A Metasurface-based Stacked Patch Antenna for Wideband Circularly-Polarized Radiation

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***Abstract*— A metasurface-based stacked antenna is proposed for wideband circularly polarized (CP) applications. The proposed antenna consists of a metasurface, a patch radiator, a stacked patch, and a coaxial feed along the diagonal line. The antenna prototype is with 2-VSWR bandwidth (2-VSWRBW) of 30.9% (3.28 GHz – 4.48 GHz), 3-dB axial ratio bandwidth (3dB-ARBW) of 17.5% (3.65 GHz – 4.35 GHz), and gain greater than 7.25 dBic across the 3dB-ARBW with maximum gain of 8.25 dBic at 4.0 GHz.**

Keywords*— *circularly polarized antenna, metasurface antenna, rectangular-patch, stacked antenna, wideband.

I. Introduction

Metamaterials or metasurfaces have been used as an artificial antenna ground or partial ground to enhance the performance of the single feed based CP planar antennas [1-4], which include reactive impedance surface (RIS), electromagnetic bandgap (EBG), high impedance surface (HIS), artificial magnetic conductor (AMC). Furthermore, these metamaterial surfaces can be used as a radiator or stacked radiator or parasitic radiator as well, various metasurface-based antennas were designed and demonstrated for a wideband CP radiation [5-8].

In this paper, a metasurface-based coaxial fed stacked rectangular-patch antenna is proposed for wide 3dB-ARBW. The antenna consists of a metasurface with 7×7 square unit cells, a rectangular-patch with a coaxial feed along the diagonal line, and a stacked patch with an air-layer. A wide 3dB-ARBW of 17.5% within 2-VSWRBW of 30.9% is achieved, the gain is greater than 7.25 dBic across the 3dB-ARBW.

II. Antenna Configuration

The configuration of the proposed metasurface-based stacked CP antenna is shown in Fig. 1. The antenna is designed with three pieces of Rogers RO4003 (ε_r = 3.5, loss tangent = 0.0027) substrates with thickness of h_1 = 3.2 mm for metasurface, h_2 = 0.762 mm for patch radiator, and h_3 = 0.762 mm for stacked patch radiator, respectively. The slotted square-patch unit cells (7×7) based metasurface is designed on the upper surface of the lower substrate with thickness of h_1, the radiating patch is designed on the upper surface of the middle substrate with thickness of h_2. The inner conductor of the coaxial feeding line goes through the lower/middle substrates as well as the metasurface and connect to the rectangular patch radiator. To avoid the possible contact between the feeding probe and the unit cells of the metasurface, a clear area (3.0 mm diameter) without any metallic traces are implemented as shown in Fig. 1(b). The stacked rectangular-patch is designed on the upper surface of the upper substrate with thickness of h_3 and stacked over the radiating rectangular-patch radiator using an air layer and fixed by using four plastic screws. The optimized antenna design parameters are: metasurface; square unit cell size: 5.95 mm × 5.95 mm, four square slots with size of 1.75 mm × 1.75 mm in four quadrants of square unit cell, distance between adjutant unit cells in x-direction and y-direction is 1.3 mm, and metasurface with 7×7 unit cells, radiating rectangular-patch; width = 16.15 mm, length = 21.48 mm, feed location; x = -7.92 mm, y = -5.24 mm, stacked rectangular-patch; width = 19.8 mm, length = 24.95 mm with air-layer, h_{ar} = 6.5 mm. The antenna ground plane size is 60 mm × 60 mm.

For fabrication convenience, four holes with diameter of 3.0 mm are embedded at the corners of the substrates, respectively. The plastic screw with diameter of 2.5 mm is used to assemble the structure with an air-layer thickness of h_{ar} = 6.5 mm.

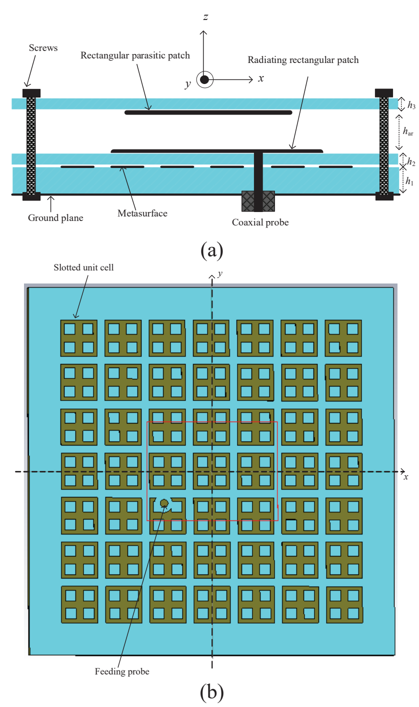
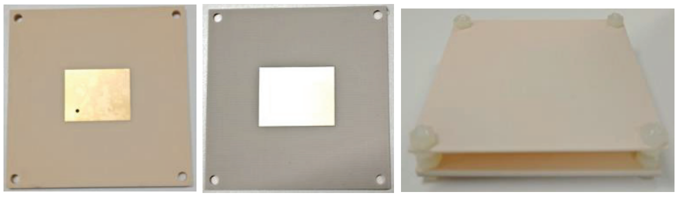


Fig. 1. Antenna configuration; (a) cross-sectional view of the antenna and (b) top view of the metasurface.

