Circularly Polarized Spiral-Grid Array Antenna for Beam Scanning

#Y. Iitsuka, J. Yamauchi, and H. Nakano
College of Engineering, Hosei University
Koganei, Tokyo, Japan 184-8584, yasushi.iitsuka.o8@gs-eng.hosei.ac.jp

1. Introduction

An edge-fed Kraus-type grid array antenna (E-GAA) radiates a linearly polarized wave, whose direction varies with frequency [1]. In contrast to the E-GAA, a center-fed Kraus-type grid array antenna (C-GAA) radiates a linearly polarized wave in the direction normal to the grid array plane [2]. The long and short side lines of each grid cell for these GAAs act as the transmission-line and radiation elements, respectively.

The long side lines for the Kraus-type C-GAA are modified to meandering lines in [3]. It is found that the meandering lines contribute to controlling the HPBW in the H-plane, keeping the HPBW in the E-plane constant. In [4], the long side lines are replaced with bent lines, and it is revealed that, as the bend angle is increased, the HPBWs in the two principal planes become wider.

The short side lines for the Kraus-type C-GAA have also been modified in [5], where the strip conductors are used. By selecting the conductor width, this C-GAA shows a wide frequency response of the VSWR. Note that this C-GAA radiates a linearly polarized wave.

An array antenna that radiates a circularly polarized (CP) wave is found in [6], where c-figured elements are placed above the Kraus-type C-GAA. The maximum radiation from this array is in the direction normal to the grid array plane. A CP C-GAA in [7] has loops for the grid short sides, each having perturbation elements. The maximum radiation from this CP array is in the direction normal to the grid array plane, as in [6].

This paper presents a novel E-GAA that radiates a CP beam, whose direction varies with frequency. This CP E-GAA uses spiral elements for the grid short sides. The radiation characteristics, including the beam direction, axial ratio, and radiation pattern, are analyzed and discussed.

2. Configuration

Fig. 1 shows a conventional wire E-GAA, where point F is the feed point and point P is the terminal point, which is loaded with a resistor R (= 50 Ω). The grid array is placed above a conducting ground plane (GP). The ground plane is assumed to be of infinite extent in the following analysis. The height of the grid array above the ground plane is extremely small ($H_{GP} = 0.05\lambda_{12}$, where λ_{12} is the free space wavelength at a test frequency of 12 GHz). The number of x-directed radiation elements is n (= 27). The length of the grid long side line is L_y (= $1\lambda_{12}$), while the length of the grid short side line is L_x (= $0.5\lambda_{12}$). The wire radii of the grid are ρ_1 (= $0.002\lambda_{12}$) and ρ_2 (= $0.01\lambda_{12}$).

Fig. 2 shows a proposed CP E-GAA, which is a modification of the structure shown in Fig. 1. The x-directed radiation elements of Fig. 1 are replaced with spiral elements. The spiral elements are located at height H_{sp}(= $0.05\lambda_{12}$) from the grid plane. The number of spiral turns is 1.5. The rotational sense of the spiral is counterclockwise for radiating a right-handed circularly polarized wave. The wire radius of the spiral element is ρ_{sp} (= $0.002\lambda_{12}$).

3. Discussion

Analysis is performed using the method of moments [8]. A frequency range of 12 to 17 GHz is used. The solid line in Fig. 3 shows the frequency response of the beam direction for the proposed CP E-GAA. For comparison, the dotted line shows the beam direction for the conventional LP E-GAA shown in Fig. 1. It is found that the beam direction for each of the GAAs varies with frequency. The gradient of frequency response curve for the proposed CP E-GAA is steeper than that for the conventional LP E-GAA.

Fig. 4 shows the frequency response of the axial ratio in the direction of the main beam for the proposed CP E-GAA. The analysis reveals that the axial ratio is less than 3 dB within a frequency range of 14.1 to 16.6 GHz (a bandwidth of approximately 16 %). Within this frequency range, the beam direction varies from 4^o to 33^o in the x-z plane, as shown in Fig. 3.

Fig. 5 shows the radiation patterns for the proposed CP E-GAA in the x-z plane at 14.1 and 15.2 GHz. As the frequency is increased, the beam width becomes wider. Note that the gain at 15.2 GHz is decreased by 3 dB from its maximum value (24 dBi). The VSWR of the proposed CP E-GAA is desirably small within an axial ratio bandwidth of 14.1 to 16.6 GHz. During the presentation, experimental results will be shown for checking the validity of the analysis results.

