Reflectarray Elements Based on Two-Resonance Behavior for Dual-Polarization Use

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Abstract

This paper proposes wide-band reflectarray elements based on two-resonance behavior for dual-polarization use. The usefulness of the proposed elements is verified from the calculated reflection phases of the infinite arrays for the various structural parameters. Finally, we design reflectarray and evaluate its wide-band frequency characteristics numerically and experimentally.

Keywords : microstrip reflectarray, infinite periodic array, resonance elements.

1. Introduction

Microstrip reflectarrays are very attractive aperture antennas because of their planar structure and a simple feed system [1]. However, the bandwidth is usually limited, because the reflection phase of each element greatly depends on the frequency. Although the authors have developed single-layer reflectarrays with microstrip elements arranged densely [2] so far, it is difficult to obtain a sufficient range of the phase shift because of single resonant property of each element. To obtain the same performance in single-layer structure as in two- or three-layer one [3, 4], we had already reported to use two-resonance elements with different lengths as a unit cell for single polarization [5]. For realizing a dual-polarization operation, this paper proposes new-element shape and arrangement. The proposed elements possess the liner phase property with the almost same slope characteristic for both polarizations over the wide frequency range. A design example of the reflectarray constructed by these elements is demonstrated and its effectiveness is verified by comparing of the radiation patterns between the calculated results and the measured ones in the Ku band.

2. Frequency characteristics of reflection phase

Figure 1 shows basic geometry of microstrip reflectarrays consisting of a planar array with variable length printed on the grounded single-layer substrate. The design of a reflectarray makes use of the reflection-phase shift due to the resonant phenomenon of the element. Figure 2 shows the phase characteristics for the previous elements [5]. It is necessary to arrange additional two resonant elements perpendicular to the conventional ones, to achieve the dual-polarization use. However, if the element length becomes long, the elements come in contact mutually. Therefore, in this paper the four resonant elements of each cell are bent convexly and each of them is arranged as shown in the inset of Fig. 3. Their reflection phase characteristics for the TE-wave and the TM-wave incidence are shown in Fig. 3. The calculation is performed as the unit cell dimension $d_x = d_y = 9.6$ mm, the incident angle $\theta_s = 30°$, the thickness $h = 3.0$ mm between the film and the ground plane, the distance $d = 3.0$ mm between the elements, and the strip width $w = 0.6$ mm of the element. The phases for both incident waves have the liner phase properties with the almost same slope characteristic in wide frequency range over 10.0-18.0 GHz. Therefore it is obvious that the wideband dual-polarization reflectarray element is realized. The reflection-phase properties are analyzed by the method of moments based on the spectral domain Green function with the periodical boundary condition.

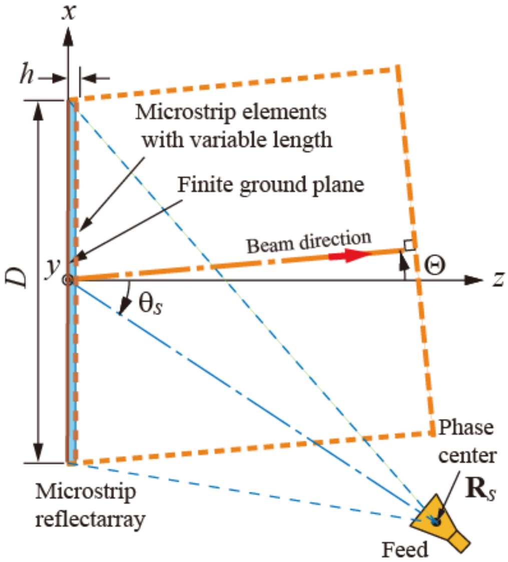


Fig. 1. Antenna configuration.

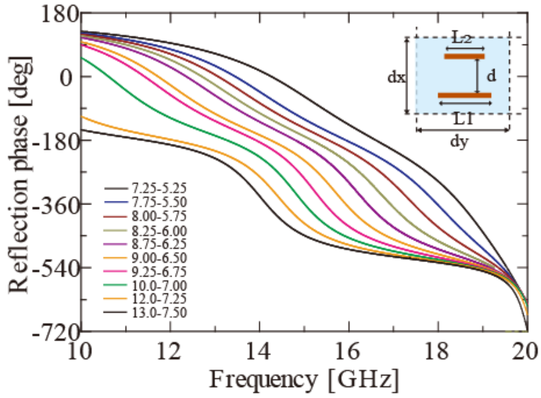


Fig. 2. Reflection phase properties of previous elements.

