Single-layer Flat Reflector Surface with Different Elements

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Abstract

A flat reflector surface composed of two different types of microstrip patch element is studied. Ring-loaded patch (RLP) element is used with simple square patch (SSP) element to compensate its poor reflection phase characteristic with minimized design complexity and possibility of fabrication error. The reflection phase characteristics of the two types of elements are studied, and a flat reflector surface which tilts the reflected field in 12.8° is designed.

Keywords : Reflector antenna, Reflectarray

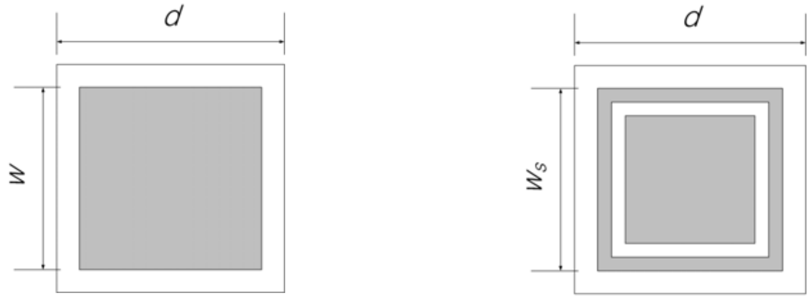
1. Introduction

Parabolic reflector antennas with high directivity have been used for various applications including broadcasting, space communication and radar. The antennas generally have curved metallic surface as a reflector to focus the field radiated from feed antenna, which requires high manufacturing cost and increases the volume and weight of the antennas. To overcome such drawbacks of parabolic reflectors, reflectarray consisted of microstrip patch element array has been developed [1]. In microstrip patch reflectarray design, each element is designed to have corresponding reflection phase to direct the reflected field. Conventional methods to control the reflection phase of the elements are attaching delay lines to the patch or varying the size of the patch. The problems of the patch element with delay line are increased cross-polarization and spurious radiation, while the method of varying the patch size cannot attain full range of reflection phase ranging from -180° to 180° [2]. To obtain wider range of reflection phase, various methods such as using multi-layer patch elements or modifying the shape of patch have been researched [3]-[6]. However, multi-layer structure increases the cost, volume and weight of the antenna and the patch element with complex shape makes the design process complicated and may increase fabrication errors. In previous works, the reflectarrays have been designed with a single element type, whether it is a simple square patch (SSP) with delay line, or variable size, or complex shaped patches. However, if a reflectarray is designed with both SSP and other complex shaped patches, the above addressed problems can be alleviated.

The purpose of this work is to check the possibility of designing reflectarray with both SSP and other complex shaped element. A reflector surface presented in this work has been designed mostly with SSP element, which is easy to design and fabricate with small amount of fabrication errors. However, as addressed above, SSP element cannot provide full range of reflection phase. Therefore, a complex shaped element which is a ring-loaded patch (RLP) is used only when the SSP element cannot satisfy the required reflection phase.

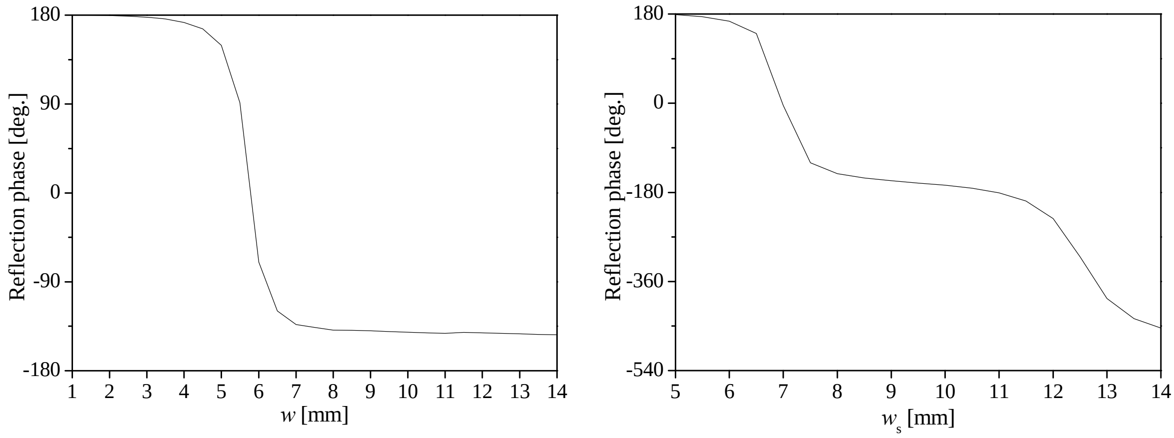
2. Reflection Phase Characteristic of the Elements

