

Broadband Circularly Polarized Reflectarray Antenna Using Metasurface Polarizer

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Abstract - A broadband circularly polarized (CP) reflectarray antenna is proposed. By removal of the four corners of the finite square reflectarray, radiation from surface wave on the array is reduced at the corners. As a result, the 3-dB axial ratio (AR) bandwidth of 27% can be obtained at the center frequency. Furthermore, a design way to control the surface wave by keeping the ground plane square is presented. Due to its principle, the proposed modification of the metasurface can be effective not only for the proposed antenna, but also for other antennas with metasurface.

Index Terms —Broadband antenna, reflectarray antenna, circular polarization, metasurface, polarizer, surface wave.

1. Introduction

Reflectarray antennas consist of an illuminating feed antenna and a reflector with many radiating elements [1]. Due to the light weight and high gain properties, reflectarray antennas are becoming attractive for the applications such as radar antennas or spaceborne antennas.

Many studies have presented reflectarray antennas or their analysis method [2], [3]. These papers mainly focus on the reflection phase characteristics of elements in order to form a pencil beam. However, in most cases, linearly polarized (LP) reflectarray with LP horn is discussed.

On the other hand, metasurface has been widely studied recently [4], [5]. Among its several characteristics, frequency-dependent reflection characteristics is especially useful for antenna applications. One of the most interesting applications using this property is a linear-to-circular polarization (CP) converting function based on polarization dependent metasurface [6]. This polarizer changes in-phase orthogonal incident field components into 90° out-of-phase reflected field components. This metasurface-based polarizer easily generates a wideband CP.

Both of reflectarrays and metasurface polarizers are the structures that metal elements are arranged on a ground plane periodically in small period. This similarity implies a possibility of metasurface-based reflectarray. In this paper, a novel type of broadband CP reflectarray antenna based on metasurface polarizer has been proposed. A modified finite array geometry of the metasurface is presented to obtain a wide axial ratio (AR) bandwidth.

2. Structure Design

The proposed metasurface polarizer consists of a flat array of rectangular microstrip patches on a grounded dielectric substrate (RT duroid/5880, $\epsilon_r = 2.2$, thickness is 3.2 mm). A feed antenna is a uni-directional, broadband LP waveguide antenna with a linear probe modified from a CP antenna with a L-shaped probe [7]. Overall antenna is shown in Fig. 1 (a). The Unit cell of periodic structure is designed as shown in Fig. 1 (b).

The four corners of the proposed reflectarray is removed except ground plane, as shown in Fig. 1 (c). This modification is effective to reduce the radiation from surface wave that is reflected at the edges of the finite array.

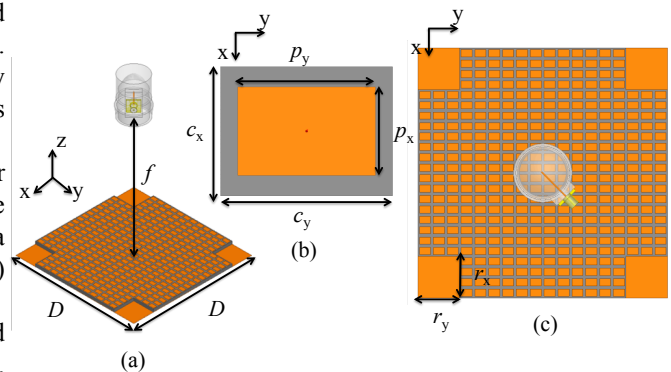


Fig. 1. Structures of the metasurface polarizer based reflectarray antenna. (a) shows the overall antenna structure, (b) shows the unit cell of the polarizer and (c) shows the geometry of the reflectarray with removal. $f = D = 144$, $p_x = 4.1$, $p_y = 6.4$, $c_x = 6.0$, $c_y = 8.0$, $r_x = r_y = 24$. (All dimensions are in mm.)

3. Simulated Results

(1) Simulation of Reflection Phase

Periodical boundary condition is used to simulate the reflection characteristics of x - and y - polarized incident waves normally impinging onto the surface. Fig. 2 shows the reflection phase of E_x and E_y components of reflected wave. Phase difference is around 90° from 7.6 GHz to 10 GHz that is the operation band of the LP antenna.

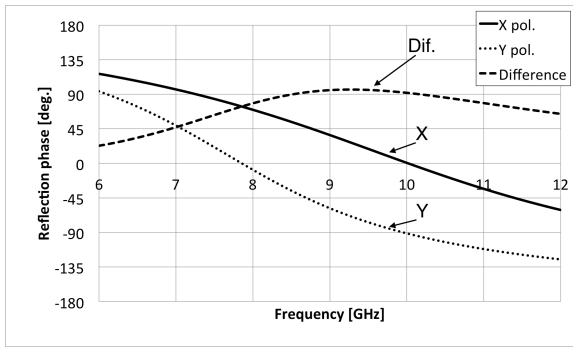


Fig. 2. Reflection phase

(2) Removal of the Corners

Fig. 3 shows the AR characteristics of the square reflectarray. At 7.6GHz and 8.6GHz, AR becomes higher. This may be caused by surface wave around the corners. Electric field on the surface shows that the surface wave is reflected and emphasized at the edges and the corners as shown in Fig. 4 (a). Then, the corners are removed, as shown in Fig. 1 (c), the AR improving due to the reduction of the emphasized surface wave (Fig. 3 and 4 (b)).

