Element Design for Dual Circularly Polarized Reflectarrays with Dual Linearly Polarized Feed

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***Abstract*—In this paper, a novel single-layer broadband subwavelength multi-resonance element is proposed to design a dual circularly polarized (CP) reflectarray with a dual linearly polarized (LP) feed. The simulated results show an adequate phase range over 360^0 and low mutual coupling between the two orthogonal polarizations of the element. Also, a superior bandwidth performance has been verified, compared to conventional cross-dipole element.**

Keywords—Broadband arrays, circularly polarization, reflectarrays, mutual coupling

I. Introduction

The robustness against environmental interference for circularly polarized (CP) antenna is considered to be of significant importance in satellite communications due to the Faraday rotation effect of the ionized layer of the atmosphere. Microstrip reflectarray antennas can easily be implemented for circularly polarization using a CP feed [1]. However, the CP feed of CP reflectarray antennas is more complicated, especially in millimeter wave or higher frequency bands. An alternate method to design a CP reflectarray is to use a linear polarized (LP) feed based on the following principle. The polarization of an LP feed is along the diagonal direction of the unit cell of a periodic structure and then its linearly polarized field is decomposed into two components with equal amplitude. By adjusting the x- and y-axis dimensions of the element, the LP wave generated by the feed can be converted into a CP collimated beam. With a dual-LP feed, the reflectarray can transform the dual-LP incidences from the feed into dual-CP radiation, the handedness of which depends on the phase relationship between the two orthogonal linear polarizations.

The paper is mainly focused on the design of broadband and low mutual coupling CP element. A novel subwavelength multi-resonance element with Jerusalem cross and open loop is proposed to provide adequate phase range and obtain wider bandwidth. It has to be noted that the proposed single-layer subwavelength element with multiple resonances makes the design very challenging. The full-wave simulation of the proposed element is also presented to validate the broadband performance of the proposed subwavelength multi-resonance element with low mutual coupling between orthogonal field components.

II. Proposed Element

The most severe drawback of reflectarrays is the poor bandwidth performance which is limited primarily by two factors. The first one is the intrinsically narrow bandwidth of the microstrip elements. The second is the frequency dependence of the phase delay of the incident field. In particular, the first factor is quite critical and becomes dominant in moderate size reflectarrays. It was shown recently that the bandwidth of reflectarray can be improved by using subwavelength elements [2]-[3] and single-layer multi-resonant elements can provide phase range exceeding 360^0 [4]. The subwavelength multi-resonant element with Jerusalem cross and open loop as shown in Fig. 1 is proposed for this design. The Jerusalem cross consists of an end-loaded crossed dipole, with the vertical current flows to charge the capacitors formed by the horizontal conductors, leading to the possibility of a denser lattice. The open loop is intentionally used to reduce the coupling between orthogonal field components and it simultaneously resonates at high frequency. The gaps between the Jerusalem cross and open loop are set to avoid the

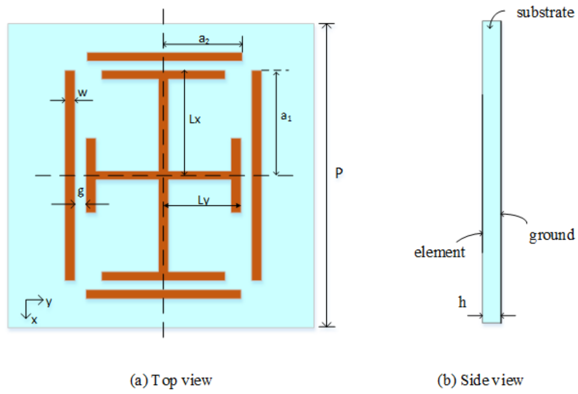

Fig. 1. Geometry of the subwavelength multi-resonant element: (a) top view and (b) side view.

