Bandwidth Enhancement of Microstrip Antenna Using Artificial Ground Structure With Rectangular Unit Cells

#Ryota Nobe [1], Takeshi Fukusako [2]
[1,2] Dept. of Computer Science and Electrical Engineering, Kumamoto University
2-39-1, Kurokami, Kumamoto 860-8555, Japan
[1]nobe@st.cs.kuammoto-u.ac.jp, [2]fukusako@cs.kumamoto-u.ac.jp

Abstract

In this paper, broadband circularly polarized antenna using artificial ground structure is presented. Bandwidth gets wider when the substrate is extended in the Y-axis. This antenna is simulated by HFSS10.1. Simulated results are 56.30% (4.48 - 7.99 GHz) in S_{11} bandwidth and 32.33% (5.47 – 7.41 GHz) of axial ratio bandwidth.

Keywords : Circular Polarization Broadband antenna Artificial ground structure

1. Introduction

Circularly polarized antennas have been widely used in wireless telecommunication because they can reduce multipath interference and the electric field vector alignment between the transmitter and receiver is not required. So they are used in mobile telecommunication, such as, satellite telecommunication, radars, Global Positioning System (GPS). Circularly polarized microstrip antennas are low profile, low cost, and easy to fabricate but has narrowband characteristics. In this paper, we propose broadband circularly polarized microstrip antenna by using Artificial Ground (AG) Structure [1], [2] which is one of the metamaterials [3]. The AG structure is Electromagnetic Band Gap (EBG) structure [4] without vias and has rectangular cells. The wave from microstrip antenna is reflected by the AG and composed with the wave of the antenna.

The previous research [2] achieved an impedance bandwidth of 48.6 % < -10 dB S_{11} from 4.52 to 7.42 GHz, and an < 3 dB axial ratio bandwidth of 20.4 % from 5.40 to 6.63 GHz. In this paper, the effect of the surface wave on AG structure by changing the length of both the ground and the dielectric substrate is studied. An impedance bandwidth of 56.30 % < -10 dB S_{11} from 4.48 to 7.99 GHz and the axial ratio bandwidth of 32.33 % < 3 dB from 5.47 to 7.41 GHz, is achieved. A maximum gain of 8.30 dBic is also obtained.

2. The Design of the proposed antenna

The geometry of proposed antenna structure is shown in Fig. 1. This antenna has two 2 layers. Fig. 1 (a) shows the 1st layer, the AG Structure. The dielectric substrate of AG Structure is Rogers RT/Duroid 5880, which permittivity is 2.2 and loss (tan δ) is 0.001. There are 6 × 4 unit cells on the dielectric substrate. The size of the unit cell is 4.2 mm × 9.25 mm. The size of the dielectric substrate and ground are width (*gx*) and length (*gy*) respectively. The proposed antenna is a modified version of the antenna proposed in [2] with a substrate and a ground plane which have a width (*gx*) of 39 mm and length (*gy*) of 40 mm. Fig. 1 (b) shows the 2nd layer with a microstrip patch antenna. This antenna is truncated at opposite corners to generate circular polarization at the centre frequency of 6GHz. This antenna is fed with a SMA connector from the bottom of the Artificial Ground Structure. Thickness of the dielectric substrate of the 1st layer is 3.2 mm and the 2nd layer is 1.6 mm. There is an air gap of 0.5 mm between these two layers.

3. Simulated and Measured Results

The antenna structure is simulated by HFSS 10.1. Fig. 2 and Fig. 3 show the S_{11} characteristics and circular polarization characteristics when the length (*gy*) of the ground and dielectric substrate is varied. There is no change in the AG unit cells and other antenna parameters. Fig. 3 (a) shows amplitude ratio characteristics and Fig. 3 (b) shows phase difference. At around 7GHz, amplitude ratio characteristics reach 0 dB and the phase difference and the phase difference becomes 90 degrees when the length (*gy*) is 55 mm. As a result, axial ratio bandwidth gets wider. Then, S11 bandwidth is 56.30 % (4.48 - 7.99 GHz) and axial ratio bandwidth is 32.33 % (5.47 - 7.41 GHz). When compared to the structure in [2], the increase of S_{11} bandwidth is 7.70 % and axial ratio bandwidth is 11.93 %.

