RCS Reduction of a Microstrip Antennas Using Cross Polarization Conversion Metasurface

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***Abstract*—In this paper, polarization conversion metasurface for both in-band and out-of-band radar cross section reduction and gain improvement of a microstrip patch antenna is presented. The polarization converter metasurface is realized using anisotropic unit cell has a polarization conversion ratio (PCR) of more than 98% and 180°±26° reflection phase deference between its diagonal axes. A chessboard-like metasurface is realized using this unit cell and its mirrored one to achieve the required phase cancellation. The patch antenna is placed at the center of the chessboard and surrounded by the anisotropic unit cell. RCS of the antenna is significantly reduced while its radiation characteristics are preserved and its gain is improved by about 2dB. The proposed design is being fabricated now and the measured results will be presented and discussed at the symposium.**

I. INTRODUCTION

Antenna is a very essential part of any wireless communication system. However, antennas usually greatly contribute to the total radar cross section (RCS) of any platform [1]-[2]. RCS reduction using metasurface have attracted much attention recently due to the interesting scattering properties which are not found in natural materials. In this paper, a design approach for both in-band and out-of-band RCS reduction of a probe-fed microstrip antenna using polarization conversion metasurface is presented. Anisotropic unit cell is used to compose the metasurface of chessboard configuration. A significant RCS reduction is achieved and the radiation characteristics of the patch antenna are preserved. Furthermore, the gain of the patch antenna is enhanced by about 2dB. The proposed design is verified through numerical simulations, and measurement results will be presented at the symposium.

II. DESIGN OF THE ANISOTROPIC UNIT CELL

The front view of the proposed anisotropic unit cell and its mirrored one is shown in Fig.1 (a). The optimized dimensions of the unit cell are given in the caption of Fig.1.The relative permittivity of the dielectric substrate used is ε_r=3.38 and thickness of 3.04mm. The anisotropic unit cell has a sub-wavelength size of $0.4\lambda_{12GHz}$. Full numerical simulation of the anisotropic unit cell has been carried out using F-solver of CST microwave studio with appropriate periodic boundary conditions. Fig.1 (b) shows the reflection phase characteristics of the anisotropic unit cell. As can be seen the reflection phase difference between u- and v-axis reflection phases is about 180°±26° under both x- or y-polarized incident wave. This means that the incident wave will be rotated to its orthogonal component and reflected back. The polarization conversion ratio

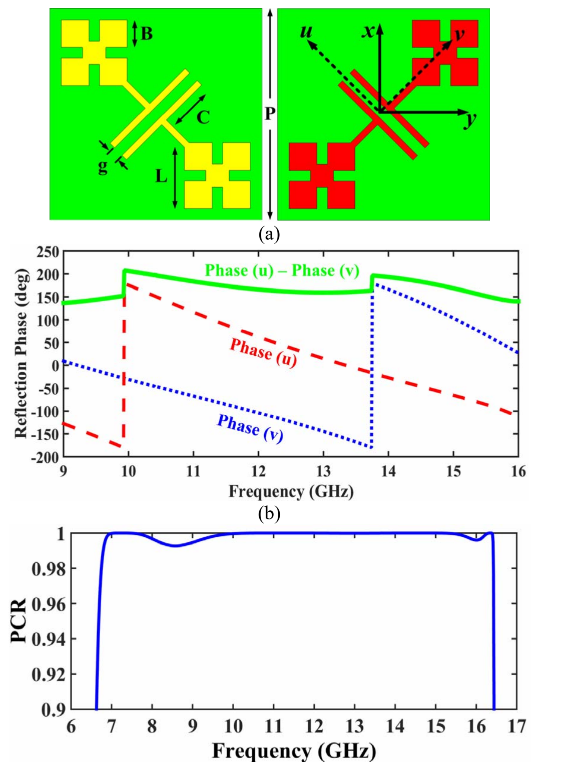
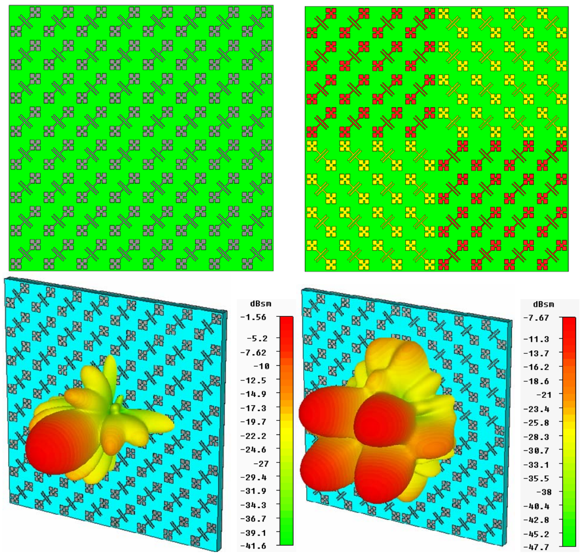


Fig. 1. (a) Unit cell layout (in mm): P=12=$0.4\lambda_{12GHz}$, B=1.5, C=1.2, L=2, and g=0.2. (b) reflection phase curves. (c) Polarization conversion ratio (PCR).

(PCR) of the unit cell is computed using the co-pol and cross-pol reflection coefficients and presented in Fig.1 (c). It can be seen that the PCR is more than 98% from 7GHz to 16GHz.

