Radiation Characteristics of a Spiral GAA and a Loop GAA

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1. Introduction

A Kraus-type grid array antenna (GAA) radiates a linearly polarized beam, whose direction varies with frequency [1][2]. The long and short side lines of each grid cell for this GAA act as the transmission-line and the radiation elements, respectively. The direction of the linear polarization coincides with the direction of the short side lines.

An array antenna that radiates a circularly polarized (CP) wave is found in [3], where c-figured elements are placed above the short side lines of the Kraus-type GAA. The radiation beam from this array is in the direction normal to the grid array plane. An array antenna in [4] also radiates a CP wave, where loops having perturbation elements are used for the radiation elements. The radiation beam from this array is in the direction normal to the grid array plane, as in [3]. Note that these two grid array antennas are designed as a broadside CP array antenna and do not have a beam scanning function.

Recently, the short side lines for the Kraus-type GAA have been replaced with spiral elements [5] and open loop elements (without perturbation elements) [6] in order to obtain a CP beam scanning function (the CP beam direction varies with frequency). These arrays are designated as the spiral GAA and the loop GAA, respectively. This paper presents a comparison between the radiation characteristics of the spiral GAA and the loop GAA. The axial ratio, beam direction, and radiation pattern are discussed.

2. Discussion

Fig. 1 shows a spiral GAA and a loop GAA. Point F is the feed port and point T is the terminal port loaded with a resistor R (= 50 Ω). The number of the CP radiation elements is n (= 27). The grid cell is defined by $L_x \times L_y$ (= $0.5\lambda_6 \times 1\lambda_6$, where λ_6 is the wavelength at a test frequency of 6 GHz). The ground plane is assumed to be of infinite extent in the following analysis.

The spiral GAA and the loop GAA are designed to radiate a right-handed CP wave. The outermost radius of the spiral arm and the radius of the open loop are r_{SP} and r_{LP}, respectively. The spiral elements are located at height H_{SP} (= $0.1\lambda_6$) above the ground plane, while the loop elements are located at height H_{LP} (= $0.05\lambda_6$). Note that the number of spiral turns is chosen to be 1.5, and the open angle of the loop is set to be $2\alpha = 30^o$.

Analysis is performed using the method of moments [7]. It is revealed that appearance of the 3-dB axial ratio frequency region (AR-FR) for the spiral GAA differs from that for the loop GAA. This fact is illustrated in Fig. 2, where Fig. 2(a) is for the spiral GAA, and Fig. 2(b) is for the loop GAA. The spiral GAA has two distinct AR-FRs (around a frequency 8 GHz for r_{SP} = 7 mm $\equiv r_{SP1}$ and around a frequency 5.25 GHz for r_{SP} = 10 mm $\equiv r_{SP2}$), while the loop GAA has an AR-FR around 6 GHz. Note that the AR bandwidth for the loop GAA is wider than those for the spiral GAA. Also, note that the VSWR within the AR-FR is less than 2, as desired (although not illustrated).

Fig. 3 shows the beam direction as a function of frequency, where Fig. 3 (a) is for the spiral GAA (r_{SP} is chosen to be r_{SP1} and $r_{SP} = r_{SP2}$), and Fig. 3(b) is for the loop GAA with r_{LP} = 9.5 mm $\equiv r_{LP1}$. As seen from Fig. 3(a), the beam from the spiral GAA is within the positive x space (forward radiation) for r_{SP1} and within the negative x space (backward radiation) for r_{SP2}, that is, the spiral GAA has either the forward radiation or the backward radiation for a given radius r_{SP}. In contrast, the beam from the loop GAA has backward- and forward-radiation characteristics for a given r_{LP}, depending on frequency. It follows that the loop GAA is more suitable for a beam scanning antenna than the spiral GAA.

Fig. 4 shows the radiation pattern in the x-z plane, where Fig. 4(a) is for the spiral GAA having $r_{SP} = r_{SP2}$ at a backward-radiation frequency 5.5 GHz, and Fig. 4(b) is for the loop GAA having $r_{LP} = r_{LP1}$ at a backward-radiation frequency 5.7 GHz and a forward-radiation frequency 6.55 GHz. It is found that the side-lobe level is small for both array antennas. It is also found that the half power beam width for the spiral GAA is slightly wider than that for the loop GAA.