Fig. 4 and Fig. 5 shows the simulated and measured S_{11} and Axial Ratio characteristics. Measured S_{11} and Axial Ratio characteristics show wide bandwidth. Measured S11 bandwidth is 55.33 % (4.55 - 7.87 GHz) and measured axial ratio bandwidth is 29.50 % (5.39 - 7.16 GHz). Measured and simulated S_{11} characteristics are in good agreement. In Fig. 5, the difference between simulated and measured axial ratio may be due to the surface wave on the Artificial Ground. Fig. 6 shows the gain characteristics. There is a reduction in gain in measurement. This may be due to the air gap between the 1st and the 2nd layer. A maximum gain of 8.30 dBic is obtained in simulation and 7.00 dBic. Fig. 7 shows the radiation pattern in XZ and YZ planes at 6 GHz in measurement. The simulated and measured results are agreeing each other.

4. Conclusion

A circularly polarized microstrip antenna using rectangular Artificial Ground Structure with rectangular unit cells is presented. The length of the substrate and ground plane control the amplitude ratio and phase difference characteristics. Measured results of S_{11} bandwidth is 55.33 % (4.55 - 7.87 GHz) and Axial Ratio bandwidth is 29.50 % (5.39 – 7.16 GHz), which are in good agreement with the simulated results.