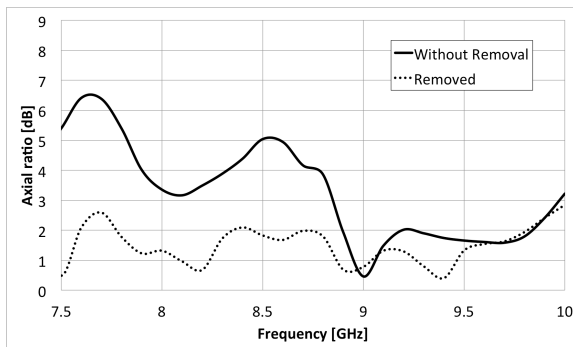


Fig. 3. Effect of removal on AR

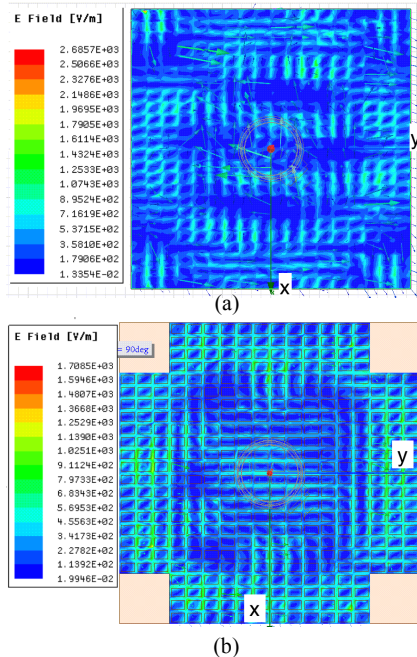


Fig. 4. Electric field distributions (a) square, 7.6GHz, (b) removed, 7.8GHz

(3) Effect of the Square Ground Plane on AR

There are three ways to remove the corners: Removing (a) the layer of the patches, (b) the patches and the substrate and (c) all layers of the patches, the substrate and the ground plane. However all of these modifications are effective to improve AR, most effective way is (b), as shown in Fig 5. This result shows that a boundary condition of the propagation of the surface wave is affected by the way of removal.

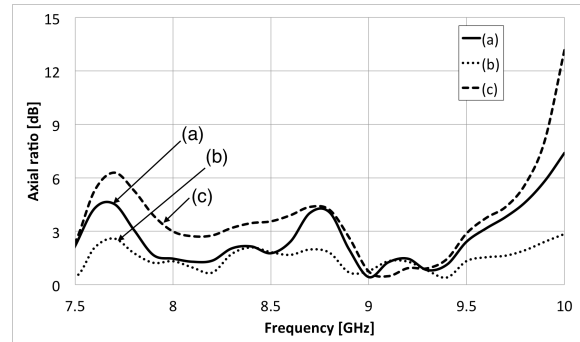


Fig. 5. Effect of the square ground on AR

4. Conclusion

This paper has presented a circularly polarized reflectarray antenna consisting of metasurface polarizer. Because of the finite array configuration of the reflectarray, deterioration of the axial ratio is caused by radiation from surface wave on the array. On the basis of the observation of the electric field distribution, it is revealed that the surface wave effects on AR at the four corners of the square reflectarray. For this reason, removing the corner regions of the array is effective to mitigate the deterioration. In addition, it is shown that the square ground plane can control the surface wave of the edge and axial ratio.

References

- [1] J. Huang and J. A. Encinar, *Reflectarray antennas*. Wiley: New Jersey, 2007, pp. 1-7.
- [2] K. Konno, Q. Chen, K. Sawaya, S. Kameda and N. Suematsu, "Reflectarray Design by Induced Electromotive Force Method," in *Proc. IEEE Antennas Propagat. Soc. Int. Symp.* 2013, Orlando, FL, USA, pp. 1342-1343.
- [3] Y. Mao, S. Xu, F. Yang and A. Z. Elsherbeni, "A Novel Phase Synthesis Approach for Wideband Reflectarray Design," *IEEE Trans. Antennas Propagat.*, vol. 63, no. 9, Sep. 2015.
- [4] S. Maruyama and T. Fukusako, "An Interpretative Study on Circularly Polarized Patch Antenna Using Artificial Ground Structure," *IEEE Trans. Antennas Propagat.*, vol. 62, no. 11, Sep. 2014.
- [5] F. Yang and Y. Rahmat-Samii, "Reflection Phase Characterizations of the EBG Ground Plane for Low Profile Wire Antenna Applications," *IEEE Trans. Antennas Propagat.*, vol. 51, no. 10, Oct. 2003.
- [6] M. Kamiya, R. Kuse, T. Hori and M. Fujimoto, "Patch Type Metasurface with Polarization Conversion Function," *IEICE Tech. Rep.*, AP 2014-39, pp. 103-106. May 2014 (Japanese).
- [7] R. Yamauchi and T. Fukusako, "A Broadband Circularly Polarized Waveguide Antenna Design for Low Cross-polarization," *IEICE Trans. Comm.*, to be published.