3. Conclusions

The radiation characteristics of the spiral GAA and the loop GAA are investigated to obtain a scanning function for CP radiation. The investigation is performed varying the outermost radius of the spiral arm r_{SP} and the radius of the loop r_{LP}. The spiral GAA has a three-layer structure composed of the ground-plane layer, the feed-line layer, and the spiral-element layer. The loop GAA has a two-layer structure composed of the ground-plane layer and the loop-element layer, where the feed lines are in the loop-element layer.

The spiral GAA has two 3-dB axial ratio frequency regions, unlike the loop GAA. The spiral GAA shows either a backward-radiation characteristic or a forward-radiation characteristic for a given radius r_{SP}. In contrast, the loop GAA has backward and forward radiation characteristics for a given r_{LP}, depending on the operating frequency. Within the 3-dB axial ratio region, the VSWR is less than 2, as desired. The side-lobe level in the radiation patterns for the spiral GAA and the loop GAA is small. It is concluded that the loop GAA is more suitable for a beam scanning antenna than the spiral GAA.

Acknowledgments

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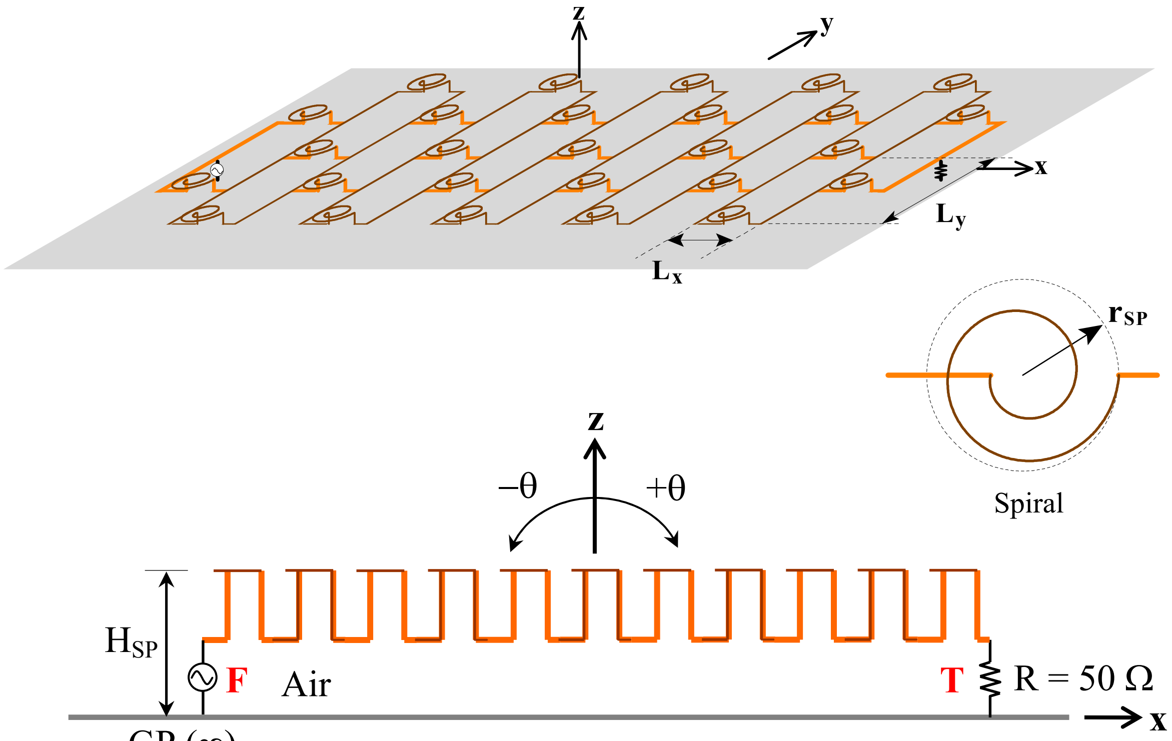
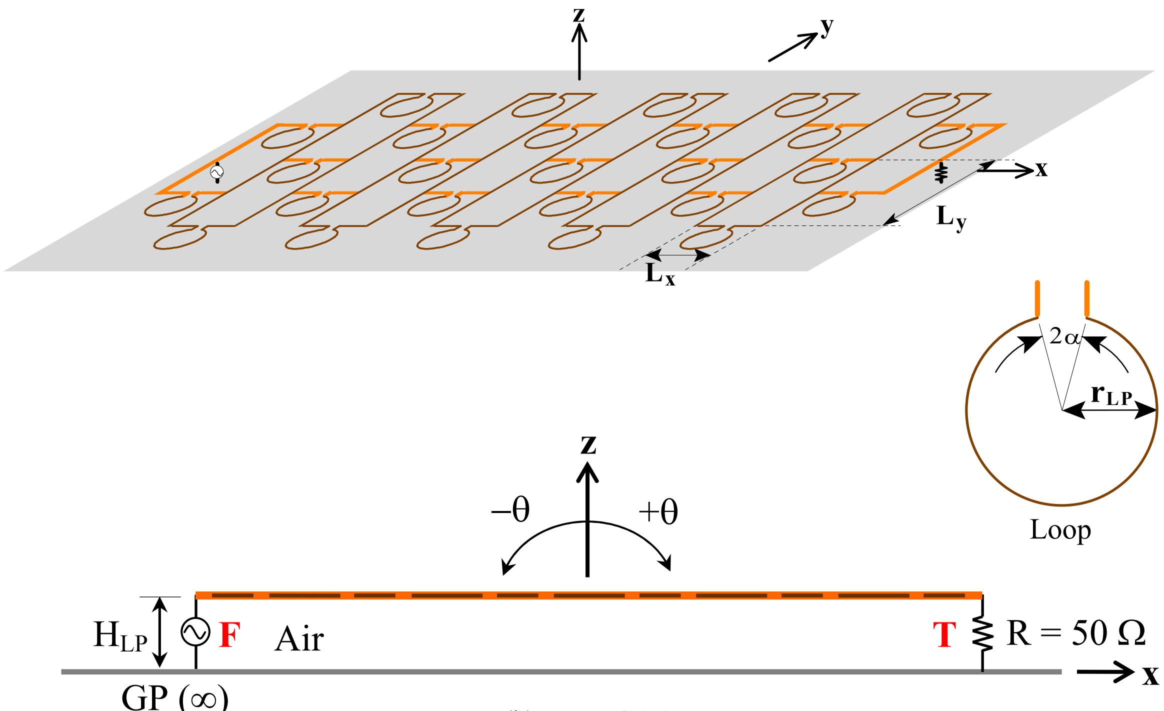
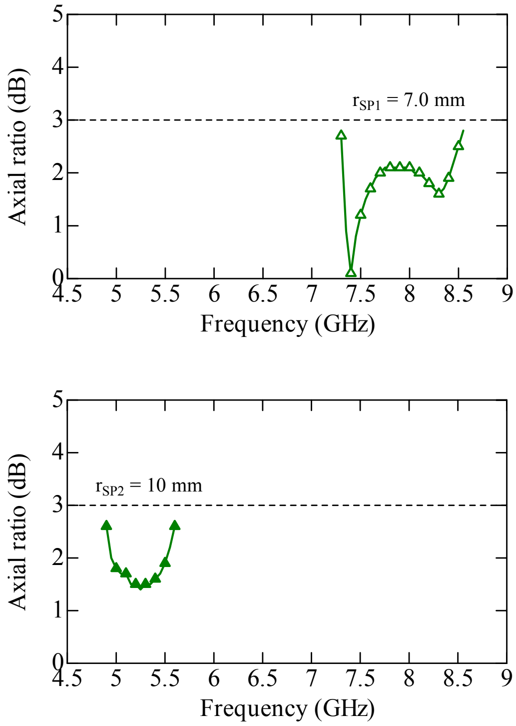


