One Layer of Reflectarray Antenna Changing Beam Direction by Polarization

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***Abstract*—Reflectarray antenna applies the reflection phase control function of a metal loaded frequency selective reflector to a reflector antenna, It is possible to control the reflection phases of vertical (V) and horizontal (H) polarization with a single reflectarray if the shape and arrangement of the elements are appropriately designed In this study, we investigate a high-precision reflectarray using three linear elements in a single-layer structure. The results of the analysis demonstrate that the mutual coupling between the H and V components is reduced, and the effect of manufacturing error is minimized. Consequently, it is inferred that the beam can be emitted in different directions for each polarization.**

***Index Terms*—frequency selective reflector(FSR), single layer, polarization, efficiency**

I. INTRODUCTION

A reflectarray[1] antenna applies the reflection phase control function of a metal loaded frequency selective reflector to the reflector antenna. A plane wave can be formed by controlling the phase of the reflected spherical wave radiated from the primary source by appropriately selecting the shape and dimensions of the reflecting element. In addition to shaped beams, the application of multiple beams to cover a service area has been studied.

In particular, for multi-beam application, a coverage area equivalent to that of conventional beams is realized by combining the coverage area in the elevation direction using the dependence of the beam shift on frequency and the cover in the azimuth direction using the change in the beam direction due to polarization. Based on these characteristics, a multi-scanning beam method has been proposed [2],[3].

In this paper, we report on an element that changes the beam direction depending on the polarization in one layer.

II. ELEMENT DESIGN

A. Design Model

Fig.1 shows the design model. In this study, we examined the Ku-band reflectarray. The variation of the beam direction by polarization depends on the resonant element. Therefore, the element requirements are as follows:

(1) Covers a 360° reflection phase region for each polarization.

(2) Independent phase control such that the two polarizations do not affect each other's reflection phase.

We examined the conditions that satisfy these two criteria. The element design parameters are listed in Table I. This device has an A layer on the ground plane, and the resonant elements of each polarization are printed on the A layer in such a manner that each polarization does not interfere with each other, thus realizing independent phase control. The thickness of the A layer was set to h_A=0.1274λ_0 to achieve a single layer.

We achieved a 360° reflection phase region cover for both the polarized waves by using three line elements. The three line elements extended ℓ_{A1} and ℓ_{B1} to 0.3944 λ_0, with ℓ_{A2}=0.3266λ_0. In addition, by changing the length of ℓ_{B2} to 0.3266λ_0, we achieved phase control with a gradual phase change and an element that is resistant to manufacturing errors. Here, the total element lengths are ℓ_A and ℓ_B, and ℓ_A = ℓ_{A1} + 2ℓ_{A2} and ℓ_B = ℓ_{B1} + 2ℓ_{B2} are defined.

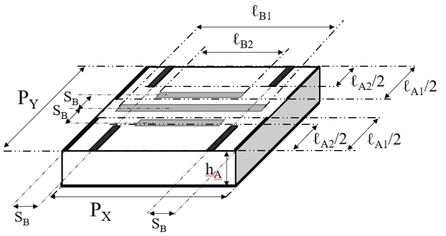

Fig. 1. Phasing element

TABLE I
ELEMENT DESIGN PARAMETERS

Thickness h_A	0.1274λ_0
Dielectric constant ϵ_r	2.59
tanδ	0.0028
Line width w	0.004λ_0
Element lengthℓ_A,ℓ_B	0.004-1.048λ_0
Element spacingP_X= P_Y	0.41λ_0

When designing the elements in a single layer, the vertical(V)-polarized elements were placed with the horizontal(H)-polarized elements moved 1/2P_X in the x-axis direction and 1/2P_Y in the y-axis direction. The spacing between the three lines was set to S_{A1}=S_{B1}=0.0349λ_0.

B. Design Results

In this study, the element length of the V polarization was first fixed at ℓ_A=1.048λ_0 and the element length of the H polarization ℓ_B was varied between 0.004 and 1.048λ_0. The element length of the H polarization was then fixed at ℓ_B=1.048λ_0 and the element length of the V polarization ℓ_A was varied between 0.004 and 1.048λ_0. The results of the analysis are depicted in Fig.2. It was confirmed that both polarizations covered a phase region of 360° or more. A phase shift of approximately 20.83° was observed for the H polarization when the element length of the V polarization was changed, and the phase shift of approximately 19.05° was observed for the V polarization when the element length of the H polarization was changed. Based on these results, it can be inferred that the interference between the elements is small, and independent phase control is possible for each polarization.

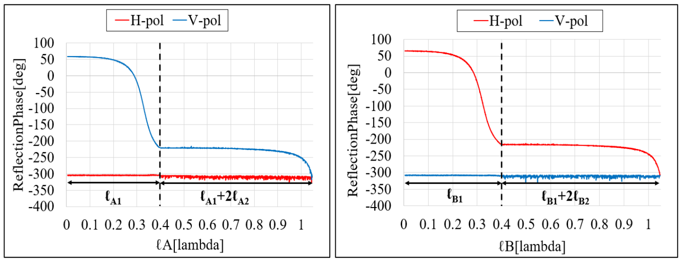

Fig. 2. Reflection phase characteristics of V-pol and H-pol

III. ANALYSIS RESULT

A. Reflector design

The design parameters of the reflectarray are listed in Table II. Here, the position of the primary radiator is F, and the center of the mirror surface is O.The beam directions are designed to be separated from each other by one beam width (=3.04°).

TABLE II
REFLECTARRAY DESIGN PARAMETERS

Tilt angle[deg]	25
Beam direction [deg]	±1.52
Diameter of opening surface D	20.33λ_0
Distance from F to O R	18.29λ_0
Clearance c	3.85λ_0

A full wave analysis was performed on the designed reflectarray using the LinkedField function of HFSS (by ANSYS). Fig. 3 shows a comparison between the calculated values of the radiation patterns for H polarization and V polarization at the center frequency of f_0. The beam shape was maintained at the center frequency. Table III lists the beam direction, gain, and aperture efficiency for each polarization. Based on the results, we can successfully swing the beam in the desired beam direction and improve the aperture efficiency by approximately 20%.

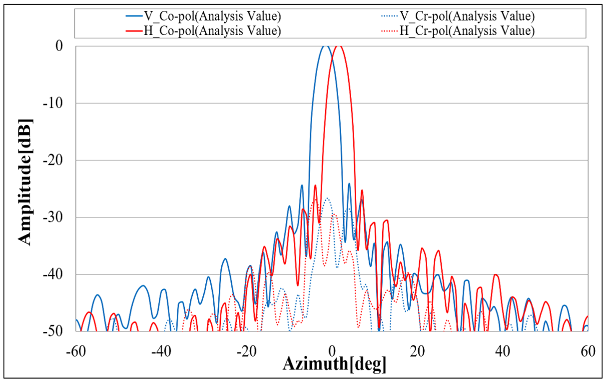

Fig. 3. Radiation pattern of V-pol and H-pol

TABLE III
BEAM DIRECTION AND GAIN ANALYSIS RESULTS

Fre.	Pol.	Beam direction[deg]	Gain[dB]	Efficiency[%]
f_0	V	-1.518	33.82	62
	H	+1.523	33.89	63

IV. CONCLUSION

In this study, we attempted to improve the aperture efficiency by changing the structure from two layers to one layer using three wire elements. Consequently, the aperture efficiency was successfully improved by approximately 20% during the analysis, and the beam direction was almost the same as the desired beam direction. In the future, we plan to evaluate the performance of the newly designed single-layer reflectarray antenna through actual prototyping and measurement.

REFERENCES

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