978-1-6654-7962-2/22/$31.00 ©2022 IEEE

Development of Scanning Spot Beam Reflectarray Antenna

Yusuke Kaimori
Kanazawa Institute of Technology
7-1 Ogigaoka, Nonoichishi,
Ishikawa 921-8501, Japan
b1714005@planet.kanazawa-it.ac.jp

Shigeru Makino
Kanazawa Institute of Technology
7-1 Ogigaoka, Nonoichishi,
Ishikawa 921-8501, Japan
makino@neptune.kanazawa-it.ac.jp

Masayoshi Takao
Kanazawa Institute of Technology
7-1 Ogigaoka, Nonoichishi,
Ishikawa 921-8501, Japan
b1833012@planet.kanazawa-it.ac.jp

Shinichi Yamamoto
Mitsubishi Electric Corporation
5-1-1 Ofuna, Kamakura
Kanagawa 247-0056, Japan
Yamamoto.Shinichi@dr.MitsubishiElectric.co.jp

Yasuhiro Nishioka
Mitsubishi Electric Corporation
5-1-1 Ofuna, Kamakura
Kanagawa 247-0056, Japan
Nishioka.Yasuhiro@bx.MitsubishiElectric.co.jp

***Abstract*— Conventional multispot beams and multiscanning beams have been developed using a single reflector by combining the characteristics of reflectarray antennas, which change the beam direction, depending on the frequency and polarization. In this study, we developed a design method and obtained measurement results of a scanning spot beam reflectarray antenna whose beam direction is changed by the frequency in the elevation direction and polarization in the azimuth direction.**

***Keywords*— reflectarray antenna, scanning spot beam, polarization, frequency**

I. INTRODUCTION

In a multi-beam communication system with reflectarray antennas, covering a service area using a few mirror planes can be achieved by changing the beam direction based on the polarization and frequency [1][2][3]. In this paper, we present the measurement results of a reflectarray fabricated using the design method described in a previous report [4].

II. ELEMENT DESIGN

A. Design model

Fig. 1 shows the linear element employed to change the phase according to the reflectarray polarization [5][6]. Table I lists the element parameters. The lengths of the three linear elements were extended to achieve gradual phase control as follows: l_{A1} and l_{B1} to $0.36\lambda_0$, l_{A2} to $0.25\lambda_0$, and l_{B2} to $0.32\lambda_0$. Let the total element lengths be l_A and l_B, respectively, and let $l_A = l_{A1} + 2l_{A2}$ and $l_B = l_{B1} + 2l_{B2}$.

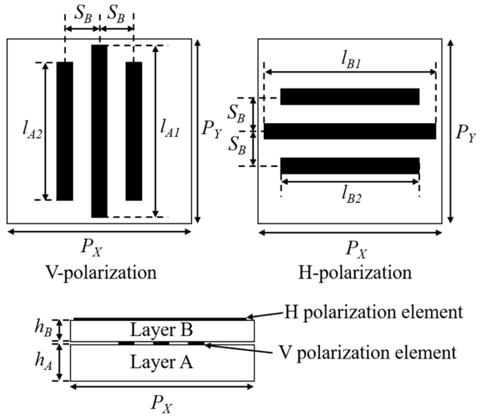

Fig. 1. Element design

TABLE I. ELEMENT DESIGN PARAMETERS

Element spacing $P_X = P_Y$	$0.38\lambda_0$
Element length l_A, l_B	$0.01-0.87\lambda_0$, $0.01-1.01\lambda_0$
Line width w	$0.02\lambda_0$
Line spacing S_B	$0.05\lambda_0$
Thickness h_A, h_B	$0.15\lambda_0$, $0.02\lambda_0$
Dielectric constant ε_r	2.56, 2.59
tan δ	0.0015, 0.0017

B. Design results

The H-polarization element length was fixed at $l_B = 1.01\lambda_0$, and that for the V-polarization, l_A, ranged from $0.01\lambda_0$ to $0.87\lambda_0$. Similarly, the V-polarization element length was fixed at $l_A = 0.87\lambda_0$, and that for the H-polarization, l_B, was varied from $0.01\lambda_0$ to $1.01\lambda_0$. Figs. 2 and 3 show the respective analysis results. Both polarizations covered a phase region of 360° or larger. When the element length of the H-polarization was changed, the V-polarization phase changed by a maximum of approximately 0.53°. When the element length of the V-polarization was changed, the H-polarization phase changed by a maximum of approximately 2.04°. Therefore, it can be inferred that the interference between the elements was slight, and independent phase control was possible for each polarization.