(a) Spiral GAA

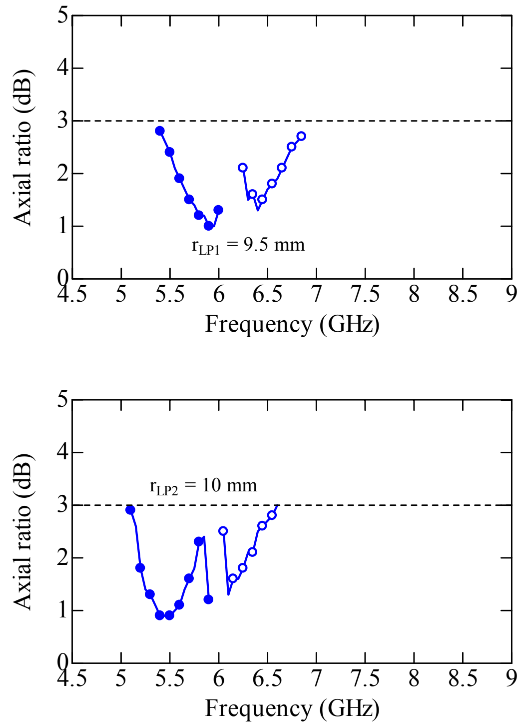


(b) Loop GAA

Figure 1: Circularly Polarized Grid Array Antennas

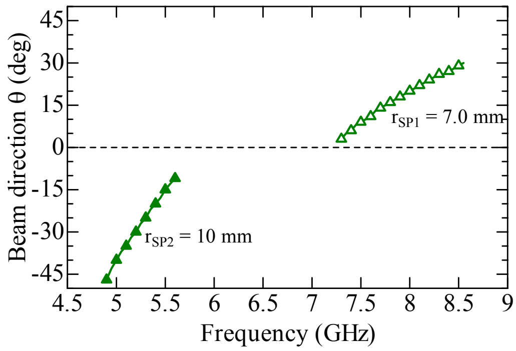


(a) Spiral GAA

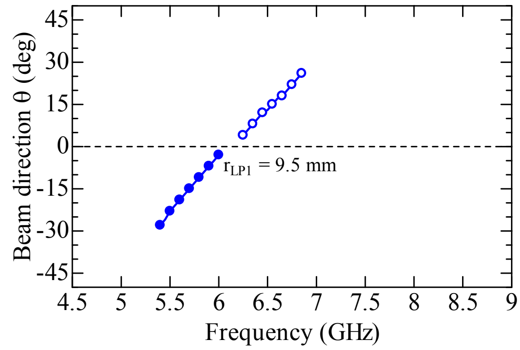


(b) Loop GAA

Figure 2: Axial Ratio as a Function of Frequency

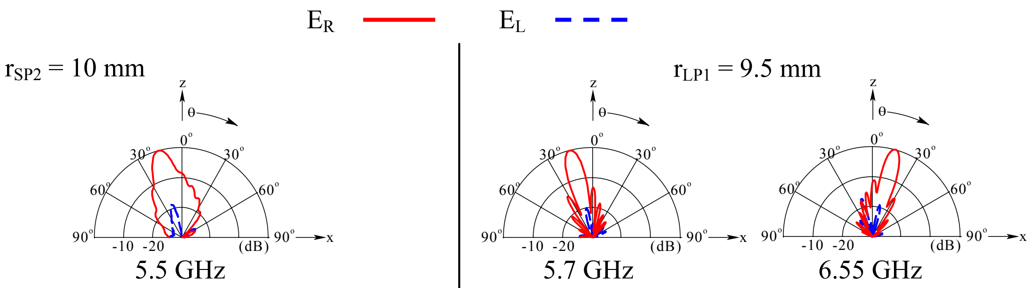


(a) Spiral GAA



(b) Loop GAA

Figure 3: Beam Direction as a Function of Frequency



(a) Spiral GAA

(b) Loop GAA

Figure 4: Radiation Patterns