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Reflectarray Antenna Capable of 1-Bit Switchable W-Band Beamforming Network

Bismark Asamani*, Seongmin Pyo**★

Abstract

This paper presents a new reflectarray antenna capable with 1-bit switchable capability for W-band beamforming network. The proposed antenna has been optimized using two unit-cells with sizes of 1.0 mm and 1.3 mm to form a total number of 193 radiating elements on a square aperture surface of length 30 mm. These radiating elements are spaced 0.5 wavelengths apart and fed by a 15 dBi pyramidal horn antenna as the feed antenna placed 53 mm away from the aperture center. The proposed reflectarray achieves a realized peak gain of 22.52 dBi, a half-power beamwidth of 5.1° in both *E*- and *H*-planes at the test frequency of 80 GHz and operates over a wide bandwidth from 74 GHz to 90 GHz.

Key words : Reflectarray antenna, W-band, 2 states, square unit cell, beamforming, switching states

Ⅰ. INTRODUCTION

For services like audio and videostreaming, videoconferencing, cloud storage and online gaming, there is a growing demand for high-speed wireless data transmission. A move to higher frequency bands such as W-band, which offer huge bandwidth for increased channel capacity to meet these requirements has become necessary [1]. However, atmospheric attenuations, limited coverage, and high path loss are some challenges associated with these higher frequency bands [2]. Traditional antennas such as parabolic reflectors, lens antennas, and microstrip arrays are usually employed to solve the aforementioned challenges. Limited beam scanning capability, bulky nature, and manufacturing difficulties at these higher frequencies make the parabolic reflectors not suitable even though they are highly efficient radiators. On the other hand, microstrip arrays that offer a low profile, lightweight, and beam scanning abilities suffer from complexity and serious losses of feed networks, making them less efficient [3]. For the advantages of low profile, low cost, high gain, beam scanning ability, surface mount ability, and high efficiency [4], a W-band reflectarray antenna using 2 kinds of unit-cell is therefore proposed in this paper.

* Master's Degree Student, Dept. of Information and Communication Engineering, Hanbat National University
** Associate Professor, Dept. of Information and Communication Engineering, Hanbat National University
★ Corresponding author
E-mail : spyo@hanbat.ac.kr, Tel : +82-42-821-1202
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II. DESIGN METHODOLOGY

The traveling electromagnetic waves from the feed arrive at each element on the aperture with different phases and this is referred to as the spatial phase delay [5]. While compensating for these phase delays, the elements on the aperture surface called unit-cells, re-radiate the incident waves from the feed as depicted in Fig. 1. Split rings, hexagonal and bow-tie element types [6] are some proposed unit-cell structures used for the phase compensation. A variable size patch unit-cell element is used in this paper. The unit-cell is analyzed using floquet boundary conditions and the simulation setup of the unit-cell is shown in Fig. 2. For fabrication considerations, the patch element is printed on Rogers RT/Duroid 5880 substrates with a dielectric constant of 2.2 and thickness,

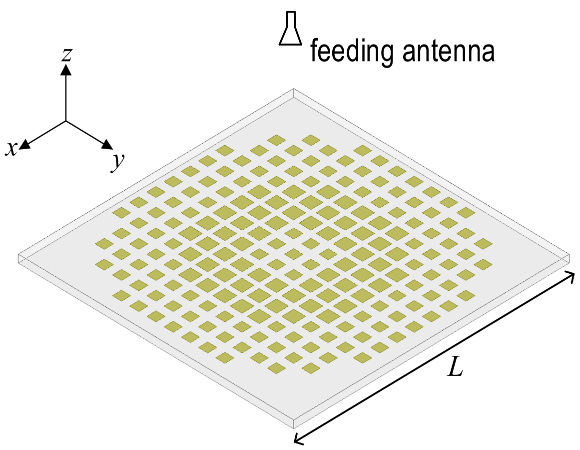


Fig. 1. Configuration of the proposed reflectarray antenna.