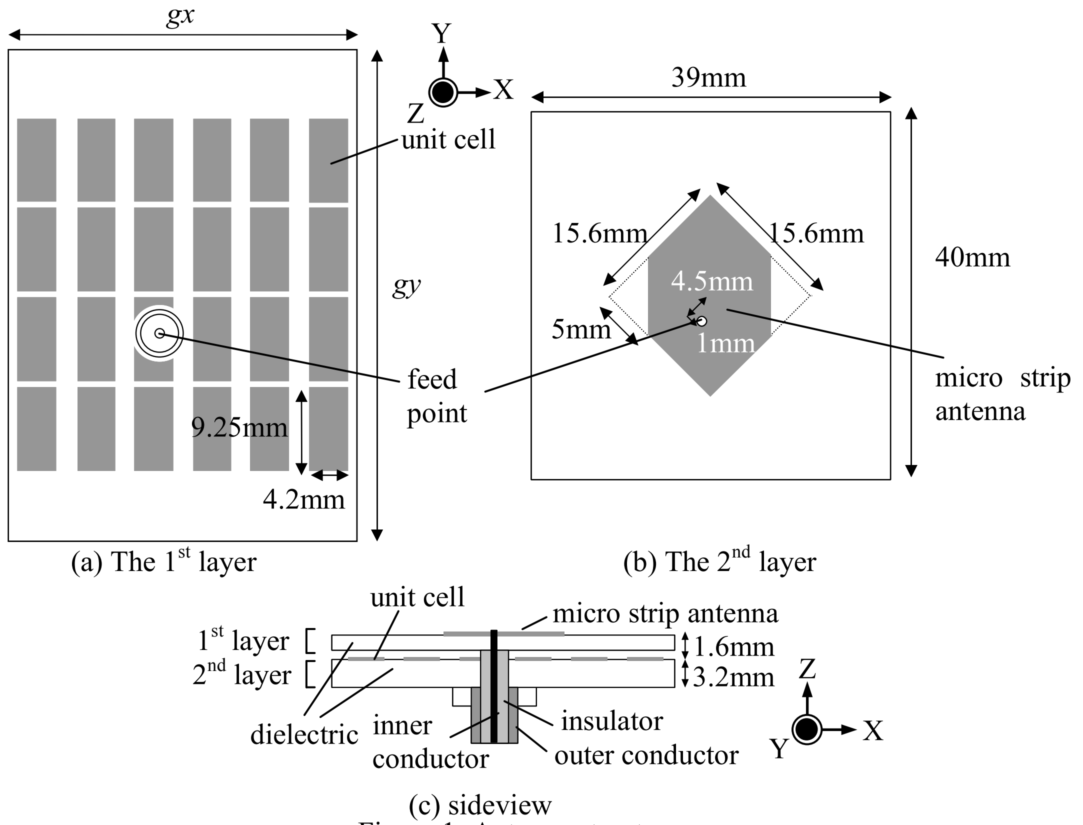


Figure 1: Antenna structure

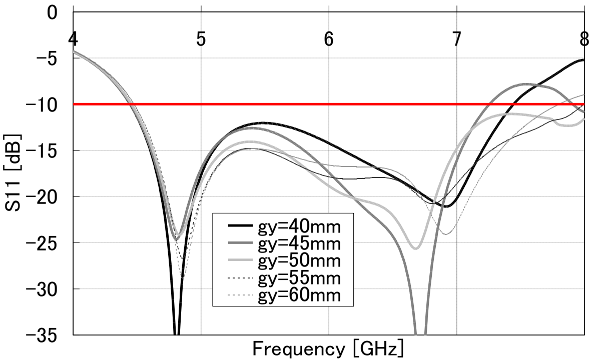
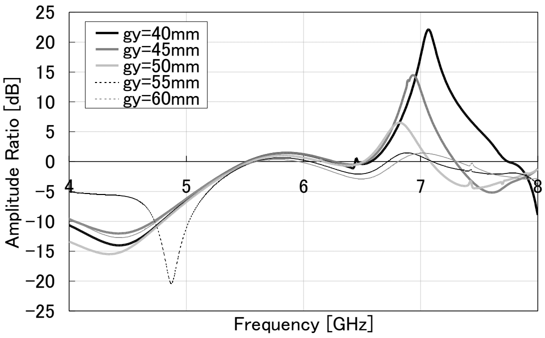
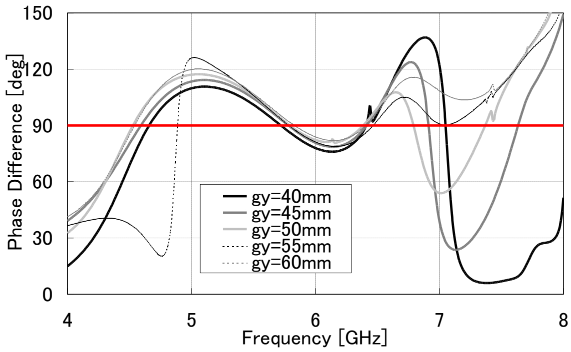


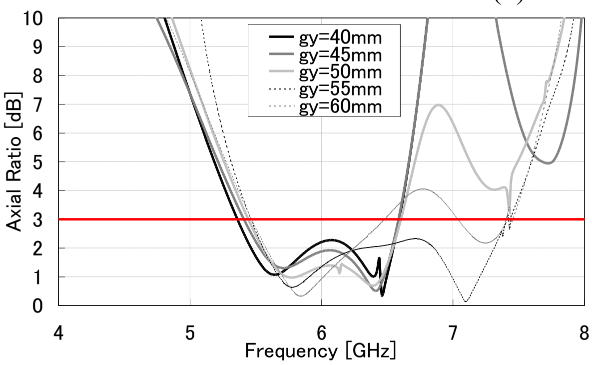
Figure 2: Effect of (*gy*) on S_{11} characteristics