III. Measured Results and Discussions

The proposed antenna was prototyped. The antenna was assembled using the plastic screws as illustrated in Fig. 2. The antenna was measured in a full anechoic chamber to validate the simulation.



(a) (b) (c)

Fig. 2. Antenna prototype; (a) rectangular-patch radiator over metasurface, (b) rectangular stacked patch, and (c) full antenna porotype.

The measured and simulated VSWR curves are compared in Fig. 3, a measured 2-VSWRBW of 30.9% (3.28 GHz – 4.48 GHz) is achieved, and a good agreement between the simulation and measurement is observed. Fig. 4 shows the comparison of the simulated and measured AR/gain(boresight). The measured 3dB-ARBW is 17.5% (3.65 GHz – 4.35 GHz). Measured gain is greater than 7.25 dBic across the 3dB-ARBW and the maximum gain is around 8.25 dBic at 4.0 GHz. Again, the simulations follow the measurements well.

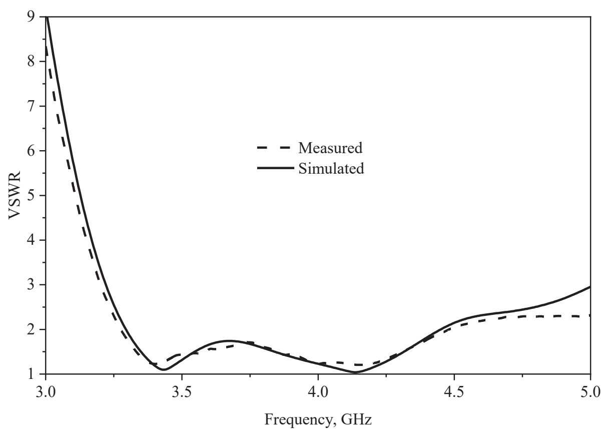


Fig. 3. Measured and simulated VSWR of the antenna.

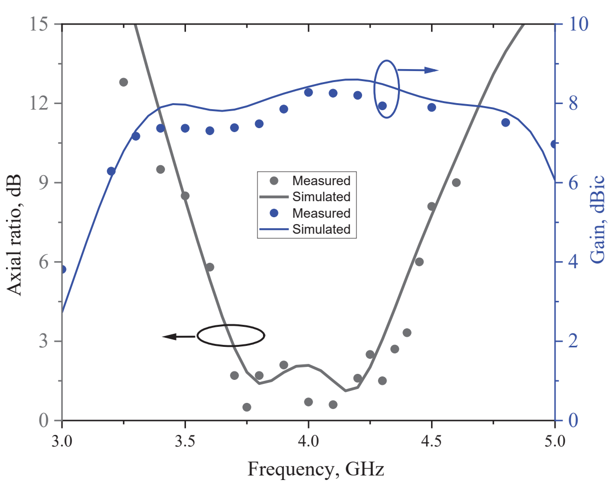


Fig. 4. Measured and simulated AR/gain (boresight) of the antenna.

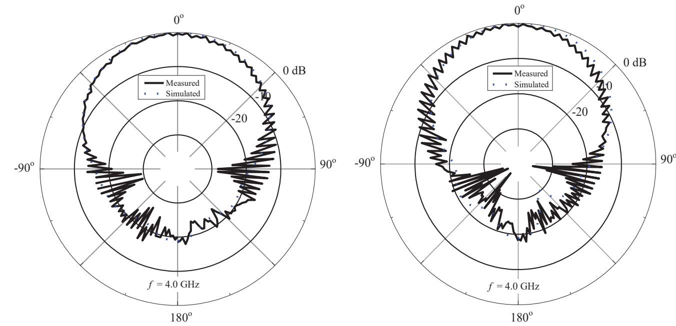


Fig. 5. Measured and simulated radiation pattrens at 4.0 GHz in *xz*-*yz*-planes.

The simulated and measured radiation patterns of the antenna prototype in *xz*- and *yz*-planes at 4.0 GHz are illustrated in Fig. 5. The ripples in the measured radiation patterns show the quality of CP radiation (AR), smaller ripple exhibits better CP radiation with smaller AR. The AR around the boresight is less than 3.0 dB and the 3dB-AR beamwidth is about 110° and 90° in *xz*- and *yz*-planes, respectively. Simulated pattern curves are also included for comparison and these curves follow the measured patterns very well.

IV. Conclusion

A metasurface-based stacked microstrip antenna has been demonstrated for wideband CP radiation with high gain, which is useful for wideband wireless systems.

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