Adaptation of Reflectarray Antenna to Yield Scanning-Spot Beam

Yusuke Kaimori[1*], Shigeru Makino[1], Shota Takino[1], Sanshiro Shigemitu[1]
[1]Kanazawa Institute of Technology 7-1 Ogigaoka, Nonoichi-shi, Ishikawa, 921-8501, Japan
[*]email: b1714005@planet.kanazawa-it.ac.jp

***Abstract*—Herein, a novel reflectarray antenna design with a mirror configuration is proposed. Through adaptation of the reflectarray antenna's frequency and polarization (two of its characteristics that change beam direction), a multi-scanning beam can be realized, whose performance matches that of a conventional multi-spot beam with one reflecting mirror. A scanning-spot beam that changes beam direction using frequency in the elevation direction and polarization in the azimuth direction in the Ka band is examined. As a result, it is verified that the proposed design efficiently covers the desired service area.**

Keywords—reflectarray, mirror configuration, scanning spot beam

I. Introduction

As per prior research, in a multi-beam communication system using reflectarray antennas, a service area can be covered using a few mirror planes by changing the beam direction with respect to its polarization and frequency [1]-[4]. In this paper, a new reflectarray design is proposed that changes the beam direction using a mirror configuration and a linear element.

II. Element design

A. Design model

Fig. 1 shows the linear element employed to change phase according to the reflectarray polarization [5]. Table I lists the element parameters. For gradual phase control, the lengths of the three linear elements are extended as follows: l_{A1} and l_{B1} to $0.36\lambda_0$, l_{A2} to $0.215\lambda_0$, and l_{B2} to $0.24\lambda_0$. Here, the total element lengths of layer A and layer B are l_A and l_B, respectively, and they are defined as $l_A = l_{A1} + l_{A2}$ and $l_B = l_{B1} + l_{B2}$.

B. Design results

The H-polarization element length was fixed at $l_B = 0.84\lambda_0$, and that for V-polarization, l_A, was varied from $0.01\lambda_0$ to $0.79\lambda_0$. Similarly, the V-polarization element length was fixed at $l_A = 0.79\lambda_0$, and that for H-polarization, l_B, was varied from $0.01\lambda_0$ to $0.84\lambda_0$. Fig. 2 and 3 show the respective analysis results. Both polarizations could cover a phase region of 360° or more. Moreover, a phase change of approximately 0.75 ° was observed when the element length of the V polarization was varied, and a phase change of approximately 1.19 ° was observed when the element length of the H polarization was varied. Therefore, it can be inferred that the interference between the elements is small, and independent phase control is possible for each polarization.

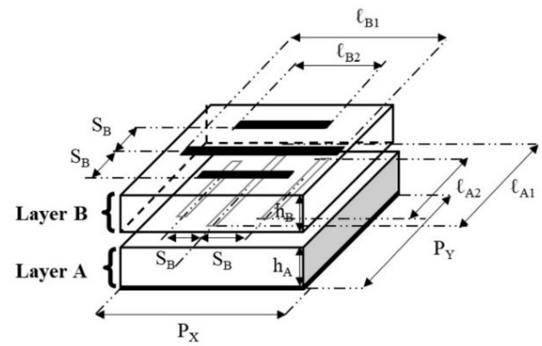

Fig. 1. Element shape

TABLE I ELEMENT DESIGN PARAMETERSA

Thickness h_A , h_B	$0.15\lambda_0$, $0.02\lambda_0$
Dielectric constant ε_r	2.56, 2.59
tanδ	0.0015, 0.0017
Line width w	$0.02\lambda_0$
Element length l_A , l_B	$0.01\sim0.79\lambda_0$, $0.01\sim0.84\lambda_0$
Element spasing $P_x = P_y$	$0.38\lambda_0$

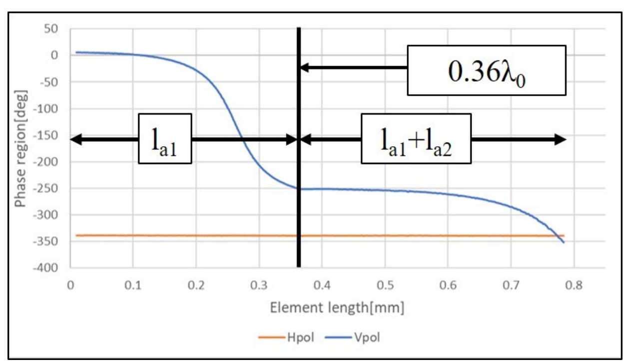

Fig. 2. Reflection phase characteristics of V-pol

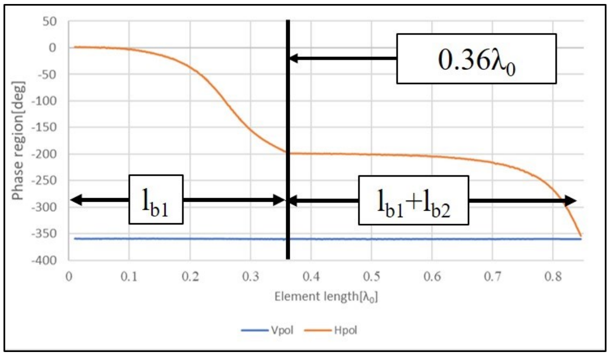

Fig. 3. Reflection phase characteristics of H-pol

III. Reflector drsign

Fig. 4 shows the mirror configuration, and Table II list the mirror surface design specifications. The five primary radiators were placed in a way that beams of frequencies f_L and f_H are located 1 beam width away from the beam at the center frequency f_0. Radiators 1 and 3 were located +2 beam widths and -2 beam widths away from the center respectively, in the elevation direction while radiator 2 was located at the center Radiator 4 was +0.87 and +0.5 beam widths away from the center in the azimuth and elevation directions, respectively, whereas radiator 5 was +0.87 and -0.5 beam widths away from the center in the azimuth and elevation directions, respectively.

