A Cross Polarization Suppressed Sequential Array for a Primary Radiator of a Parabolic Antenna

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1. Introduction

A typical parabolic antenna on a satellite adopts a horn antenna as a primary radiator, which has wide bandwidth, high gain, and circular polarized radiation. However, it has structural disadvantage such as large dimension and weight. It is desired for a primary radiator of a satellite-borne high gain antenna to be compact and light with maintaining radiation properties as that of the horn antenna.

A sequential rotated array consisting of microstrip antennas (MSA) has an advantage in low-profile geometry and light weight, and has wideband circular polarized characteristics [1]. However, a cross polarization level in the ϕ=45 degree plane is high which degrade radiation efficiency when a conventional sequential array with linear polarized MSA elements [2] is employed. To our knowledge, researches and reports are very few to overcome this problem. In addition, radiation patterns of the sequential array are affected by input impedances of element antennas whose bandwidths are narrow [3]. One of the conventional techniques to broaden the bandwidth of the MSA is an electromagnetically coupled feed. It has been reported that the MSA fed by electromagnetically coupling with an inverted-L shaped probe (L-probe fed MSA) [4][5] has the bandwidth of 36% where a VSWR is less than two [4].

In this paper, we present a sequentially rotated array antenna with a rectangular patch MSA fed by L-probe. Since it is important to decrease couplings between patch elements in order to suppress the cross-polarization level, rectangular patches with aspect ratio of k are adopted. We investigate the cross-polarization level of the sequential array and discuss the relationship between the cross-polarization level and the amount of mutual coupling.

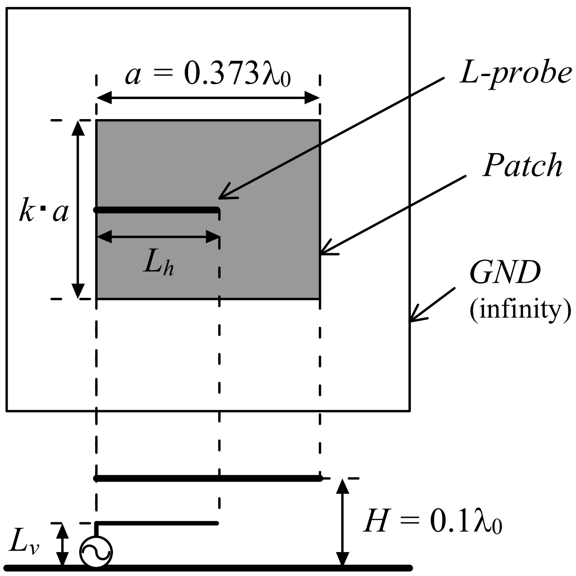

Fig.1 Geometry of the L-probe fed MSA

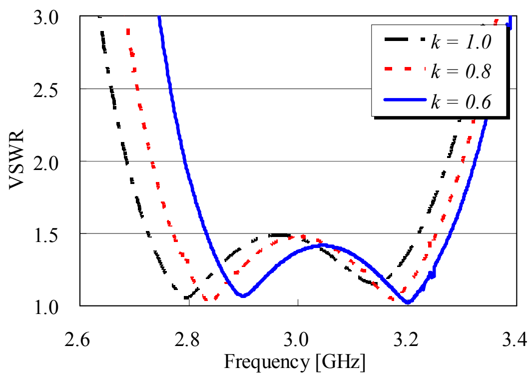

Fig.2 VSWR of the L-probe fed MSA

Table 1 Structural parameters

k	L_v	L_h
1	$0.048\lambda_0$	$0.200\lambda_0$
0.8	$0.056\lambda_0$	$0.194\lambda_0$
0.6	$0.063\lambda_0$	$0.188\lambda_0$

2. Characteristics of the Antenna Element

The geometry of the L-probe fed MSA which is the element of a sequential array is shown in Figure 1. The patch length of a is designed taking into account of a fringe effect [6], while the patch width is changed by the patch aspect ratio k. Parameters of the L-probe are the vertical length of L_v and the horizontal length of L_h. The feed location of the L-probe is just under the edge of the patch. L_v and L_h that are adjusted to optimize the input bandwidth are shown in Table 1, where λ_0 is a wavelength of the operating frequency in the free space.

