CP Metasurfaced Antennas Excited by LP Sources

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***Abstract*—A metasurface which is considered as a polarizer for microwave antennas is proposed in this paper. Preliminary results have shown that circularly polarized (CP) radiation can be obtained from linearly polarized (LP) source antennas with the use of metasurface, antenna performance such as realized gain, efficiency and bandwidth are improved simultaneously. The metasurfaced antennas have a succinct non-resonant cavity in sub-wavelength (1/13 λo) format.**

I. Introduction

Two-dimensional equivalent of metamaterial is named as metasurface, which is essentially a surface distribution of electrically small scatterers [1]. Metasurface has wide applications due to its succinct planar structure and low cost. Well-known application examples are the compact cavity resonators [2], controllable smart surfaces [3] and performance enhancement of patch antennas [4], to name only a few. Among these applications, the printed antenna performance enhancement seems to be very attractive to antenna engineers, especially, when it comes to low-profile in sub-wavelength format. Metasurfaces have been proposed for linearly polarized (LP) and circularly polarized (CP) patch antennas in [4]. After placing the metasurface atop the corresponding source antennas, namely, CP metasurface to CP source and LP metasurface to LP source, the performance of both (LP and CP) antennas, such as antenna efficiency, bandwidth and gain were shown to enhance simultaneously. This type of antenna is hence named as metasurfaced antennas [4]. Nevertheless, it is interesting to know that if CP radiation wave can be achieved when a metasurface is excited by using a LP source.

In this paper, we propose the CP metasurfaced antennas with the abovementioned idea that is verified by using different LP sources – patch and slot antennas. The conversion of LP wave to CP wave can be obtained at microwave frequency. The excellent performance of the metasurfaced antennas, such as the realized gain, axial-ratio bandwidth (ARBW) and return-loss bandwidth (RLBW) are achieved.

II. Geometries of Antennas and Unit-cell

Both the metasurfaced antennas are designed to operate at 2.45 GHz and intended for WiFi and/or WiMAX applications. The geometries of the CP antennas and unit cells are illustrated in Fig. 1. The source antennas and metasurface are fabricated using the low-cost FR-4 laminates (ε_r = 4.2, tanδ ≈ 0.03) with a thickness of h_1 = 1.6 mm and h_3 = 0.8 mm, respectively. The source of Antenna A shown in Figs. 1(b) and 1(c) is a probe-fed square patch with a dimension of 29 (W) x 29 (L) mm^2, whereas the source of Antenna B shown in Figs. 1(d) and 1(e) is a LP slot antenna with a dimension of 33 (L_s) x 3 (W_s) mm^2 etched on the ground plane. The width (W_F) and length above slot (L_f) of the microstrip feed-line are both adjusted at 3 mm respectively. The grounded substrate of both antennas has a lateral dimension of 120 x 120 mm^2 and an overall cavity height of 9.4 mm.

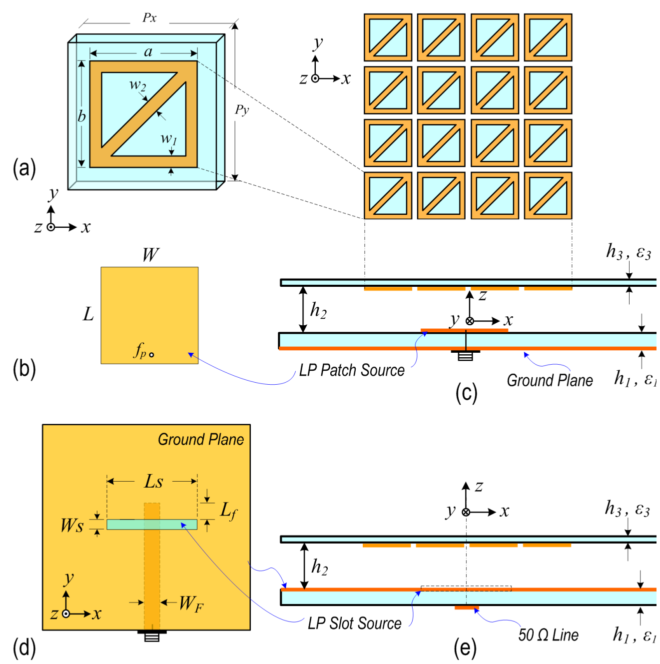

Figure 1. Geometries of the CP metasurfaced antennas: (a) metasurface and its unit-cell; (b)&(c) Antenna A: metasurface excited by probe-fed LP patch; (d)&(e) Antenna B: metasurface excited by line-fed LP slot source.

The geometrical parameters of the unit-cells of metasurface are listed in Table I, in the unit of mm.

TABLE I. Geometrical Parameters.

	P_x	P_y	a	b	w_1	w_2	h_2
Antenna A	24	24	22	22	1	2	7
Antenna B	25	23	22	21	1	1.2	7

III. ANTENNAS PERFORMANCES

At this proof of concept stage, our aim is merely focused on the possibility of polarizations conversion and the CP directive enhancement in the broadside direction when using simple LP source antenna. The preliminary results presented here for both antennas can be further improved.