(a) Amplitude Ratio



(b) Phase Difference



(c) Axial Ratio

Figure 3: Effect of (*gy*) on axial ratio characteristics

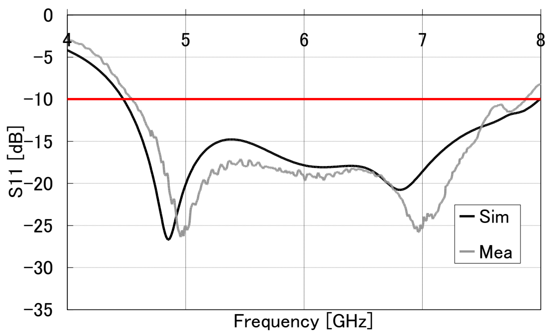


Figure 4: S_{11} characteristics

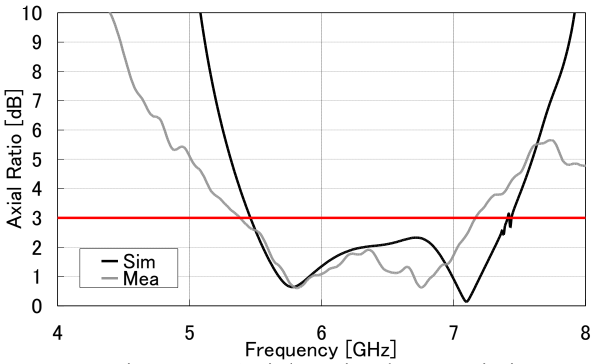


Figure 5: Axial Ratio characteristics

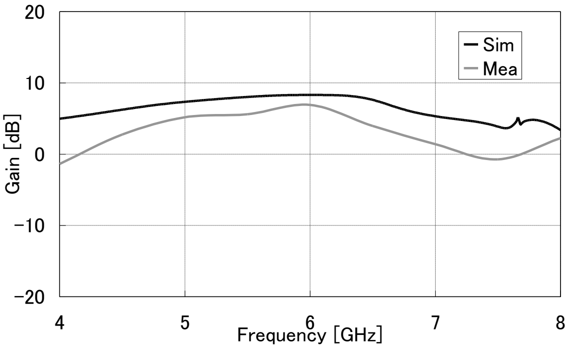
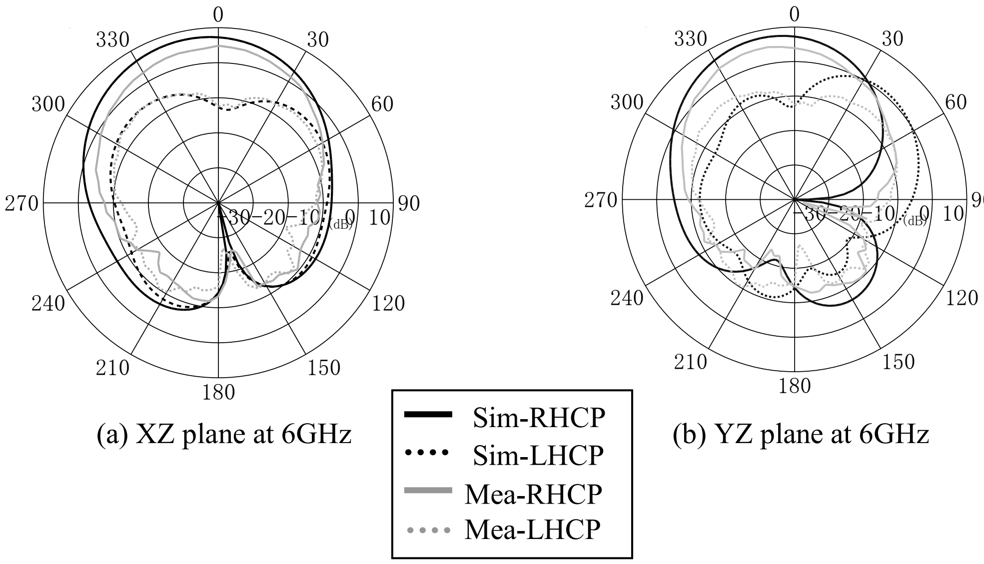


Figure 6: Simulated and measured Gain characteristics



(a) XZ plane at 6GHz

(b) YZ plane at 6GHz

Figure 7: Simulated and measured Radiation pattern

References

[1] Y. Zhang, J. von Hagen, M. Younis, C. Fischer and Q. Qiesbeck, "Planar Artificial Magnetic Conductors and Patch Antennas," IEEE Trans. Antennas & Propag., Vol. 51, No. 10, pp. 2704 – 2712, Oct. 2003.

[2] T. Nakamura, T. Fukusako, "Broadband Design of Circularly Polarized Microstrip Patch Antenna Using Artificial Ground Structure With Rectangular Unit Cells," IEEE Trans. Antennas & Propag., Vol. 59, No. 6, June 2011 (to be appeared).

[3] D. Qu, L. Shafai and A. Foroozesh, "Improving microstrip patch antenna performance using EBG substrates", IEE Proc.-Microw. Antennas Propag., vol. 153, No. 6, pp. 558 – 563, Dec. 2006.

[4] D. Sievenpiper, L. Zhang, R. F. J. Broas, N. G. Alexopolous, and E. Yablonovitch, "High impedance electromagnetic surfaces with a forbidden frequency band", IEEE Trans. Microw. Theory Tech., vol. 47, No. 11, pp. 2059-2074, Nov. 1999.