Grid Array Antenna Radiating a Circularly Polarized Wave

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1. Introduction

Center-feed (or quasi-center feed) grid array antennas (GAAs) printed on a dielectric substrate (relative permittivity $\varepsilon_r > 1$) have been investigated [1]-[6]. These GAAs are composed of microstrip lines. The investigation reveals that the radiation beam is in the direction normal to the grid array plane and the polarization of the radiation is linear, coinciding with the direction of the short side microstrip lines for the grid cells. The use of the dielectric substrate contributes to precise fabrication for the GAA. Note that, as the thickness of the dielectric substrate is increased, the radiation characteristics deteriorate due to effects of surface waves. For solving this issue, a new structure has been proposed [5][6], where the antenna pattern printed on a thin dielectric substrate is backed by an air layer. It is found that the frequency response of the gain and impedance characteristics is improved.

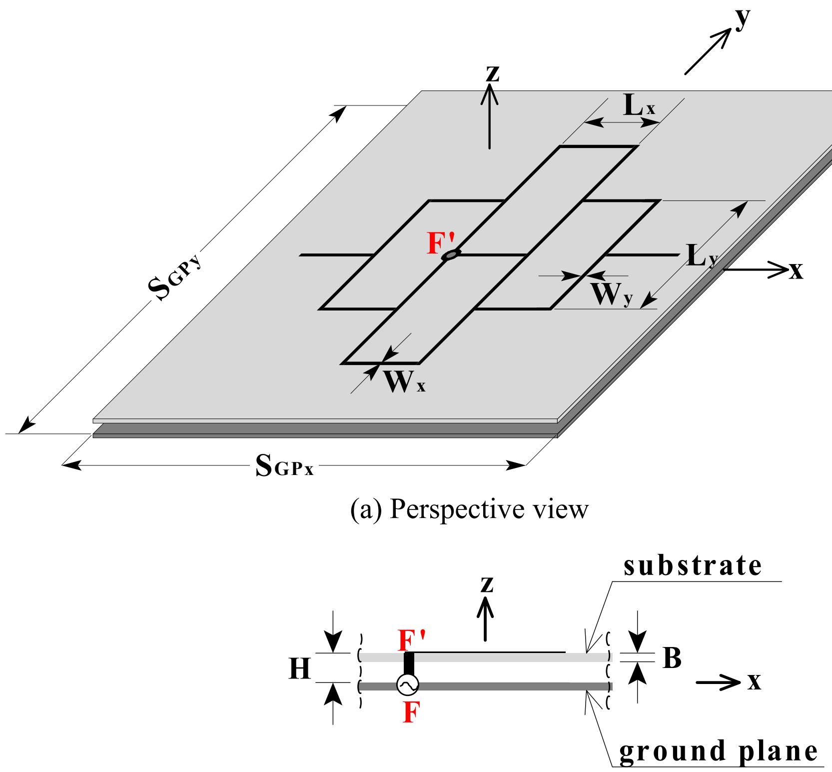
In addition to linearly polarized (LP) GAAs, a circularly polarized (CP) GAA has been proposed [7] to apply it to CP communication systems, such as a satellite communication system. To radiate a CP wave, the microstrip radiation element for each grid cell in [5] has been replaced with a square loop having two perturbation elements. The height of this CP-GAA above the grand plane is chosen to be very small: approximately 0.08 wavelength at the operating frequency. Note that the CP-GAA in [7] has two feed points and excited in balanced mode with (+1, −1) volt. For this excitation, a circuit to realize the balanced mode is required, resulting in complicated design. In order to avoid this issue, the number of feed points for the CP-GAA has been reduced to one in [8], where an electromagnetic coupling feed has been adopted for impedance matching. This paper is a sequel to [8]. The input impedance (VSWR), axial ratio, and radiation pattern, are analysed and discussed.

2. Discussion

2.1 Basis for CP-GAA

Analysis is performed using the finite integration technique (FIT by CST Microwave Studio [9]). The antenna is designed for a frequency band including 7 GHz. Fig. 1 shows a linearly polarized grid array antenna (LP-GAA), which is the basis for the CP antenna to be considered here, has a composite layer structure where the space between the grid array and the ground plane is filled with a dielectric layer (thickness B = 1 mm and relative permittivity $\varepsilon_r = 2.6$) and an air layer. The feed point is located at point F (quasi-center feed point), to which the center conductor of a coaxial feed line is connected. The length of the x-directed microstrip line, L_x, is chosen to be approximately $0.5\lambda_g$, where λ_g is the guided wavelength of the current along the microstrip line on the dielectric layer. The length of the y-directed microstrip line, L_y, is chosen to be $1\lambda_g$. The x-directed microstrip lines act as radiation elements. The number of radiation elements for the structure shown in Fig. 1 is chosen to be nine.