A. Performance of Antenna A

The return loss versus frequency for measurfaced LP patch antenna, Antenna A, is shown in Fig. 2 whereas the broadside ($\theta = 0^o$, $\phi = 0^o$) axial-ratio versus frequency is plotted in Fig. 3. The 10-dB return-loss bandwidth (RLBW) is obtained at 210 MHz (8.2%) and its axial-ratio bandwidth (ARBW) is achieved in 70 MHz (2.8%). However, the broadside gain is improved from 3.5 dBi to 10.5 dBic at 2.46 GHz, when compared to patch only case. That is, the metasurface is acted as a polarizer and offers a 7-dB enhancement in the *right-hand* realized gain.

B. Performance of Antenna B

Similar comparison is made for Antenna B, where the LP slot is metasurfaced by the same type of scatterers. The 10-dB RLBW is improved from 150 MHz (7%) (not shown in Fig. 2) to 370 MHz (15%) when being metasurfaced. As for the realized gain, the slot antenna itself has a realized gain of 4 dBi as shown in Fig. 4 and is only kept for 100 MHz around 2.45 GHz. After adding the metasurface, a *right-hand* realized gain of about 8 dBic is achieved from 2.32 GHz to 2.45 GHz and above 6 dBic from 2.45 GHz to 2.54 GHz. The 3-dB ARBW is obtained from 2.32 GHz to 2.54 GHz, in a fraction of 9%.

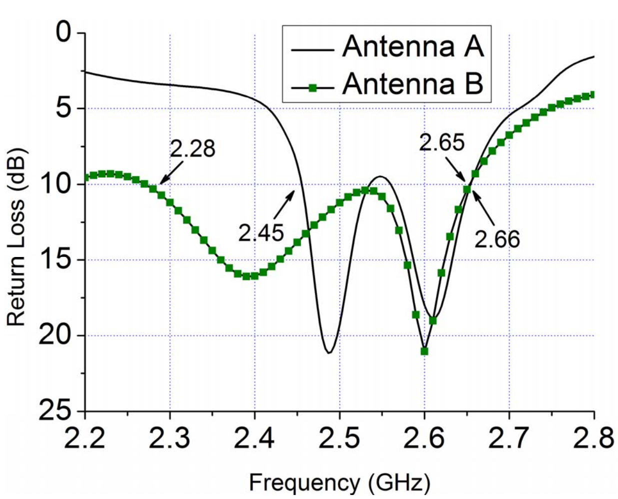

Figure 2. Return loss plots of Antennas A and B.

IV. CONCLUSIONS

The CP metasurfaced antennas excited by using different LP sources at 2.45 GHz are presented in this paper. The antennas have succinct sub-wavelength and non-resonant cavity that allows for simultaneous enhancement of bandwidth and directivity. The conversion of LP to CP radiation is achieved in the broadside direction. We concluded that the proposed metasurface can be regarded as a polarizer for the microwave antennas. The prototypes of the proposed antennas are being further optimized; more results will be reported in the conference.

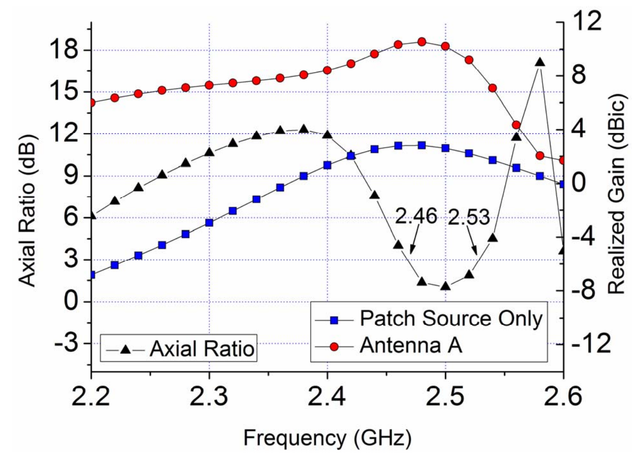

Figure 3. Axial-ratio and gain versus frequency for Antenna A.

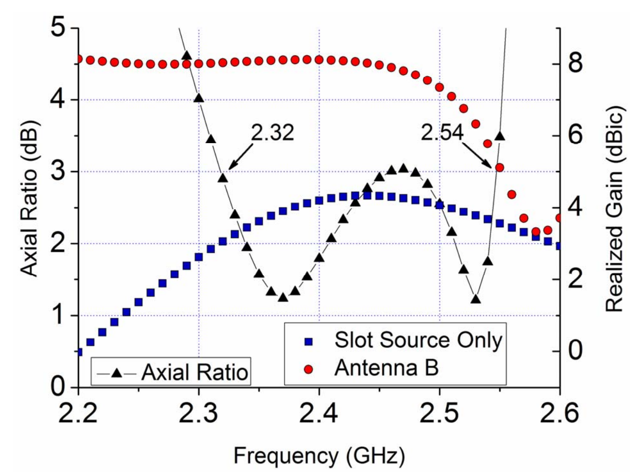

Figure 4. Axial-ratio and gain versus frequency for Antenna B.

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