4. Conclusions

A grid array antenna composed of spiral elements is investigated to radiate a circularly polarized wave. It is found that the proposed antenna has a 16% frequency band width for a 3-dB axial ratio criterion. Within this frequency band, the beam scans an angle range of $\theta = 4^o$ to 33^o.

Acknowledgments

The authors thank H. Mimaki for his assistance in the preparation of the manuscript.

References

[1] J. D. Kraus and R. J. Marhefka, *Antennas*, 3rd ed., McGraw-Hill, New York, pp. 578-581, 2003.
[2] H. Nakano, I. Oshima, H. Mimaki, J. Yamauchi, and K.Hirose, “Center-fed grid array antennas,” IEEE AP-S Int. Symp., pp.2010-2013, June 1995.
[3] N. Nakano, T. Kawano, and J. Yamauchi, “Meander-line grid-array antenna,” IEE Proc. -Microw. Antennas Propag., Vol. 145, No. 4, pp. 309-312, August 1998.
[4] N. Nakano, S. Tajima, K. Nakayama, and J. Yamauchi, ”Numerical analysis of honeycomb antenna with an electromagnetic coupling feed system,” IEE Proc. -Microw. Antennas Propag., Vol. 145, No. 1, pp. 99-103, February 1998.
[5] N. Nakano, H. Irie, H. Mimaki, and J. Yamauchi, “A strip grid array antenna,” Proc. APMC 2002, Kyoto, Japan, Vol. 3, pp. 1599-1603, November 2002.
[6] T. Kawano and H. Nakano, “Grid array antenna with c-figured elements,” IEEE AP-S Int. Symp., Atlanta, Georgia, USA, pp.1154-1157, June 1998.
[7] H. Nakano, H. Osada, H. Mimaki, Y. Iitsuka, and J. Yamauchi, “A modified grid array antenna radiating a circularly polarized wave,” MAPE, Hangzhou, China, pp. 527-530, August 2007.
[8] R.F. Harrington, *Field Computation by Moment Methods*, IEEE Press Series on Electromagnetic Wave Theory, 1993.

