Scanning Spot Beam Reflectarray Antenna Study

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***Abstract*— By combining the characteristics of a reflectarray antenna to change the beam direction according to the frequency and polarization, conventional multi-spot and multi-scanning beams using a single reflector have been proposed. We have previously shown the design method and analysis results of scanning spot beams whose beam direction is changed by frequency in the elevation direction and by polarization in the Azimuth direction. In this study, the measurement results of the scanning spot beam reflectarray antenna fabricated from the designed values are presented.**

Keywords—reflectarray, scanning spot beam, frequency, polarization

I. INTRODUCTION

In a multibeam communication system using reflectarray antennas, a service area can be covered using a few mirror planes by changing the beam direction according to the polarization and frequency [1][2][3]. In this study, the measurement results of the scanning spot beam reflectarray antenna fabricated from the designed values are presented.

II. SCANNING SPOT BEAM

This study aims to achieve an efficient coverage of the desired service area using a scanning spot beam. Fig. 1 shows the arrangement of the primary radiators. Primary radiators were placed at five locations. In Fig. 1, the green circles represent the primary radiator. These radiators were placed two beamwidths apart.

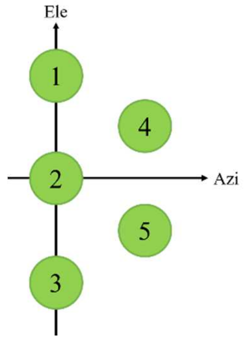

Fig. 1. Position of the primary radiator

Fig. 2 shows the beam area where green circles indicate the beams at the design frequency for each horn. For each horn, the beam must swing from the center frequency (f0) to the high-frequency (fH) side and low-frequency (fL) side by one beamwidth. As shown in the figure, fH of horn 1 and fL of horn 2 overlap to cover the service area efficiently. To realize such a change in the beam direction according to the frequency, a mirror surface should be designed. In the azimuthal direction, the area is covered by changing the beam direction, depending on the polarization. In Fig. 2, the red and blue frames represent the V and H polarizations, respectively. To change the beam direction depending on the polarization, an element design must be performed, which requires two properties: covering a 360° reflection phase-control area and having independent phase control.

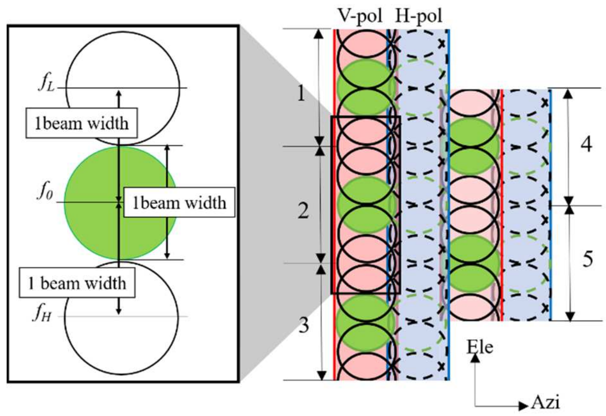

Fig. 2. Primary radiator position

III. ELEMENT DESIGN

Fig. 3 shows the linear element employed to change the phase according to the reflectarray polarization [4][5][6].

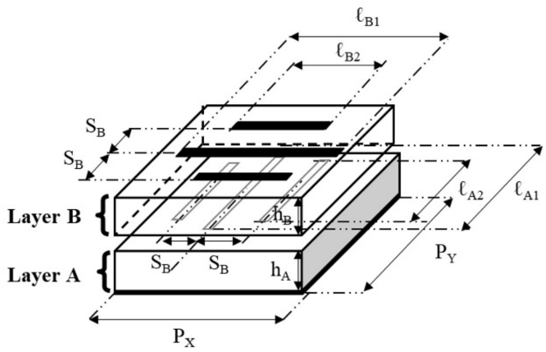

Fig. 3. Element design

The under and upper sides are the V- and H-polarized wave elements, respectively. The elements are two-layered, with V-polarized elements on the lower side of layer B and H-polarized elements on the upper side. The parameters of the elements are listed in Table I.