We used a method of moments [7] to analyze the MSA using wire grid model of forty by forty wires. The segment length of the L-probe is chosen to be 1/400 λ_0 to analyze input impedances accurately, while the radii of the wire are one twenty fifth of the segment length. These parameters for the numerical analysis were determined by considering numerical errors to be sufficiently small.

Input characteristics of the L-probe fed MSA changing k are shown in Figure 2. When k's are 1.0, 0.8 and 0.6, the bandwidths of the VSWR less than 1.5 are 16.7%, 16.1% and 14.6%, respectively and the bandwidth gradually decreases with the decrease of k.

3. Radiation Characteristics of the Sequential Array

Figure 3 shows the configuration of the sequentially rotated 4-patch array antenna consisting of the L-probe fed MSA. The elements are arranged in a square, and an element spacing d is defined by the distance between the centers of the patches. Several L-probe fed MSA's with different k's have been examined.

Radiation patterns of co-polarized and cross-polarized circular polarizations with changing elements spacing in the ϕ=45 degree plane are shown in Figure 4, when the aspect ratio k of the patch is one (square patch). When d's are changed from λ_0 to $0.5\lambda_0$, the directivity of the co-polarized component decreases from 12.6dBic to 5.2dBic and the half power beam width varies from about 28 degrees to 38 degrees. On the other hand, the cross polarized component appears in oblique directions and their levels are almost the same as 7.5dBic, which causes to decrease the antenna efficiency. When k =0.6, the radiation patterns are shown in Figure 5. The co-polarized directivity slightly decreases from 11.6dBic to 10.2dBic and the cross-polarization level greatly decreases from 8.4dBic to 1.7dBic when reducing d. In the case of k =0.8, a tendency of radiation characteristics is similar to that of k =0.6.

The directivity and the cross-polarization level in the ϕ=45 degree plane at 3.0GHz are shown in Figure 6. As stated before, when the patch is not square but rectangular, thus the aspect ratio k is not 1.0, cross-polarization levels decrease in proportion to decrease of k, although that affects directivities to be slightly decreased. Considering these radiation characteristics, decreasing d is effective to reduce the cross-polarized radiation. On the other hand, mutual couplings between elements increase the cross-polarized radiation. This is reason why the cross-polarized levels of the sequential array with square patches are not decreased, even if the spacing becomes small. Discussion on this problem will be quantitatively described in the next section.

Radiation patterns of a sequential array antenna, when k =0.6 and d =$0.5\lambda_0$, are shown in Figure 7 to investigate the nature of the cross-polarized radiation in the θ constant planes, such as θ =15, 30 and 45degrees. In each case, radiation directions of the cross-polarization are toward ϕ=±45 and ±135 degrees. On the other hand, the co-polarization radiations are almost omni-directional. Therefore, it means that it's important to suppress the cross-polarization in the ϕ=45 degree plane to increase the antenna efficiency of the sequential array antenna in this arrangement.

4. Discussion on Improvement of Radiation Characteristics

The couplings between elements are shown in Figure 8. The coupling level of k =1.0 is larger than that of k =0.6, especially, the difference between couplings of them is enlarged while patch spacing d is narrow. It means that radiated power is partly consumed at a neighbour feeding port. That causes the decrease of the antenna efficiency. When the element spacing is larger than

$0.8\lambda_0$, the coupling is less than -30dB, regardless of the aspect ratio *k*. In these range, the cross-polarized radiation is mainly determined by the element spacing *d*. When the element spacing becomes smaller than $0.5\lambda_0$, the coupling in the case of k =0.6 is almost -20dB, which affects the increase of the cross-polarized radiation pattern with and without mutual couplings as shown in Figure 9. "Array factor" means without mutual couplings.