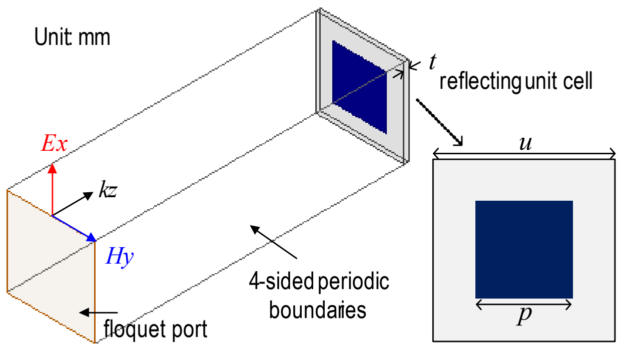


Fig. 2. Simulation setup of the reflectarray unit-cell based on Floquet method.

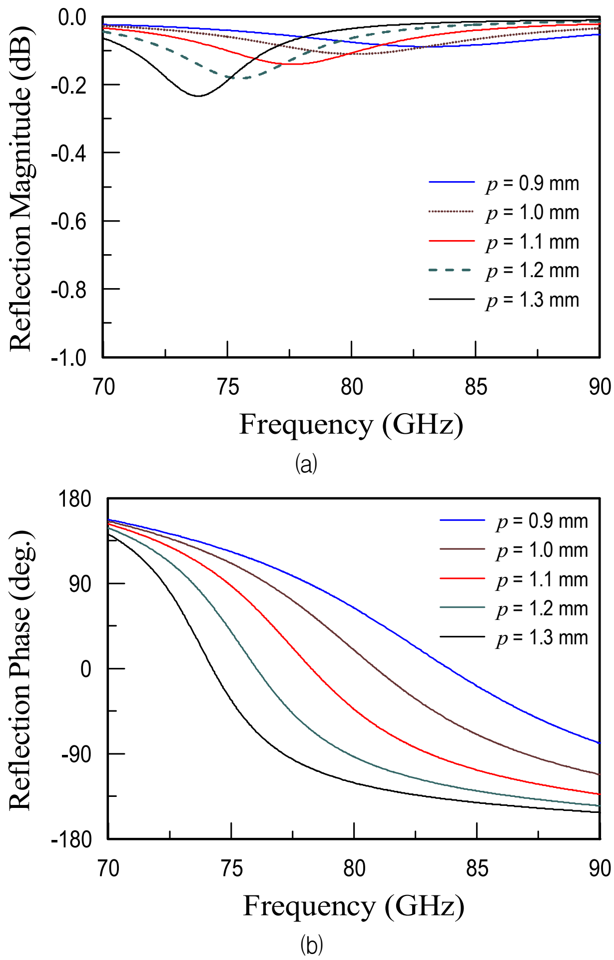


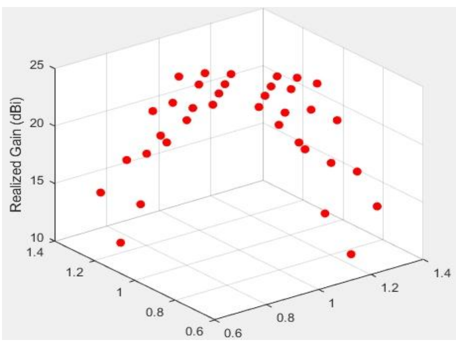
Fig. 3. Simulation results of the reflectarray unit-cell with patch size variation. (a) Reflection magnitude and (b) reflection phase.

t of 1.57 mm. The unit-cell is of size, u of 1.875 mm which is half wavelength at 80 GHz. The length of the square patch, p is varied from 0.2 mm to 1.6 mm. With an aperture of size L = 30 mm, that is 8 wavelengths at 80 GHz, and a 15 dBi pyramidal horn called FMWAN1018, the product of Fairview Microwave Co. Ltd. selected and placed at 53 mm away from the center of the aperture, 5 unit-cells size is selected to compensate for the phase delays on the aperture in this paper. The characteristics of the selected unit-cells are shown in Fig. 3.