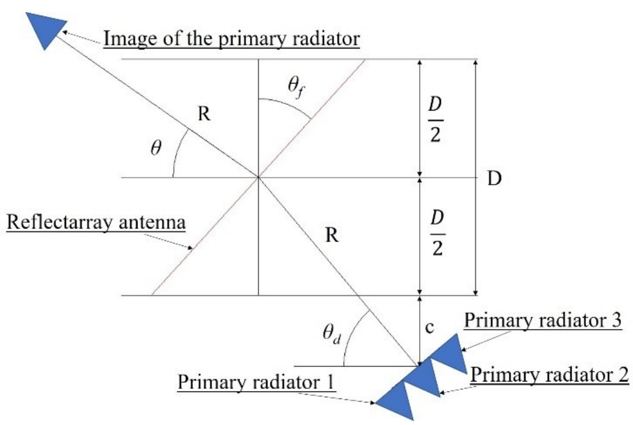

Fig. 4. Mirror configuration

TABLE II Mirror surface design parameters

Tilt angle θ_f [deg]	42.14
Image horn angle θ [deg]	34.28
Horn angle θ_d [deg]	50
Beam direction [deg]	±0.65
Diameter of opening surface D	$41.2\lambda_0$
Distance from primary radiator to the center of aperture R	$43.13\lambda_0$
Clearance c	$12.43\lambda_0$
Frequency f_L	$0.96 f_0$
Frequency f_H	$1.04 f_0$

IV. Analysis result

As per the design parameters, analysis was performed via the aperture distribution method. The resonant element used in the design was assumed to be an ideal element with no frequency characteristics. Fig. 5 shows the 35 dBi contour map for three frequencies and two polarizations at each of the five horns. Clearly, the V-polarized beam was emitted in the azimuth direction at –0.65 degrees, and the H-polarized beam emitted at +0.65 degrees in the elevation plane. The f_H beam of horn 1 and f_L beam of horn 2 overlap ±1 beam width away from the f_0 beam. Similarly, the f_L beam of horn 2 and the f_H beam of horn 3 overlap ±1 beam width away from the f_0 beam. Thus, a single reflectarray can efficiently cover the desired service area.

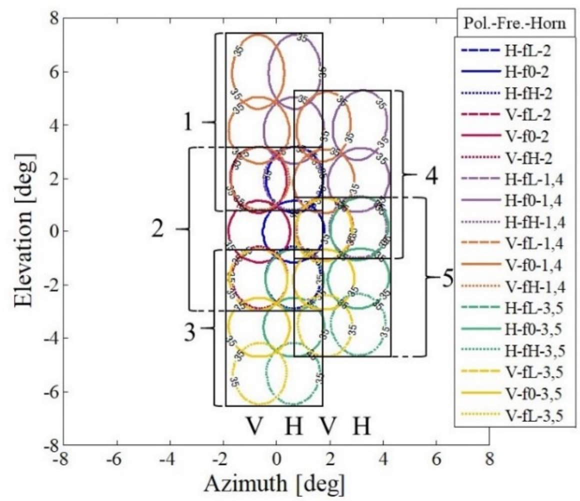

Fig. 5. 35dBi contour map

V. Conclusion

The results show that the beam direction varies depending on the polarization and frequency of the reflectarray, which was the aim of this study. In the future, we plan to fabricate a reflectarry based on the design parameters proposed in this study and further examine the validity of the design.

This study was supported by JSPS(20K04491).

References

[1] J.Huang, and J. A .Encinar, "Reflectarray antennas," Wiley Online Library, New Jersey, 2007.

[2] S. Makino, R. Obata, K. Takeshima, Y. Sunaga, M. Takikawa, H. Nakajima, "Satellite Mounted Antennas Using Refrectarray Antenna," IEICE, , 2018.

[3] M. Fukaya, R. Obata, S. Makino, H. Nakajima and M. Takikawa, "NEW SATELLITE ANTENNA CONCEPT USING REFLECTARRAY ANTENNAS," ISAP, China, October, 2017.

[4] M. Fukaya, R. Obata, S. Makino, M. Takikawa, H. Nakajima, "Reflectarray antenna changing beam direction by polarization," EuCAP, Denmark, March 2020.

[5] R. Florencio, J. Encinar, R. R. Boix, V. Losada, and G. Toso, "Reflectarray Antennas for Dual Polarization and Broadband Telecom Satellite Applications", IEEE AP, vol.63, pp. 12341246, April 2015.