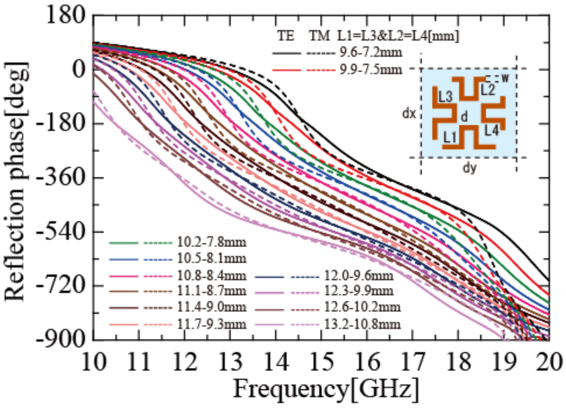


Fig. 3. Reflection phase properties of four elements for TE and TM incidence.

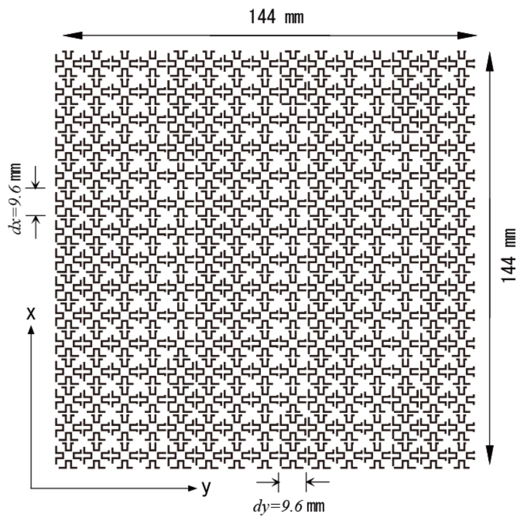
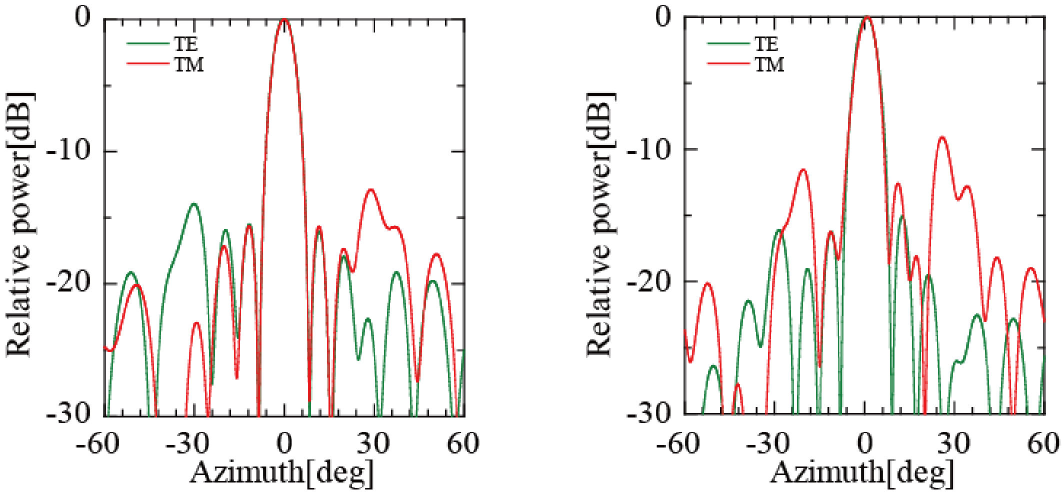


Fig. 4. Top view of designed reflectarray.

3. Design Examples and radiation pattern analysis

We now design a reflectarray with a square aperture of dimension 144×144 mm^2 (15×15 cells). The standard gain horn in the Ku band is used as a primary radiator, and R_s is chosen to be 400 mm to obtain the edge level of the aperture, -13 dB. In this case, the main-beam direction is Θ = 0° perpendicular to the flat surface of the reflectarray. It is different from the specular-reflection direction of the incident angle θ_s = 30°. The lengths L_1, L_2, L_3 and L_4 of the proposed elements are determined from the design charts for each illumination angle which is determined by the element position on the array. Figure 4 shows the top view of designed reflectarray. Figure 5 shows the calculated results of the radiation patterns for the TE and TM wave incidences at 15.0 and 18.0 GHz. It is confirmed that the sidelobe level is about -10 dB and the specular reflection level is suppressed small over 15.0-18.0 GHz. Although difference of the sidelobe level between the TE-wave and TM-wave patterns is observed in these figures, the main-beam patterns of both waves agree with each other very well.