The structure of the SSP element and the RLP element are shown in Fig. 1. The periodic distance of the elements d is 15.0 mm (half wavelength at 10 GHz) for both elements. The gap between the inner patch and the outer ring is kept constant as 1.0 mm. The width of the SSP is w and that of the ring of the RLP is w_s. The total sizes of the elements are varied to control the reflection phase. In Fig. 2, the reflection phases at 10 GHz of the SSP, and the RLP is presented. In



(a) SSP element (b) RLP element

Figure 1: Two different types of microstrip patch element



(a) SSP element (b) RLP element

Figure 2: The reflection phases of the microstrip patch elements

both types of elements, FR4 with relative permittivity 4.9 and 1.6 mm thickness is used as a substrate. It is observed that the range of the attainable reflection phase of the simple patch is limited from 180° to -145°. In order to design an arbitrary reflector surface, it is required to have element which can provide full range of reflection phase. In case of the RLP element, it can cover the full reflection phase from 180° to -180°, but compared to SSP, it has more complex structure which increases the design complexity and possibility of fabrication error.

3. Beam tilting Reflector Surface

To show that the reflector surface with certain phase properties can be designed with the combination of the two elements, a sample surface consisted of elements with linearly changing reflection phases is designed as in Fig. 3. In x-direction, total 10 elements with gradually changing

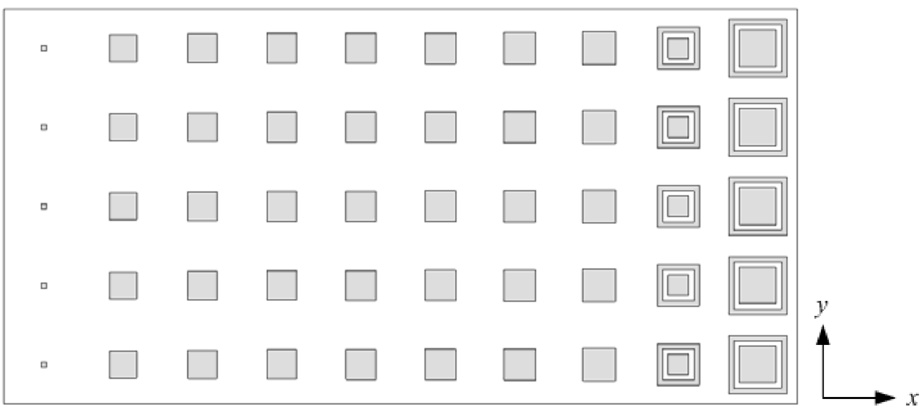


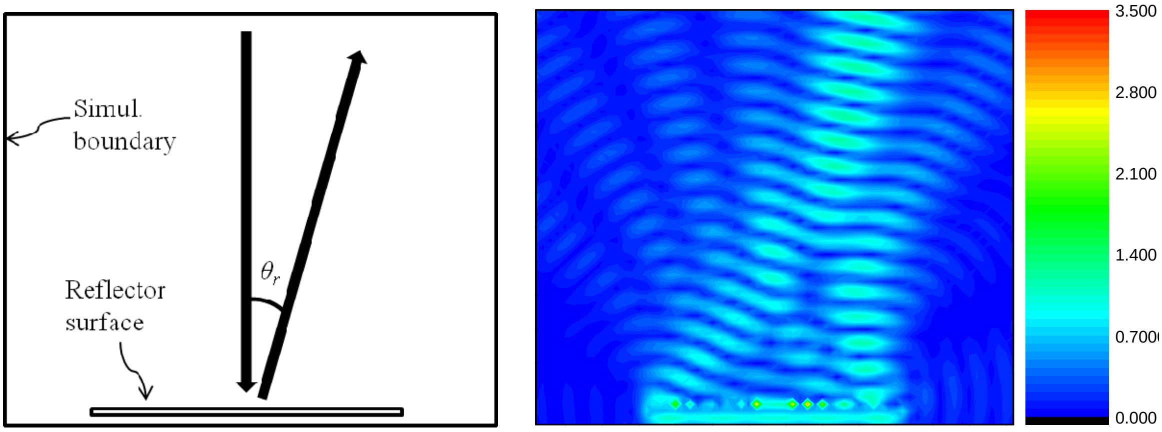
Figure 3: The beam tilting reflector surface