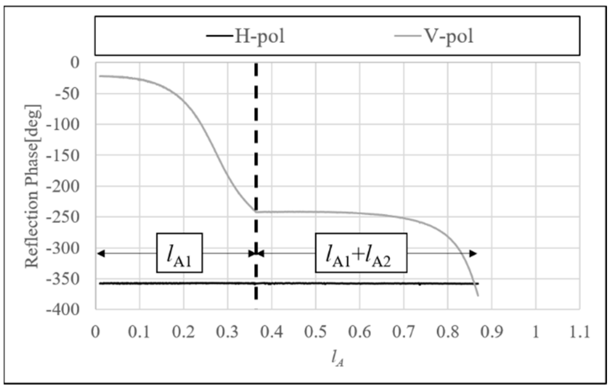

Fig. 2. Reflection phase characteristics of V-polarization

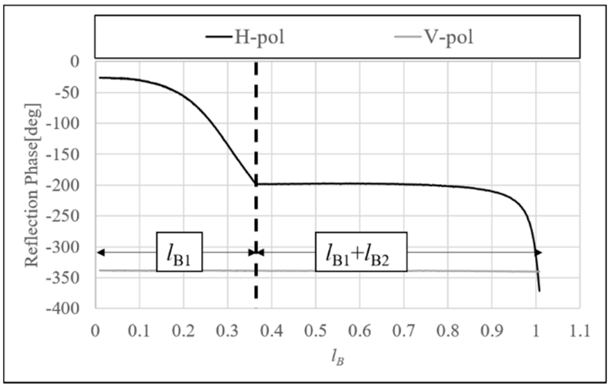

Fig. 3. Reflection phase characteristics of H-polarization

III. Reflector Design

The mirror surface was fabricated using the design values obtained in a previous study [4]. Fig. 4 shows the computer-aided design (CAD) of the mirror surface of the reflectarray with the respective elements. The aperture diameter is 41.2λ$_0$. Two CAD drawings are depicted in Fig. 4; however, because they are superposed on two layers, they appear as a single mirror surface. The image on the left is the mirror surface of the V-polarization, printed at the back of dielectric layer B. The image on the right is a mirror surface of the H-polarization, printed on the surface of dielectric layer B.

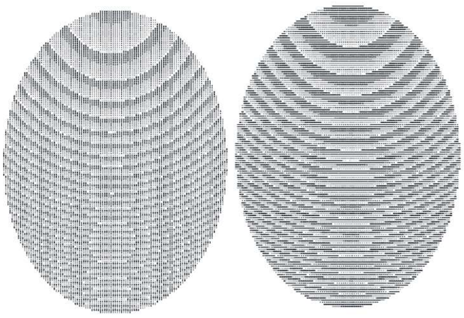

Fig. 4. CAD data of reflectarray

IV. Analysis Results

A contour map at 35 dBi is shown in Fig. 5. The analysis was performed using the aperture distribution method. In addition, ideal elements were used. The results confirmed that the desired area was efficiently covered.

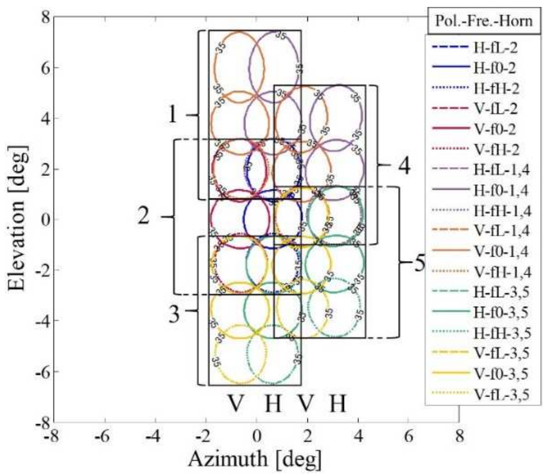

Fig. 5. 35dBi contour map

V. Measurement Results

A contour map at 35 dBi is shown in Fig. 6. Measurements were taken in the near filed and results are shown in terms of directivity gain. The desired area was efficiently covered by a single reflectarray, as indicated by the measurement results. However, the directivity gain at a high frequency (f_H) of the H-polarization was low. The beam directions at frequencies f_H and f_L were radiated ±1 beam width away from the beam at the center frequency when observed in the elevation plane. The V-polarized beam was emitted in the −0.67° direction, and the H-polarized beam was emitted in the +0.76° direction when observed in the azimuth plane (f_0). The V-polarized beam was generally consistent with the analytical results; however, the H-polarized beam changed by +0.11° compared with the analytical results.

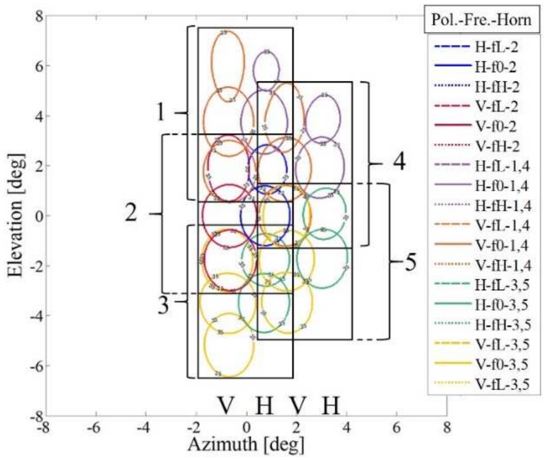

Fig. 6. 35dBi contour map

VI. Conclusion

The results of a study on reflectarrays with different beam directions based on the polarization and frequency are presented. The measurement results show that the beam changes with frequency in the elevation direction and with polarization in the azimuthal direction. Thus, it is feasible to cover the desired area efficiently using a single reflectarray. However, the gain decreased at high frequencies in the H-polarization. We believe that this may be due to the fact that the elements affecting the H and V polarization are separated by layer in the elements. In future studies, we will consider elements that do not induce gain reduction.

This study was supported by JSPS (20K04491).

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