III. MICROSTRIP PATCH ANTENNA RCS REDUCTION

Using the proposed anisotropic unit cell, polarization conversion metasurface (surface#1) is composed as shown in Fig.2 (a) and all unit cells have the same orientation. Furthermore, a chessboard-like metasurface (surface#2) is also designed as shown in Fig.2 (b) and uses both the unit cell and its mirrored one to achieve the required 180°±26° phase difference across the chessboard aperture. Both surfaces have the same dimensions of 80 × 80 mm^2. The computed 3D scattering patterns of both surfaces are shown in Fig.2 and shows that Surface#1 has a strong reflection. On the other hand for Surface#2 the boresight reflection is highly reduced and the backscattered energy is redirected along the diagonals.



(a) (b)

Fig. 2. (a) Surface#1: cross-polarization converter. (b) Surface#2: chessboard like metasurface and their 3D scattering patterns.

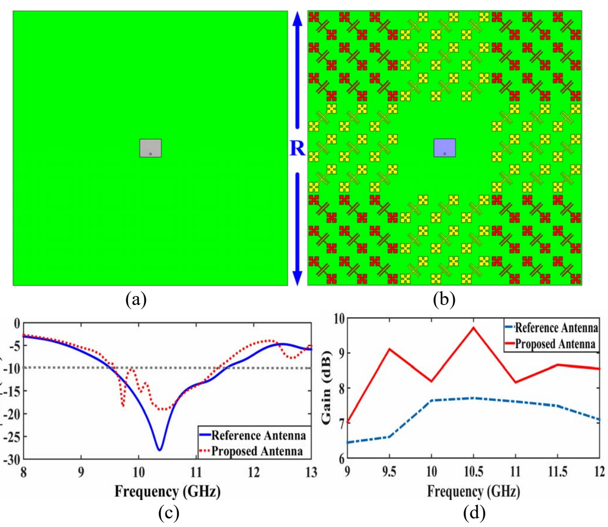
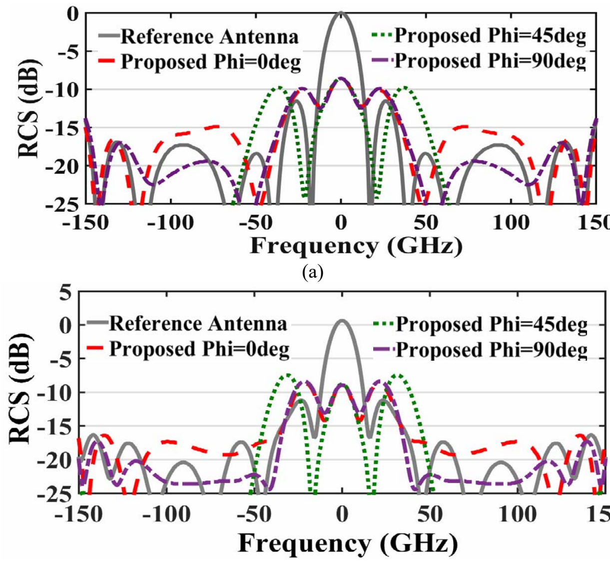


Fig. 3. (a) Layout of the reference microstrip patch antenna. (b) The proposed low RCS antenna. (c) and (d) are the $|S_{11}|$ and gain of both antennas.

Figure 3 (a) shows the geometry of the reference microstrip antenna while the low RCS antenna is shown in Fig.3 (b). The conventional patch antenna is placed at the central region of the chessboard metasurface and surrounded by the anisotropic unit cell and its mirrored one. The radiation properties are investigated first. The computed $|S_{11}|$ of both antennas are presented in Fig.3 (c) and it can be seen that both antennas are very well matched. However, the $|S_{11}|$ curve of the proposed one is a little deviated because of the coupling between the antenna and the metallic resonators of the unit cells. The gain of the antenna is improved by about 2dB as shown in Fig.3 (d). The far-field RCS patterns of the reference and proposed antennas are presented in Fig.4 and a clear RCS reduction in all planes (for instance, Phi=0°, 45°, 90° planes) is achieved. Furthermore, the 3D scattering patterns in Fig.5 show that the shape of the backscattered patterns are changed from a single lobe for the reference antenna to a number of low-level lobes for the proposed antenna in the half-space in front of the antennas.



(b)

Fig. 4. (a) In-band and (b) out-of-band RCS far-field patterns.

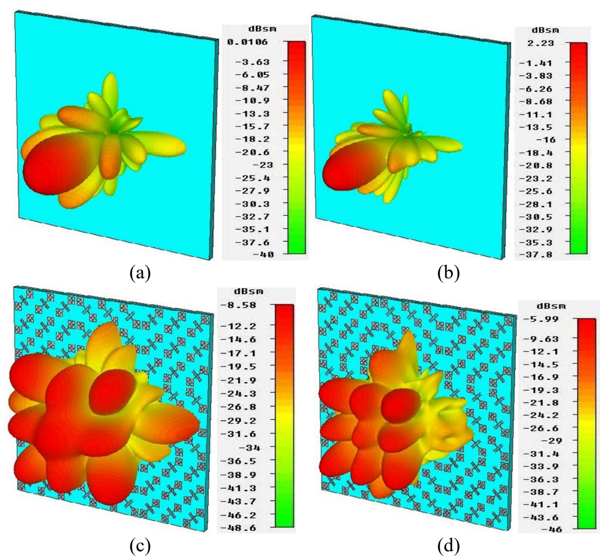


Fig.5 (a) In-band and (b) out-of-band RCS far-field patterns of the reference antenna. (c) In-band and (d) out-of-band RCS far-field patterns of the proposed antenna.

CONCLUSION

In summary, a novel approach for in-band and out-of-band RCS reduction of a conventional microstrip patch antenna using cross- polarization conversion metasurface is presented in this paper. Using the proposed technique, both in-band and out-of-band RCS is reduced and the radiation characteristics of the antenna are preserved with gain improvement.

REFERENCES

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