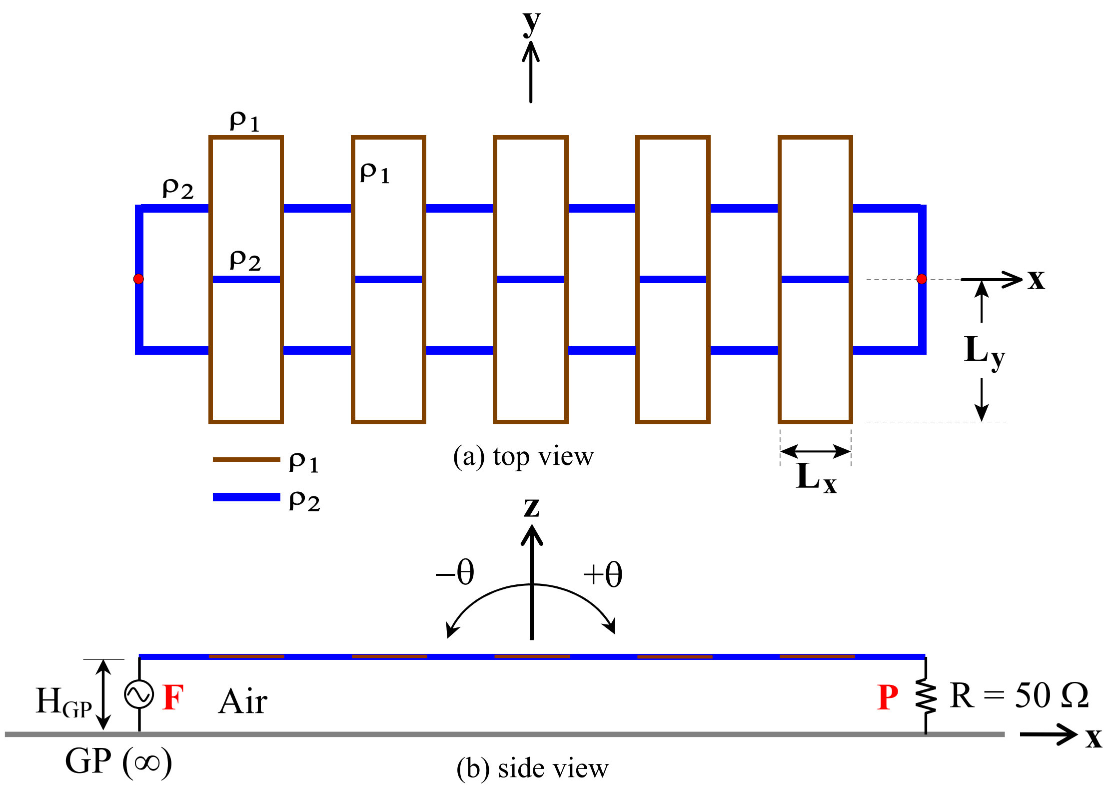

Figure 1: Conventional linearly-polarized edge-fed grid array

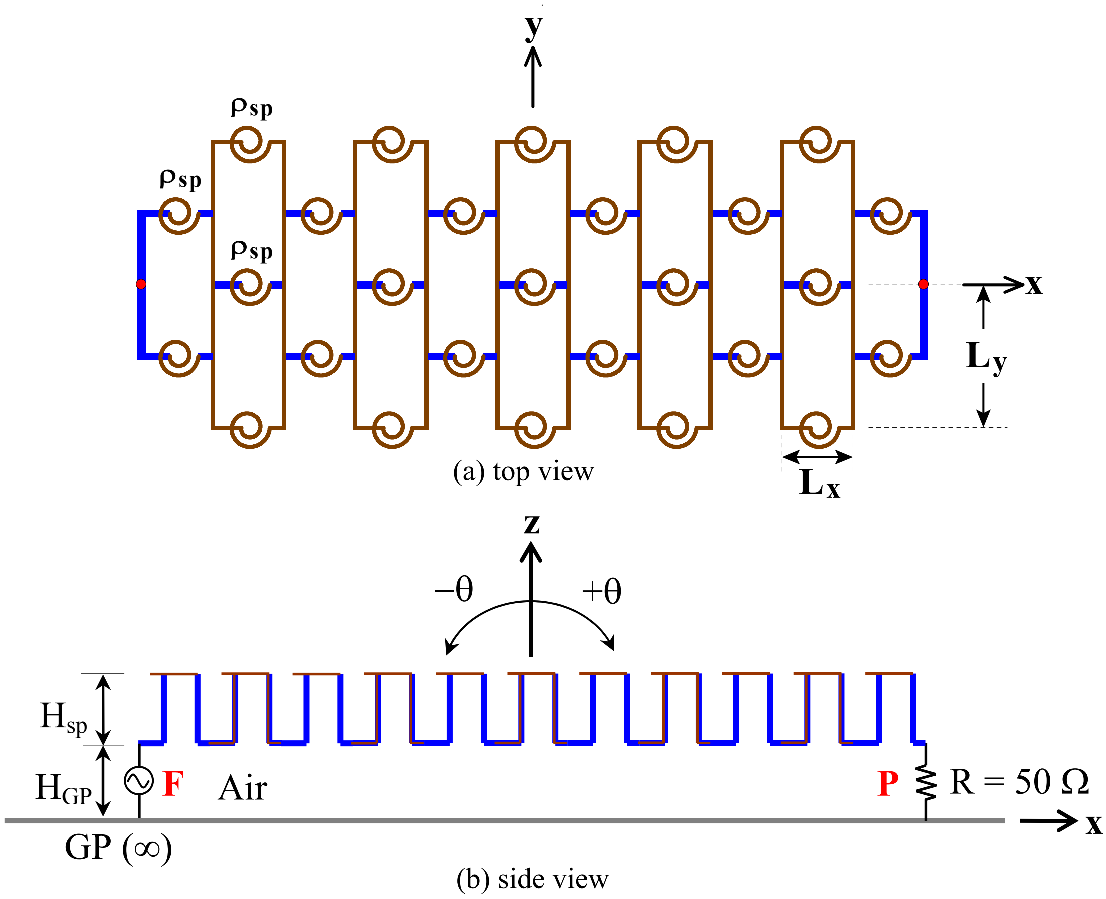

Figure 2: Proposed circularly-polarized edge-fed grid array antenna composed of spiral elements