reflection phases are arrayed. The reflection phase difference between the adjacent elements φ_e is 40.0°. The propagation direction of the reflected wave θ_r can be calculated as follows [7].

$$\theta_r = \sin^{-1}\left(-\frac{\phi_e \lambda}{2\pi d}\right) \quad (1)$$

As shown in Fig. 2, the SSP cannot provide full range of reflection phase. Therefore, if the surface is designed with only the SSP elements, there will be an error in the reflection phase distribution of the surface, which can cause an error in beam tilt angle. The error will be increased as the number of SSP elements which do not satisfy the required reflection phase is increased. In order to prevent such problem, two elements at the end of the surface have been replaced by the RLP elements which can provide required reflection phases. Since the surface mostly consists of the SSP elements with minimum number of the RLP elements, the design process complexity and the possibility of fabrication error is lower than the surface designed only with the RLP elements.

From (1), θ_r is given as 12.8°. Using full wave simulation, a normally incident plane wave was excited and the reflected near-field from the surface has been extracted. The simulation setup and the extracted electric field are shown in Fig. 4, and it is observed that the reflected field is tilted from the normal direction, as expected. The far-field pattern of the reflected field has been also calculated and it is presented in Fig. 5. The main beam direction is 12.8°, which is the same as the value calculated by (1).



(a) Simulation setup (b) Reflected E-field [V/m]

Figure 4: Reflected field simulation for plane wave incident (Near-field)

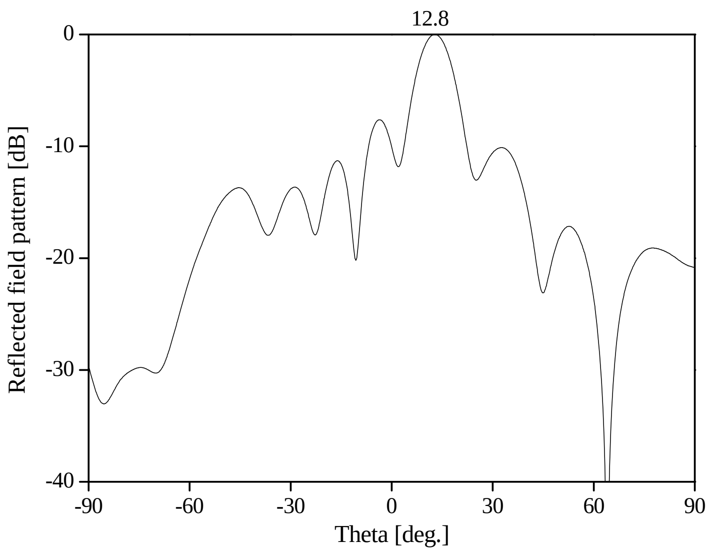


Figure 5: Reflected field simulation for plane wave incident (Far-field)

4. Conclusion

In this paper, the reflector surface composed of two different types of microstrip patch element has been studied. Although SSP element is easy to design a reflector surface, it cannot provide full range of required reflection phase. In case of complex shaped elements such as RLP element, the any required value of reflection phase can be realized, but the design process becomes complicated and the probability of fabrication error increases. Therefore, by using SSP elements and RLP elements together, the problem of insufficient range of reflection phase of SSP element has been solved with minimally increased design complexity. The reflector surface has been designed to reflect the normal incident field in the tilted angle of 12.8°, and the full wave simulation results which agree with theoretical prediction have been presented. As a future work, this type of element combination can be applied to high gain reflectarray antennas design

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