

A Wideband Unidirectional Circularly Polarized Right Angle Slot Antenna using Metasurface

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Abstract

This paper presents the metasurface used for enhancing of gain, impedance bandwidth (ZBW) and axial ratio bandwidth (ARBW) by placed metasurface above a circularly polarized right angle slot antenna (CP-SA). The CP-SA with metasurface can increases ZBW and ARBW, implying an improvement of 632% and 434%, respectively. The overlap bandwidth of ZBW and ARBW is 400 MHz. Moreover, the radiation patterns can redirect into unidirectional. The gain increases 6.3 dB when compared with the CP-SA alone. This proposed antenna is low profile, low-costs and ease to fabricate.

Keywords : Circularly polarized slot antenna (CP-SA), Metasurface, Unidirectional

1. Introduction

Circularly polarized (CP) antennas have been used in modern wireless communication systems, which are much better at penetrating and bending around environments than linearly polarized (LP) antennas. Slot antennas (SAs) are often chosen in antenna research and development because it is simple to design and low material costs. Circularly polarized slot antennas (CP-SAs) have a bi-directional radiation but the CP waves in both directions are inversed [1]. For instance, the front radiation is a left-hand circular polarization (LHCP) while the opposite radiation is a right-hand circular polarization (RHCP). The general problem of bi-directional antenna is low directivity. The simplest method to redirect the back radiation forward [2] is to use a metallic reflector, which improving gain. However, a height between the slot antenna and reflector is about a quarter-wavelength. An article used a stacked and conducting reflector together [3]. However, it can provide to higher gain, wider ZBW and ARBW than the slot antenna only. The resulting structure is not low profile and low radiation efficiencies because the power leakage into parallel conducting reflector excited by the radiating slot and feed line. The newly method is proposed for increasing the antenna gain, ZBW, ARBW and radiation efficiencies by using the metasurface structure [4]-[6]. The metasurface is 2-D planar equivalent of 3-D metamaterials. It is lower and easier to fabrication than their 3-D duplicated. Therefore, the metasurface can increases the antenna gain, ZBW and ARBW. Also, the structure of antenna can be simplified and its profile is low.

This paper proposes a unidirectional antenna using metasurface as a superstrate for a circularly polarized right angle slot antenna for WLAN (IEEE 802.11b/g) and WiMax (2.3 GHz and 2.5 GHz). The design objective here is to obtain enhancement for ZBW, ARBW and antenna gain. The proposed antenna composes of the metasurface and the CP slot antenna. Consequently, the metasurface consists of 4×4 square rings with transverse-strips (SQR-TS).

2. Antenna Configuration and Design

Figure 1 shows the configuration and prototype of the proposed antenna. It is made of the metasurface atop on CP-SA. The driven CP-SA consists of a microstrip fed line and two insulated right angle slot on ground plane. The geometric CP-SA is modified from articles [1], [7]. The CP-SA and metasurface use FR-4 substrate ($\epsilon_r = 4.2$), which the thicknesses are $h_1 = 1.6$ and $h_2 = 0.8$ mm, respectively. The prototype antenna is designed at resonant frequency 2.45 GHz. Furthermore, the metasurface has been fabricated by modeling a single unit-cell with periodic

boundary condition [6]. The CP-SA is placed below metasurface of 7.5 mm (h_{air}) about $\lambda/16$ at 2.45 GHz. The total size of proposed antenna is $108 \times 108 \times 8.9$ mm³.