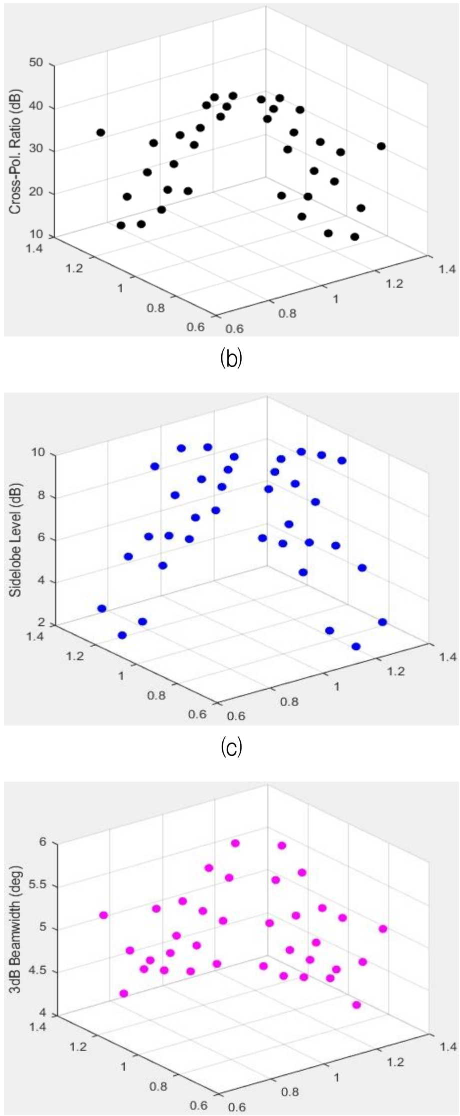
Unit-cells of size, p = 0.9 mm, 1.0 mm, 1.1 mm, 1.2 mm, and 1.3 mm with 63.89°, 19.33°, −43.14°, −93.36°, and −120.76° reflection phases, respectively, are selected as displayed in Fig. 3b. A reflection loss below 0.3 dB is recorded for the selected unit-cells indicating minimal overall element loss in the reflectarray design. The 1-bit switchable capability is achieved by the combination of two unit-cell sizes. Two unit-cell sizes p = 0.7 mm and 0.8 mm are added to the previously selected patch sizes and are tested and optimized.

III. RESULTS AND DISCUSSION

The reflectarray antenna gain for the various cell size combination is shown in Fig. 4a, while the cross-polarization levels (cross-pol.), sidelobe levels (SLL), and half-power beamwidths (HPBW) are displayed in from Figs. 4b to 4d, respectively. For p = 0.9 mm and 1.0 mm, a maximum gain of 23.3 dBi, cross-pol. of 46.5 dB, SLL of 8.2 dB, and HPBW of 4.8° is achieved. A gain of 22.8 dBi and SLL of 8.5 dB is recorded for p = 1.0 mm and 1.1 mm. For SLL above 9 dB, unit-cell combination p = 1.0 mm and 1.3 mm shows a better performance. The proposed reflectarray antenna is designed using the aforementioned unit-cell combination. The return loss of the proposed reflectarray displayed in Fig. 5 is below -10 dB for a wideband from 74 GHz to 90 GHz. The far-field radiation pattern of the proposed antenna is shown in Fig. 7. The antenna gain of 22.52 dBi is realized in both E- and H- planes. A SLL of 8.6 dB and 9.4 dB is obtained in E- and H-plane, respectively. A HPBW of 5.1° is recorded in both E- and H-planes. A cross-pol. level of 29.1 dB is achieved in the H-plane.



(a)



(d)

Fig. 4. Parametric analysis of the reflectarray antenna based on 1-bit status of the unit cell for (a) antenna gain, (b) cross-pol. ratio, (c) side-lobe level, and (d) half-power beamwidth.

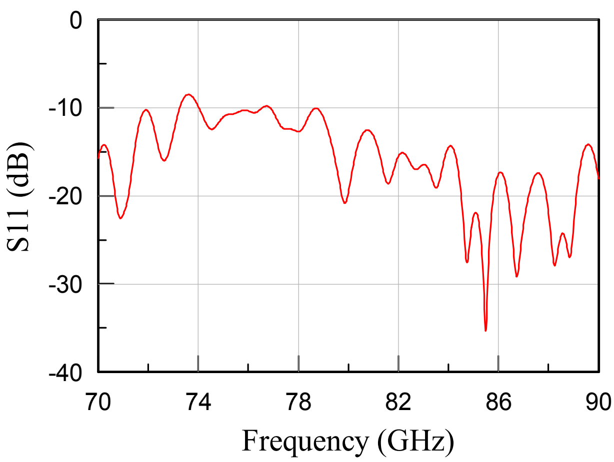


Fig. 5. Return loss of the proposed reflectarray antenna.