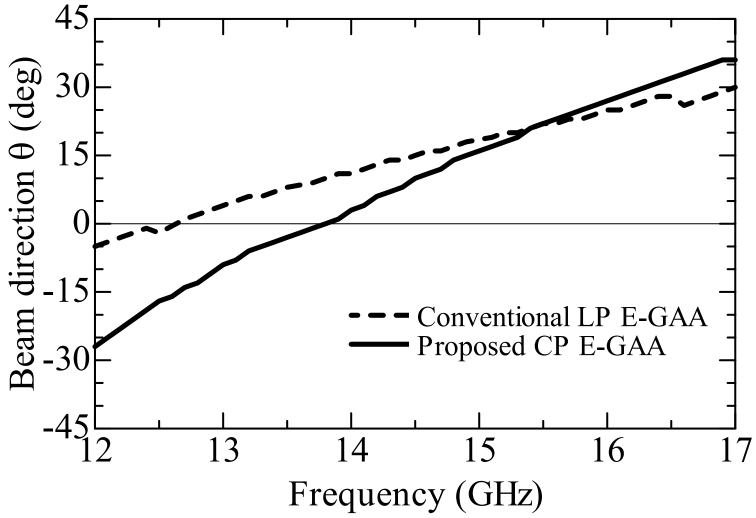

Figure 3: Beam direction as a function of frequency

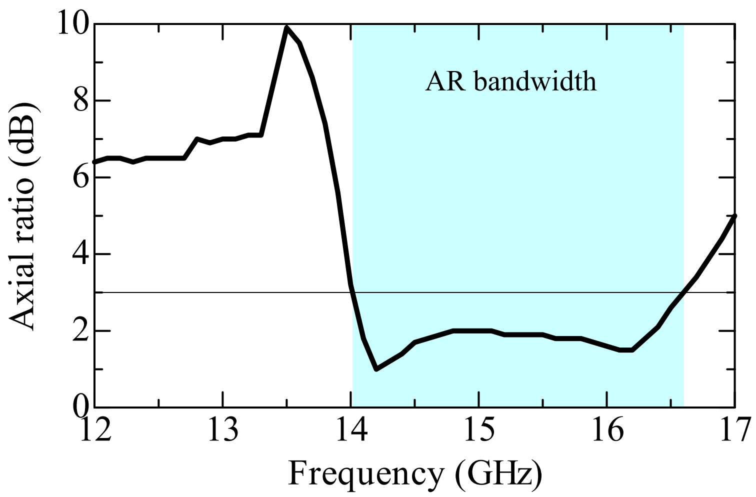

Figure 4: Axial ratio as a function of frequency

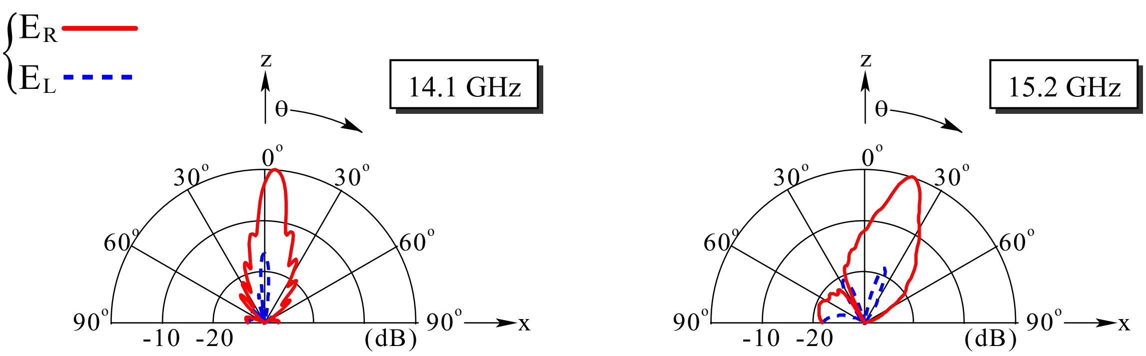

Figure 5: Radiation pattern