3. Simulation and Measurement Results

To certify the validity of our design method, a prototype antenna was fabricated and measured. A comparison of the simulated and measured results is given in Fig.2. For the ZBW defined by 10-dB return loss, the return loss results of the CP-SA with metasurface and the CP-SA without metasurface is presented in Fig. 2(a). The simulated result gives an ZBW of 640 MHz (2.21 – 2.85 GHz or 25.3%), whereas the CP-SA alone is about 100 MHz (2.4-2.5 GHz or 4%). The measured result is wider than the simulated that should be caused the effect of fabrication and the limited of FR-4 substrate. Figure 2(b) shows the comparison of the simulated and measured results for ARBW and gain. The ARBW defined by $AR \leq 3$ -dB which increases 70 MHz to 400 MHz that defined. The ARBW of the CP-SA with metasurface is 400 MHz (2.38 – 2.78 GHz or 15.5%), whereas the CP-SA alone is only 70 MHz (2.44 – 2.52 GHz or 3.2%). Also, the realized gain is increased 6.8 dB. The maximum realized gains are 7.8 dBi and 1 dBi of CP-SAs with metasurface and absent metasurface, respectively. The measured ARBW is 360 MHz (2.37 – 2.73 GHz or 14.1%). The measured gain level is around 6.0 – 7.3 dBi across the overlapped frequency band begins from 2.37 GHz to 2.73 GHz.

Figure 3(a) shows the distribution of the simulated electric field at 2.45 GHz for understanding the improvement of ARBW by use of metasurface. We note that the arrow agrees with the direction of electric field rotation which is a counter-clockwise current distribution. The proposed antenna excites RHCP property. Besides, the gain enhancement to investigate from the distribution of the simulated electric field at 2.45 GHz for CP-SA with metasurface and its alone are shown in Fig. 3(b). We can see that the distribution of electric field with metasurface is observed to be more uniform than absent metamaterial that affect to an improved effective aperture area and gain. Figure 4 shows the measured far-field radiation pattern in xz and yz plane at 2.45 GHz, which is unidirectional radiation.

4. Conclusions

This paper presents the new method for improvement of gain, impedance bandwidth and axial ratio bandwidth of a circularly polarized right angle slot antenna. The proposed antenna is not only improves its gain, ZBW and ARBW but also lower profile than the conventional method. An operating bandwidth achievement is 14.1% for the antenna prototype fabrication. The gain achievement over the overlapped bandwidth is 7 dBi.

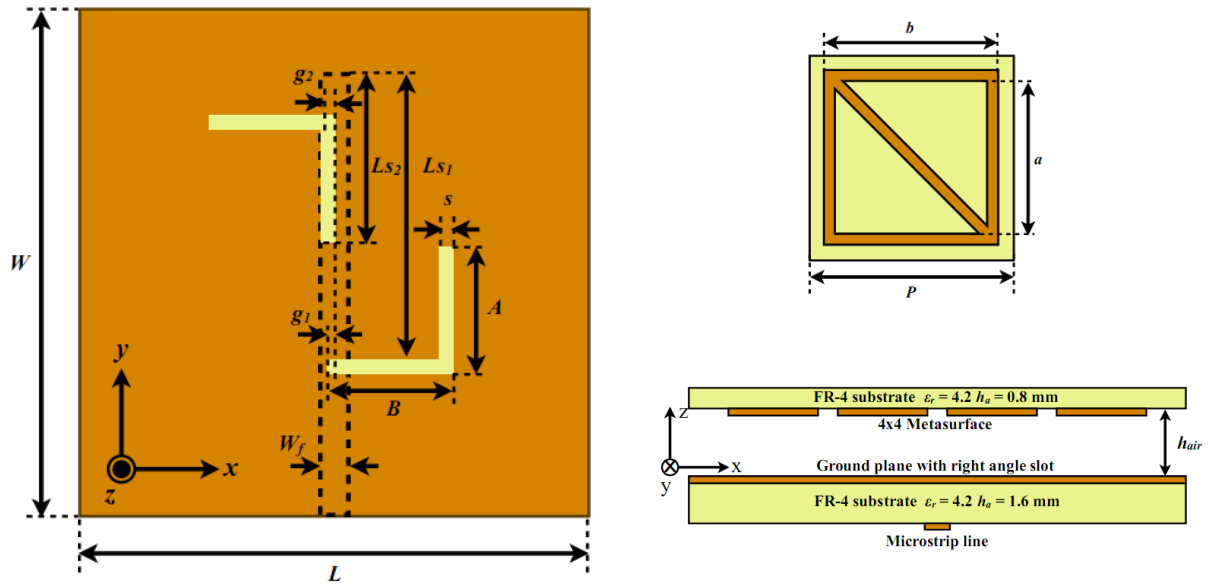
Acknowledgments

The authors would like to thank Rajamangala University of Technology Thanyaburi Pathumtanee, Thailand for measuring instruments.