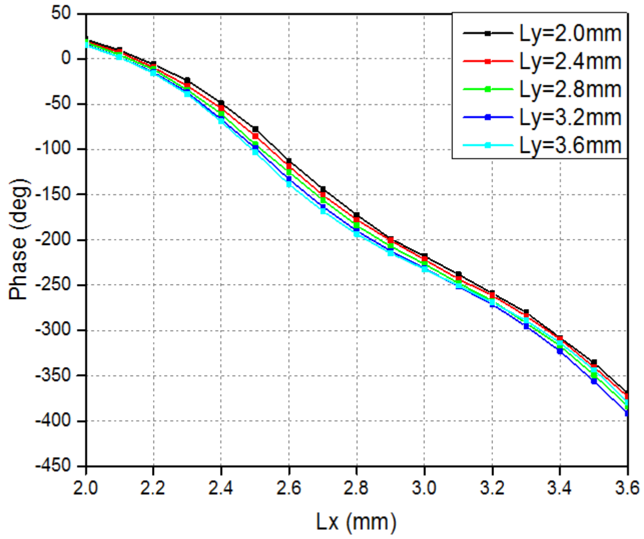

Fig. 2. Refection phase of the proposed element.

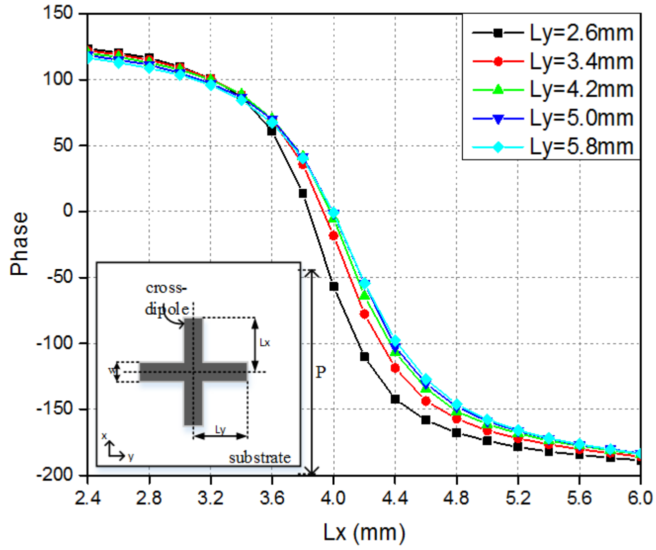

Fig. 3. Refection phase of the cross-dipole element.

physical interferences. The parameters of the elements were tuned to achieve a slower phase slope. With reference to Fig. 1, the final design parameters are as follows: h = 3mm, P = 8.3mm (λ_0/3), g = 0.2mm, w = 0.2mm, $a_1 = L_x$, and $a_2 = L_y$. The dielectric constant (ε_r) of the substrate is 2.2, h = 3mm. P = 8.3mm (λ_0/3), g = 0.2mm, w = 0.2mm, $a_1 = L_x$, $a_2 = L_y$.

The element is simulated in HFSS simulator with periodic boundary conditions. In order to work out the phase characteristics of the proposed element, only the case of a vertically polarized (x-direction) TEM plane waves, normally incident on an infinite periodic array with identical elements, is considered because the phase variation is small when the incident angle θ_i of the plane waves is less than 40^0 [5]. Fig. 2 shows the reflected phase versus the x-direction length L_x for different values of y-direction dimension L_y at 12GHz. It is seen that the phase variation of the proposed element is approximately a linear function of its size, covering in excess of 360^0. The mutual coupling between the two orthogonal polarizations of the proposed element is weak, with a maximal phase discrepancy of about 20^0.

To compare the results, a cross dipole with spacing P = 12.5 mm (λ_0/2) and width of the dipole arms w = 3mm was also designed and simulated. The phase of S_{11} with different L_y is shown in Fig. 3. The coupling between cross-dipole arms here is relatively strong with the maximal phase discrepancy of about 70^0. Also, the cross dipole elements have an inadequate phase range of less than 360^0, leading to larger phase errors in reflectarray design and reduction of antenna directivity. In addition, compared to the cross dipole, the proposed element has a smaller reflection phase slope as a function of the element sizes for achieving a larger operational bandwidth and smaller susceptibility to manufacturing errors.

III. Conclusion

A novel subwavelength element with multiple resonances is presented in this paper. The simulated reflection phase shows low mutual coupling, with the maximal phase discrepancy of about 20^0. Also, the numerical results demonstrate the proposed element achieves an almost linear behavior and adequate phase coverage of over 360^0.

Acknowledgment

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