TABLE I. PARAMETERS OF THE DESIGNED ELEMENT

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 spacing S_B	$0.05\lambda_0$
Line width w	$0.02\lambda_0$
Element length l_A, l_B	0.01~$0.87\lambda_0$, 0.01~$1.01\lambda_0$
Element spacing P_X=P_Y	$0.38\lambda_0$

IV. Reflector Design

Fig. 4 shows the arrangement of the mirror surface, and Table II lists the design values. The elevation direction can change the beam direction, depending on the frequency. To achieve this, the horn angle of the image θ was determined. θ can be obtained using Eq. (1) [7]. Based on the design value, the horn angle of the image was 34.28°. Also, multiple primary radiators should be placed to ensure that the beam shift covers the area.

$$\theta = \tan^{-1}\left(\frac{\lambda_0}{\lambda_0 - \lambda}\tan\left(\alpha\frac{\lambda_0}{D}\right)\right) \quad (1)$$

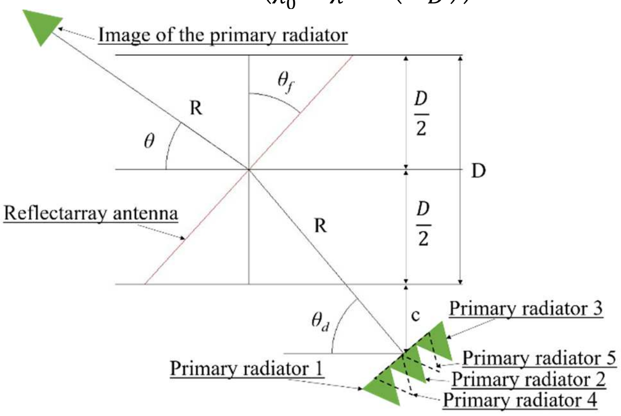

Fig. 4. The arrangement of the mirror surface

TABLE II. Design Parameters of the Mirror Surface

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

V. Analys Result

A contour map at 35 dBi is shown in Fig. 5. The analysis was performed using the aperture distribution method. The figure confirms that the beam direction changes based on the frequency and polarization to efficiently cover the desired area [6].

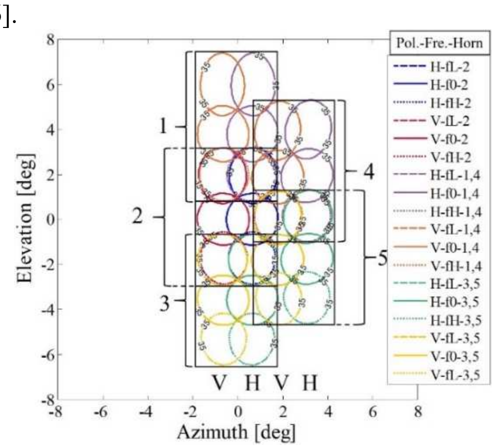

Fig. 5. Contour map of 35 dBi

VI. Measurement Result

A contour map at 35 dBi is shown in Fig. 6. The measurement results are shown in terms of directional gain. The elevation confirms that the fL beam of horn 1 and the fH beam of horn 2 overlap by a ±1 beamwidth from the f0 beam. Similarly, the fL beam of horn 2 and fH beam of horn 3 overlap by ±1 beamwidth away from the f0 beam. The Azimuths confirm that the V-polarized beam is emitted in the direction of -0.67° and the H-polarized beam in the +0.76 °direction. However, the directivity gain at the high-frequency side (fH) of the H polarization was low for the five horns.

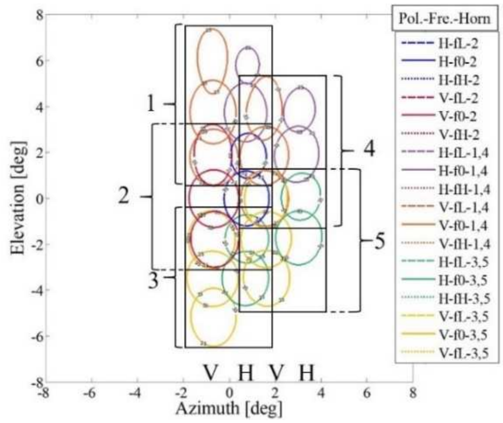

Fig. 6. Contour map of 35 dBi

VII. Conclusion

The results of a study of reflectarrays with different beam directions depending on the polarization and frequency are presented. Based on the measurement results, the beam changes in the elevation direction depending on the frequency, and in the Azimuthal direction depending on the polarization. In addition, the desired area can be efficiently covered using a single reflectarray.

The gain reduction in the H polarization is believed to be caused by the element design. In the future, we plan to design a device that does not degrade the gain.

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