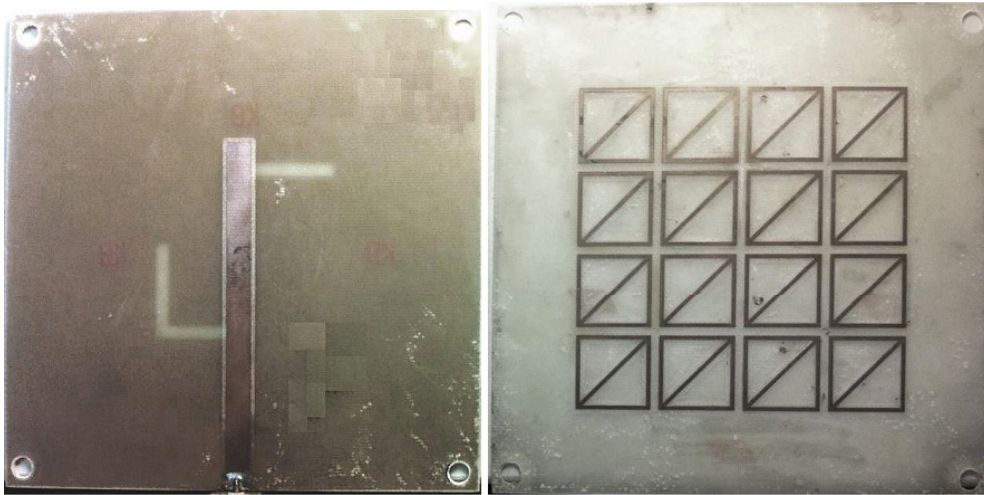
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(a)



(b)

Figure 1: (a) Antenna and unit cell of metasurface configuration and (b) the prototype antenna. Geometry parameters are: $W = L = 108$, $W_f = 6$, $A = B = 22.3$, $s = 3$, $g_1 = 1$, $g_2 = 2.5$, $LS_1 = 46$, $LS_2 = 27.2$, $h_{air} = 7.5$ and the length of 50Ω microstrip line is 88.5. The metasurface geometry parameters are: $p = 20$, $a = 16$ and $b = 18$. (Unit: mm)

