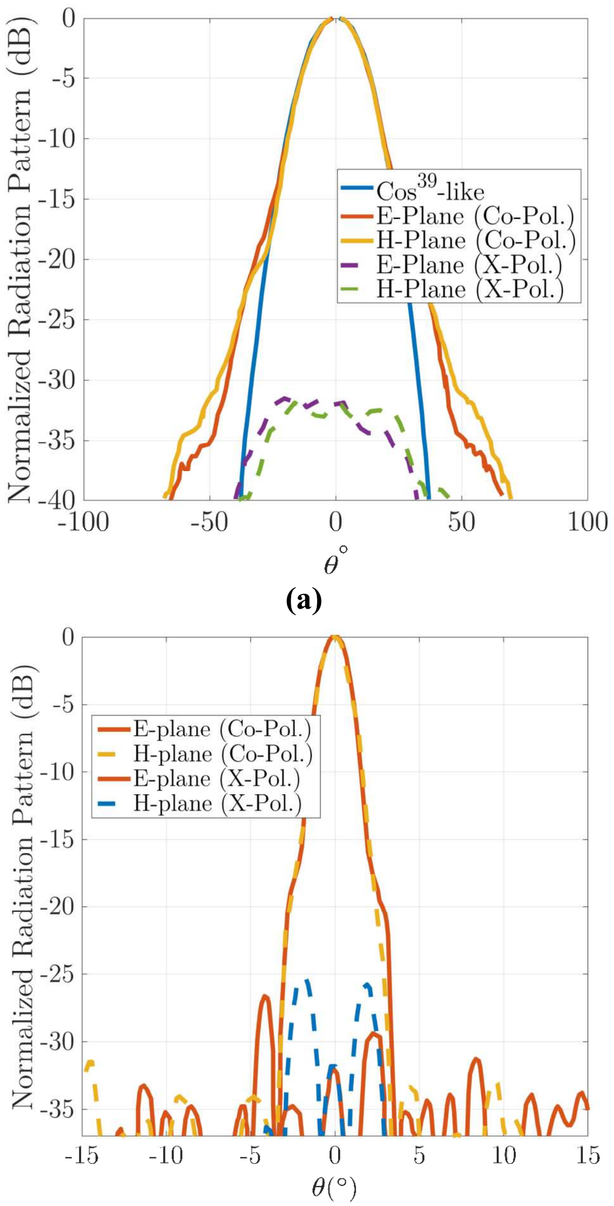

Figure 3. The normalized radiation pattern along E- and H-plane cuts for (a) Horn antenna (b) Half-wave ZP.

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