5. Conclusion

We have presented the L-probe fed MSA array with sequential rotation for a primary radiator of a parabolic antenna and showed that the cross-polarization can be reduced by using rectangular patches and adjusting element spacing. A bandwidth of the L-probe fed MSA with rectangular patch is obtained 14.6%, when the patch aspect ratio is 0.6. A sequential array with rectangular patch elements, whose patch spacing is $0.5\lambda_0$, achieved the directivity of 10.8dBic and the cross-polarization level of 1.7dBic which are improved 5.6dB and 5.8dB, respectively, compared to square patch sequential array antenna.

References

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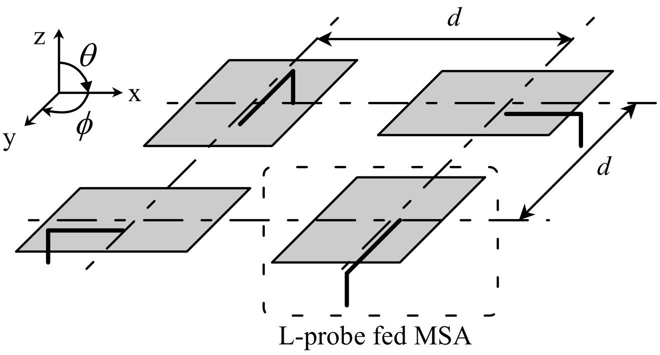
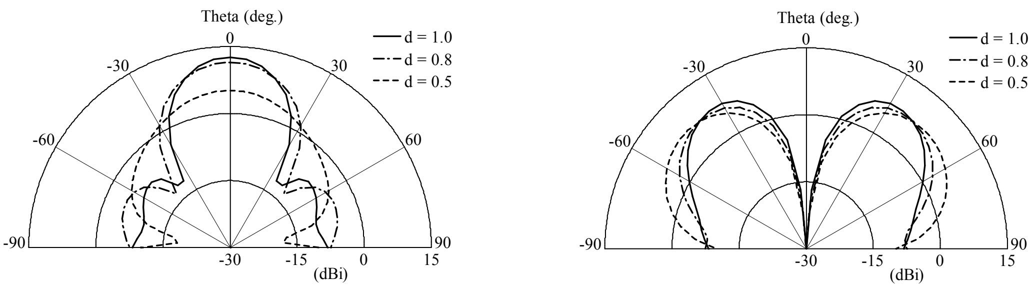
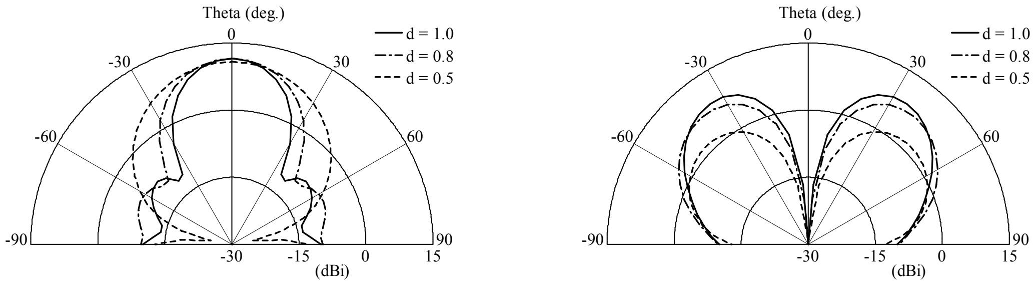


Fig.3 Sequential array with L-probe fed MSA



(a) Co-polarization (b) Cross-polarization

Fig.4 Radiation pattern in the case of k =1.0 (ϕ =45deg.)



(a) Co-polarization (b) Cross-polarization

Fig.5 Radiation pattern in the case of k =0.6 (ϕ =45deg.)

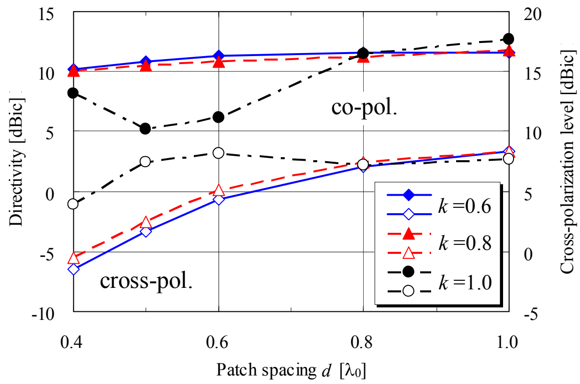


Fig.6 Directivities and X-pol. levels as a function of patch spacing.