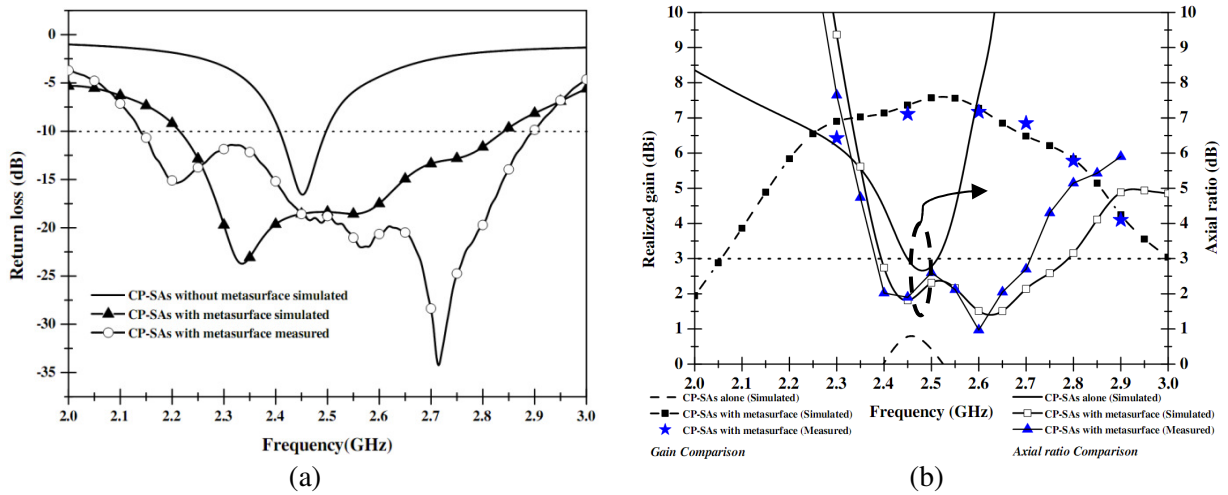


Figure 2: Simulated and Measured results for the CP-SA with metasurface and CP-SA alone (a) return loss (b) Realized gain and Axial ratio.

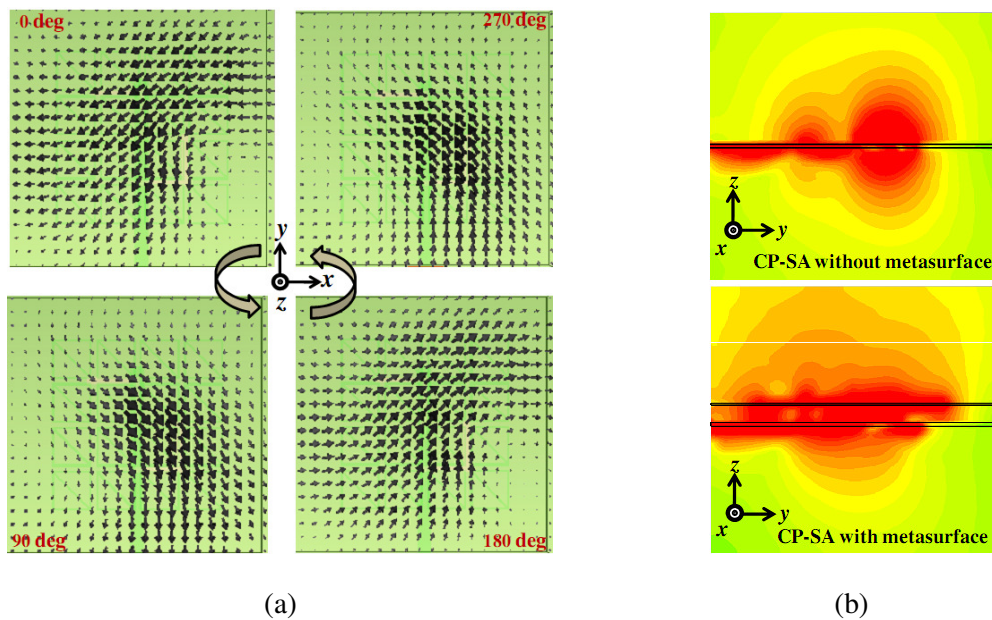


Figure 3: The distribution of the simulated electric field for the CP-SA at 2.45 GHz (a) The rotated electric field of CP-SA with metasurface (b) Electric field of the CP-SA without metasurface and CP-SA with metasurface.

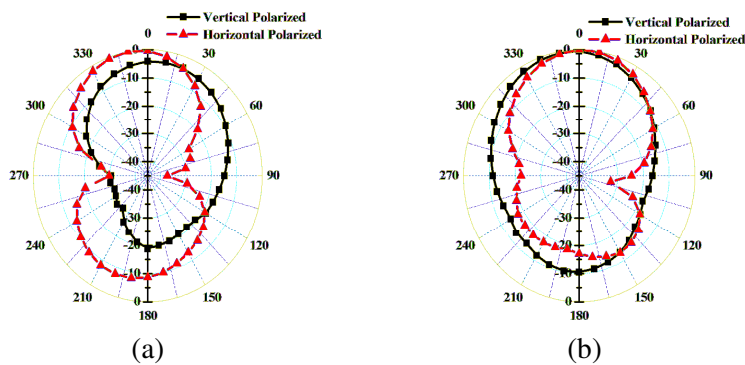


Figure 4: The radiation pattern of the proposed antenna at 2.45 GHz (a) xz - plane (b) yz - plane