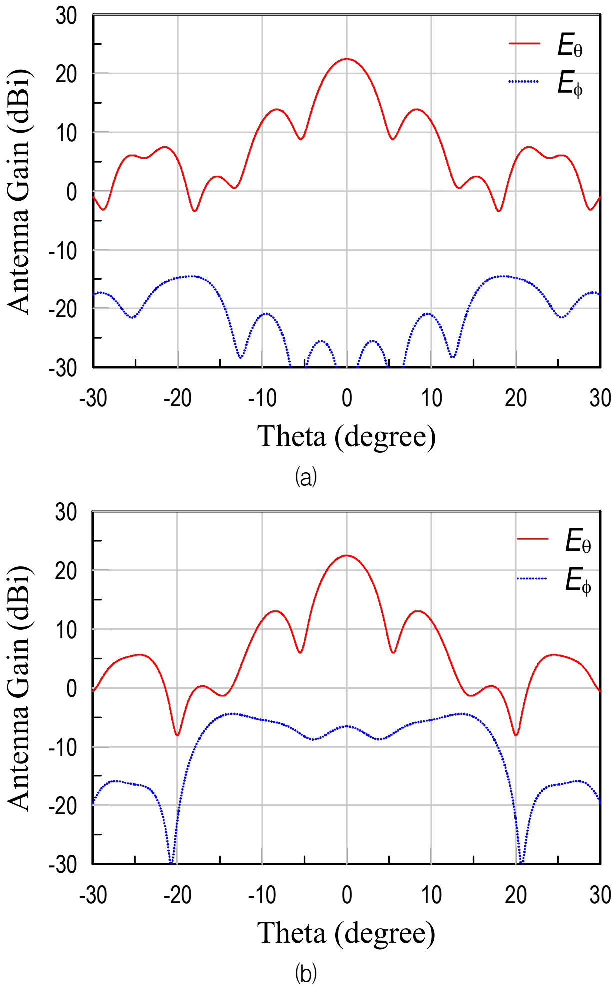


Fig. 6. Far-field radiation patterns of the proposed reflectarray antenna at 80 GHz of test frequency at (a) *E*-plane (f = 90°) and (b) *H*-plane (f = 0°).

Ⅳ. CONCLUSION

The reflectarray antenna with 1-bit switchable capability for W-band beamforming network operating at 80 GHz is demonstrated. A 1-bit switchable capability is achieved by a combination of two unit-cell sizes. Good antenna performance is obtained using the two cell size combination. A gain of 22.52 dBi is recorded for 1.0 mm and 1.3 mm unit-cell size combinations at the test frequency. A sidelobe level over 8 dB and a cross-polarization level over 29 dB is also achieved for the proposed antenna.

References

[1] L. Chorchos, J. P. Turkiewicz, S. Rommel, and S. Spolitis, “W-band real-time transmission utilizing a reconfigurable RAU for NG-PON networks,” *Advances in Wireless and Optical Communications*, pp.66-69, 2016. DOI: 10.1109/RTUWO.2016.7821857

[2] M. H. Dahri, M. H. Jamaluddin, and M. R. Kamarudin, “A review of wideband reflectarray antennas for 5G communication systems,” *IEEE Access*, vol.5, pp.17803-17815, 2017. DOI: 10.1109/ACCESS.2017.2747844

[3] Y. -W. Wu, Z. -C. Hao, and Z. -W. Miao, “A planar W-band large-scale high-gain substrate-integrated waveguide slot array,” *IEEE Trans. Antennas Propag.,* vol.68, no.8, pp.6429-6434, 2020. DOI: 10.1109/TAP.2020.2969999

[4] G. Wu, S. Qu, and S. Yang, “Wide-angle beam-steering reflectarray with mechanical steering,” *IEEE Trans. Antennas Propag.,* vol.66, no.1, pp. 172-181, 2018. DOI: 10.1109/TAP.2017.2775282

[5] P. Nayeri, F. Yang, and A. Z. Elsherbeni, Reflectarray Antennas: Theory, Design and Applications, New York: Wiley, 2018.

[6] M. H. Dahri, M. H. Jamaluddin, and M. R. Kamarudin, “Aspects of efficiency enhancement in reflectarrays with analytical investigation and accurate measurement,” *Electronics*, Vol.9, No.11, 2020. DOI:10.3390/electronics9111887