

A new broadband reflectarray antenna using novel single-layer elements (Postprint)

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Abstract

A novel single-layer reflectarray element for broadband use is proposed. Ansoft HFSS is used to analyze the reflection phase for the element. By varying the element size, a slow slope of the reflection phase curve with the phase range over 600° is achieved. A center-fed 121-element reflectarray antenna is designed using the proposed elements and a linearly polarized pyramidal horn antenna is used as the feed of the reflectarray. The simulated results show that the gain of 24.42dB at the center frequency of 13.58GHz with 3-dB gain bandwidth of 36.8% (from 11.08 16.08GHz), demonstrating a wideband performance compared to the conventional designs.

Full Text

A New Broadband Reflectarray Antenna Using Novel Single-Layer Elements

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ABSTRACT

A novel single-layer reflectarray element for broadband use is proposed. Ansoft HFSS is used to analyze the reflection phase characteristics of the element. By varying the element size, a slow slope of the reflection phase curve is achieved with a phase range exceeding 600° . A center-fed 121-element reflectarray antenna is designed using the proposed elements, with a linearly polarized pyramidal horn antenna employed as the feed. The simulated results demonstrate a gain of 24.42 dB at the center frequency of 13.58 GHz with a 3-dB gain

bandwidth of 36.8% (from 11.08 to 16.08 GHz), showing superior wideband performance compared to conventional designs.

Index Terms—reflectarray, single-layer, broadband, center-fed

1. INTRODUCTION

Reflectarray antennas combine features of both reflector antennas and array antennas [1], offering potential applications in space-based radar due to their flat profile, low cost, low weight, high efficiency, and high gain characteristics. However, their inherent narrow bandwidth typically limits practical applications. For reflectarrays, bandwidth is constrained by two primary factors [2]: the narrow bandwidth of the individual elements and differential spatial phase delay.

Numerous studies have investigated bandwidth improvement techniques for reflectarrays [3-6]. In [3], a two-layer reflectarray with rectangular patches of variable size demonstrated superior bandwidth performance compared to conventional single-layer designs. Reference [4] presented a disk element with attached phase-delay lines, achieving a 3-dB gain bandwidth of approximately 18%. A prime-focus reflectarray employing rectangular patch and rectangular ring elements was introduced in [5], with measured results showing a 1-dB gain bandwidth of 30%. In [6], a new phase-shifting element achieved a large simulated bandwidth of 18%. Additionally, by replacing conventional near-resonant patches with artificial impedance surfaces consisting of closely spaced electrical patches on a grounded dielectric substrate, 1-dB gain bandwidths exceeding 20% were obtained [7].

This paper presents a novel single-layer element structure specifically designed for bandwidth enhancement. The reflection phase response is obtained by varying the element size, achieving a 600° reflection phase range. A center-fed 121-element reflectarray is subsequently designed using these proposed elements.

2. ELEMENT DESIGN

The proposed reflectarray element consists of four quarter circles and a quasi-crossed dipole, as illustrated in Fig. 1 [Figure 1: see original paper]. The length of the quasi-crossed dipole is denoted as a . The four quarter circles are identical with radius r , and the gap between the quarter circles and the quasi-crossed dipole is g . The elements are assumed to be printed on a dielectric substrate with relative permittivity of 2.25 and thickness h . The lattice period of the element L is 13 mm, which corresponds to 0.59 wavelengths at 13.58 GHz.

The phase response is controlled by varying the element size. The relationships between the parameters are defined as $r = k \cdot a$ and $g = k \cdot a$. After optimiza-

tion, the final design parameters are: $k = 0.432$, $k = 0.048$, and $h = 2$ mm. The element is simulated using Ansoft HFSS with master-slave boundaries and Floquet ports to analyze its reflection characteristics.

Fig. 2 [Figure 2: see original paper] shows the reflection phase response of the element for different incident angles at 13.58 GHz. The results demonstrate that incident angle has minimal influence on the phase response when the angle does not exceed 30° . Fig. 3 [Figure 3: see original paper] presents the reflection phase response versus the length of the quasi-crossed dipole a for different frequencies (11.58–15.58 GHz). The reflection phase range of the element reaches 600° at 13.58 GHz, which significantly exceeds the minimum required range of 360° .

3. REFLECTARRAY DESIGN AND RESULTS

A center-fed 121-element reflectarray using the proposed element is designed and simulated based on the phase response performance at 13.58 GHz. The reflectarray is configured to generate a beam in the broadside direction. The model of the proposed reflectarray antenna is presented in Fig. 4 [Figure 4: see original paper]. A linearly polarized pyramidal horn antenna is designed to serve as the feed for the reflectarray.

The radiation patterns of the pyramidal horn antenna at 13.58 GHz are shown in Fig. 5 [Figure 5: see original paper]. The distance between the phase center of the horn antenna and the reflectarray is 143 mm, corresponding to an F/D ratio of 1. Fig. 6 [Figure 6: see original paper] illustrates the simulated radiation patterns of the reflectarray antenna in both E-plane and H-plane at the center frequency of 13.58 GHz, showing a simulated gain of 24.42 dB. The simulated gain of the reflectarray and feed horn across frequencies from 10.58 GHz to 17.08 GHz is depicted in Fig. 7 [Figure 7: see original paper], demonstrating a 3-dB gain bandwidth of approximately 36.8% (11.08–16.08 GHz).

4. CONCLUSION

A novel single-layer reflectarray element structure for bandwidth improvement has been proposed. The reflection phase curve exhibits sufficient phase variation range across a wide frequency band. Using this element, a center-fed 121-element reflectarray operating at 13.58 GHz has been designed and presented. A pyramidal horn antenna is used as the feed for the reflectarray. The simulated results show that a 3-dB gain bandwidth of 36.8% is achieved. Experimental verification will be conducted in future work.

5. REFERENCES

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