(a)15.0 GHz. (b)18.0 GHz.

Fig. 5. Calculated radiation patterns of TE and TM incidence.

4. Experimental verification

Figure 6 is the photograph of the fabricated reflectarray, and Fig. 7 is the close-up one. The conductor strips are the copper with thickness 18 μm printed on a thin dielectric film (Polyimide) with thickness 125 μm and also the interval between the film and ground plane is kept by a polyfoam (dielectric constant ε_r = 1.07) with thickness h = 3.0 mm. The far-field measurements are performed at 15.0 and 18.0 GHz. Figure 8 shows the experimental results of the radiation patterns for the TE-wave and the TM-wave incidences. The main-beam patterns and the first sidelobe ones for both incident waves agree with each other very well. The measured results of the aperture efficiency at 15.0 GHz are about 45% for both waves. It is clarified from this experimental verification that the proposed reflectarray element works well for the dual-polarization use.

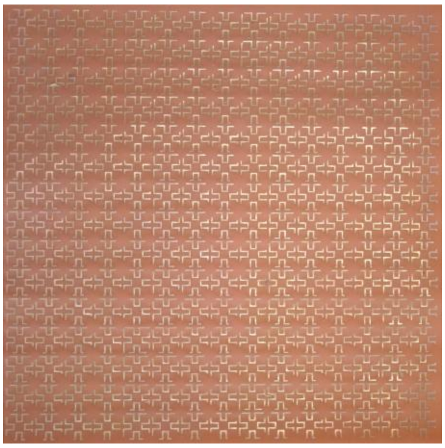


Fig. 6. Photograph of fabricated reflectarray.

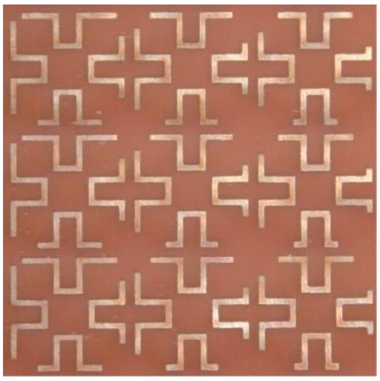
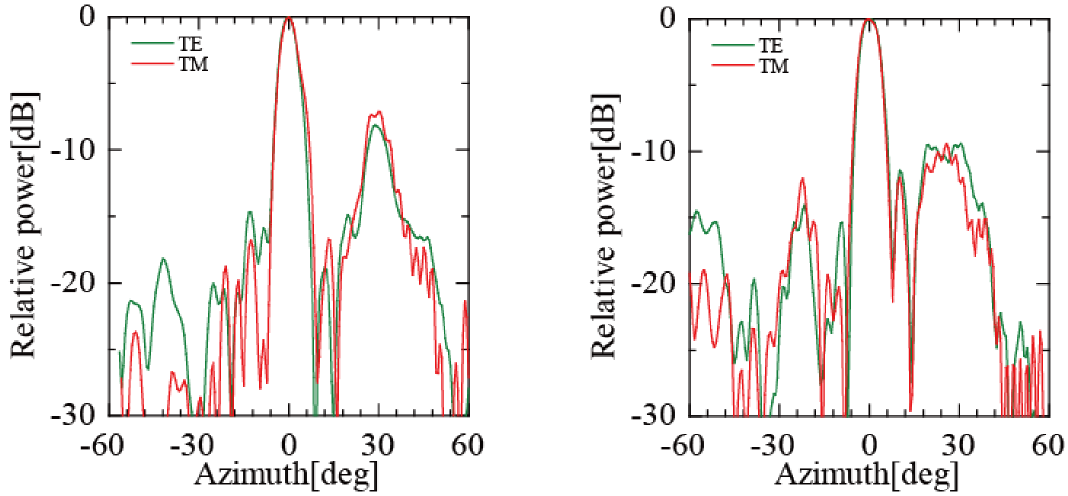


Fig. 7. Close-up view in middle of fabricated reflectarray.



(a)15.0 GHz. (b)18.0 GHz.

Fig. 8. Measured radiation patterns of TE and TM incidence.

5. Conclusion

We have presented the single-layer reflectarray based on two-resonance behaviour for dual-polarization use. The performance of the proposed reflectarray has been verified by the numerical evaluation and the experiment for the designed reflectarray antenna. The detail discussion on frequency characteristics and cross polarization components of the reflectarray will be presented at the talk.

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