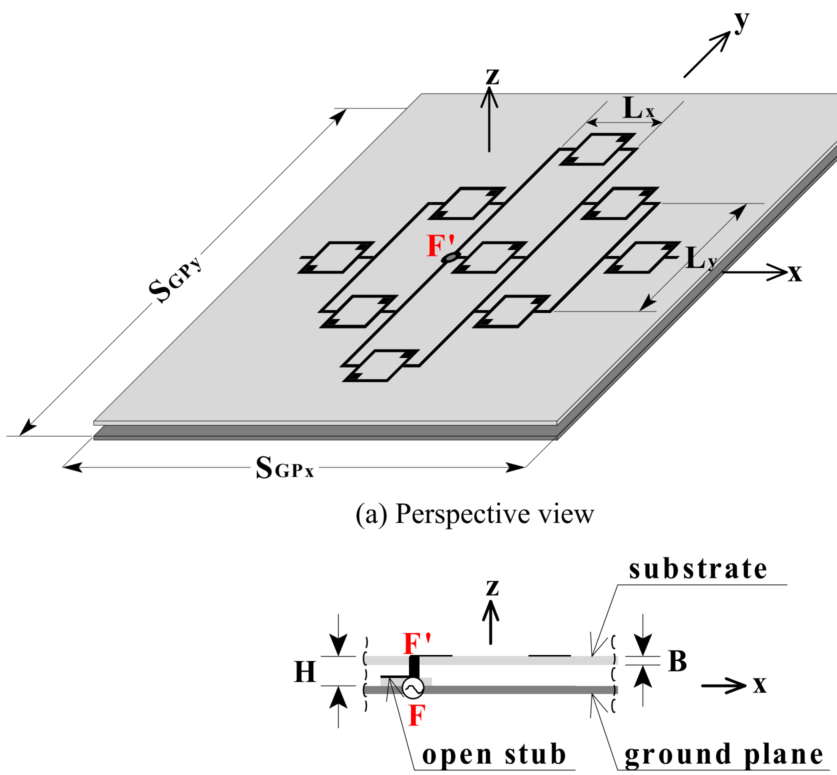
Adjusting the widths of the x- and y-directed microstrip lines, W_x and W_y, and the height H (the thicknesses of a dielectric layer plus an air layer), the input impedance for the LP-GAA is matched



(a) Perspective view

(b) Side view

Figure 1: LP-GAA for the basis of a CP GAA



(a) Perspective view

(b) Side view

Figure 2: CP-GAA with an open stub

to a 50 Ω feed line. The VSWR bandwidth is relatively broad; more than 10%. Within this VSWR bandwidth, the LP-GAA radiates a narrow (pencil) beam in the broadside direction.

2.2 CP-GAA

Based on the preliminary investigation, a CP-GAA is proposed in this section. Fig. 2 shows the CP-GAA, which is a modification of the structure shown in Fig. 1 (LP-GAA). The radiation elements are loops, each having two perturbation elements to radiate a circularly polarized wave [7][8]. To match to a 50 Ω feed line, an open stub, printed on a small dielectric substrate ($\varepsilon_r = 2.6$), is introduced, as shown in Fig. 2(b). The structure of this matching section is simpler than that in [8] where an electromagnetic coupling feed is used.

The distance from the ground plane to the grid plane, referred to as the antenna height H, is very small: H = 3.5 mm, corresponding to 0.08 wavelength at 7 GHz. The ground plane is finite with an area of $S_{GPx} \times S_{GPy}$ = 109 mm x 109 mm (≈ 2.55 wavelengths at 7 GHz), which is the same as that of the dielectric substrate on which the grid array is printed. The shortest distance from the outermost elements of GAA to the edge of the dielectric substrate is approximately one quarter wavelength at 7 GHz.