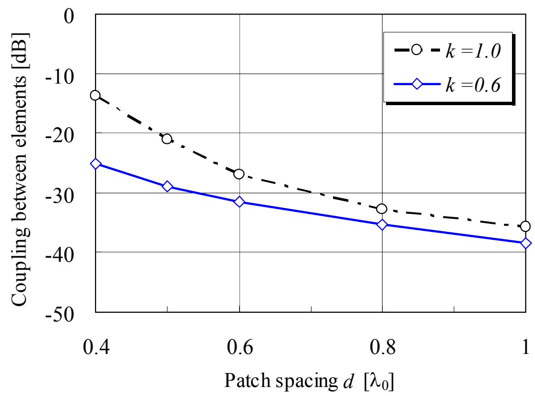
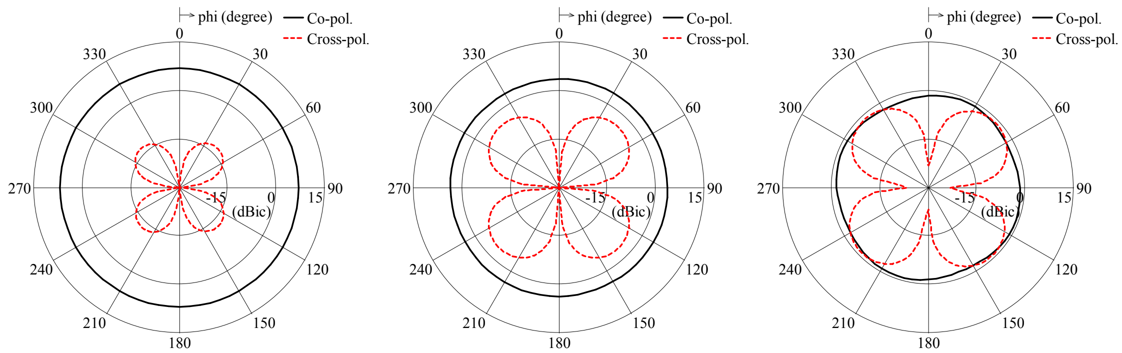
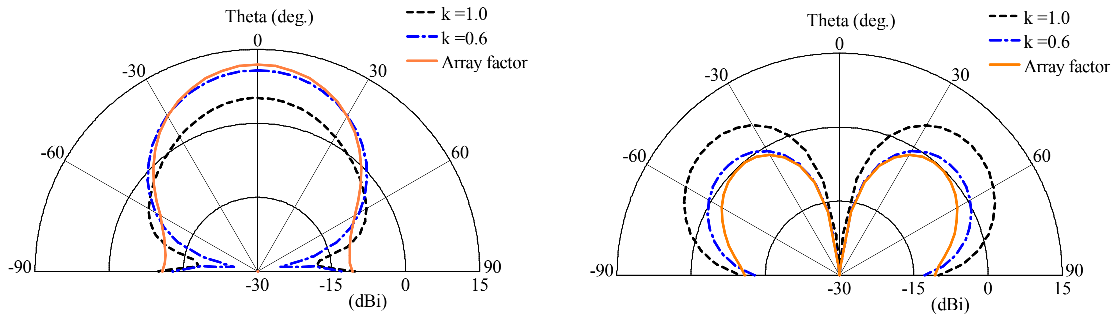


Fig.8 Couplings between elements as a function of patch spacing.



(a) θ= 15 degree (b) θ= 30 degree (c) θ= 45 degree

Fig.7 Radiation patterns in the θ plane (k =0.6 and d =0.5λ_0)



(a) Co-polarization (b) Cross-polarization

Fig.9 Comparison between radiation patterns in the case of d =0.5λ_0 (ϕ =45deg.)