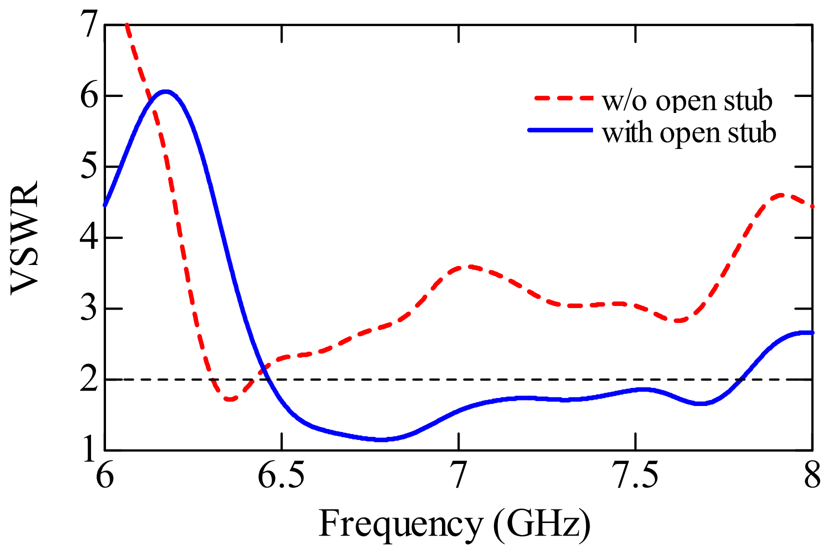


Figure 3: VSWR as a function of frequency

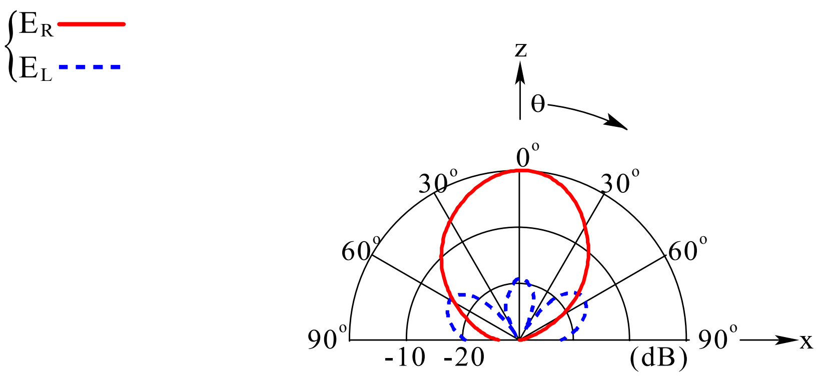


Figure 4: Radiation pattern

Fig. 3 shows the VSWR after the width and length of the open stub are optimized, together with the VSWR for a CP-GAA without an open stub. These VSWRs are calculated relative to 50 Ω. The bandwidth for the CP-GAA with the open stub is approximately 18% for a VSWR = 2 criterion (from 6.5 GHz to 7.8 GHz), and that for the CP-GAA without an open stub is 2% (from 6.3 GHz to 6.4 GHz). It follows that the open stub leads to a large increase in VSWR frequency bandwidth.

The axial ratio at frequencies around 6.85 GHz is less than 3 dB, and the frequency bandwidth for a 3-dB axial ratio criterion is approximately 2% (6.78 GHz – 6.9 GHz), which is the same as that of the previous CP-GAA with blanched mode excitation [7] and that with electromagnetic-coupling excitation [8]. The 3-dB axial ratio bandwidth is within the VSWR bandwidth (6.5 GHz – 7.8 GHz). It can be said that the addition of the open stub has little effect on the axial ratio characteristic.

Fig. 4 shows the radiation pattern in the x-z plane at 6.85 GHz, where a CP wave is radiated. It is found that the main beam is around the z-axis at this frequency and the radiation pattern is almost symmetric with respect to the z-axis. The half-power beam width is 40^o in the x-z plane and 25^o in the y-z plane. Note that the gain for the right-handed CP wave at 6.85 GHz is approximately 14 dBi in the z-axis, and the bandwidth for a 3-dB reduced gain criterion is calculated to be approximately 13%.

3. Conclusions

A single-feed CP-GAA with an open stub is proposed. It is found that the open stub is suitable for impedance matching. The open stub does not distract the radiation characteristics. This CP-GAA has an approximately 2% frequency bandwidth for a 3-dB axial ratio criterion. Across this 3 dB axial ratio bandwidth the VSWR is less than 2, and the gain is approximately 14 dBi.

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