Design of circularly-polarized high-gain green antenna

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***Abstract* - A circularly-polarized high-gain green antenna using a solar panel as a frequency selective surface for Fabry-Perot cavity is proposed. First, the transmission and reflection coefficients of a square solar cell were analyzed for predicting the operating frequency of a green antenna with circular polarization and high gain operation. Next, the green antenna was constructed, and it consists of a square solar panel with 6 × 6 solar cells and a circularly polarized patch antenna backed with a metal ground plate. The achieved impedance bandwidth of the proposed green antenna is 154 MHz (2.928 ~ 3.082 GHz), and the CP bandwidth is 76 MHz (2.907 ~ 2.983 GHz). The antenna gain within the CP bandwidth is 13.0 ~ 13.9 dBic.**

***Index Terms* —Green antenna, frequency selective surface, Fabry-Perot cavity, solar panel, circular polarization.**

I. INTRODUCTION

In the past few years several solutions have been proposed to design high directive antennas. One of the solutions is to use Fabry-Perot cavity (FPC) antenna. The FPC antenna basically consists of a primary radiator backed with a ground plane and a frequency selective surface (FSS) or electromagnetic band gap (EBG) superstrate. Various FSS structures for enhancing antenna performance have been investigated by a number of authors [1]-[3]. Recently, Pu *et al*. [4] proposed a dual-function FPC antenna that use a solar panel as a FSS. Such an antenna can be named green antenna because it not only has the capability of producing electricity, but also is able to achieve highly directional radiation with linear polarization (LP).

Circularly polarized (CP) antennas with highly directive radiation are desired in many telecommunication applications, such as satellite and radar systems. A FPC antenna that is based on a symmetry FSS structure with ring-shaped metallic arrays is available for circular polarization [5]. It is noted that the symmetry FSS structure has an identical reflection (or transmission) phase for a normally incident plane wave that is independent of its polarization state. In this paper, a CP green antenna is developed with an asymmetrical FSS structure of a solar panel. The reflection and transmission phases of the solar panel as a function of polarization state was first analyzed with the help of the electromagnetic simulation software HFSS. The axial ratio and gain performances of the green antenna were then presented and discussed.

II. ANTENNA STRUCTURE AND DESIGN

The structure of the proposed CP green antenna is shown in Fig. 1(a), which consists of a solar panel performed as a FSS, a truncated square patch antenna as a CP primary radiator, and a ground plane. The cavity height is *h*. The solar panel is composed of 6 × 6 square solar cells, and has a lateral size of 256 × 256 mm^2 (2.56 × 2.56 λ_0^2 at 3.0 GHz). The truncated square patch is printed on a FR4 substrate with thickness of 1.6 mm and dielectric constant of ε_r = 4.4. The antenna radiates a left-hand CP wave at 3.0 GHz.

The geometry of the square solar cell is described in Fig. 2(a). It includes cover glass, bus bar (or metal finger), P-N semiconductor, rear electrode, and tedlar film. In this design, the solar cell simulation was introduced to estimate the suitable operating frequency of the solar panel for directivity enhancement and circular polarization operation. The solar cell behavior was studied using Floquet model analysis, as shown in Fig. 2(b). Fig. 3 shows the reflection phase of the solar cell. It is seen that in the frequency range of 2.95 ~ 4 GHz, the phase difference between x- and y-polarization state of the incident plane wave is less than 10^0. Fig. 4 shows the transmission phase of the solar cell. The phase difference less than 10^0 between two orthogonal polarization is also obtained from 3 to 4 GHz. From the results, it indicates that the highly directive radiation and circularly polarized operation for the solar panel can be realized in the frequency range of 3 ~ 4 GHz.

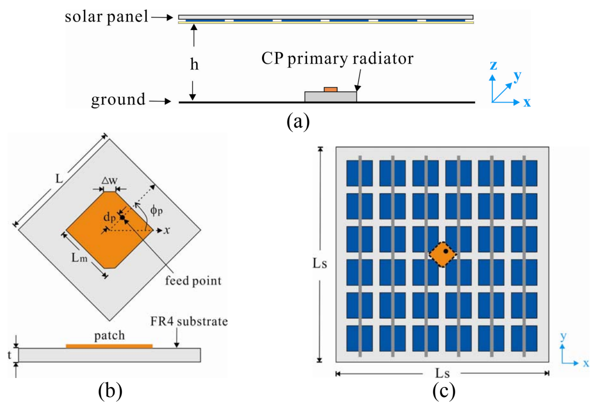

Fig. 1 (a) Structure of the proposed circularly polarized green antenna, (b) CP primary radiator, (c) solar panel. h = 55 mm, L_s = 256 mm, L = 46.4 mm, L_m = 23.2 mm, ϕ_p = 45°, d_p = 6 mm, Δw = 3.3 mm, t = 1.6 mm.

III. RESULTS AND DISCUSSIONS

The performance of the complete antenna structure was studied. Fig. 5 presents the simulated return loss of the green antenna by tuning the cavity height *h*. It is seen that the impedance bandwidth is slightly affected by the cavity height *h*. The 10-dB return loss bandwidth for the case of *h* = 55 mm is 154 MHz (2.928~3.082 GHz, 5.13%). The simulated axial ratio of the green antenna is shown in Fig. 6. When *h* = 55 mm, the minimum axial ratio is approximately 0.32 dB at 2.95 GHz, and the 3-dB axial ratio bandwidth is 76 MHz (2.907 ~ 2.983 GHz, 2.53%), which is larger than that (44 MHz) of only primary radiator. Fig. 7 shows the realized gain of the antenna. The gain variation of the green antenna between 11.3 and 13 dBic was attained within the CP bandwidth (2.907 ~ 2.983 GHz. Fig. 8 presents the simulated radiation patterns of the antenna. The maximum radiation at $\theta = 0^\circ$ is exhibited in the two principal planes. As both E_θ and E_ϕ at $\theta = 0^\circ$ are nearly equal, it also shows that the proposed antenna has good CP radiation.

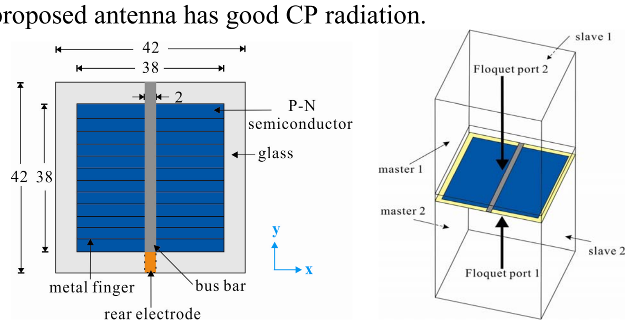

Fig. 2 (a) Layout of the square solar cell (unit: mm) (b) simulated model.

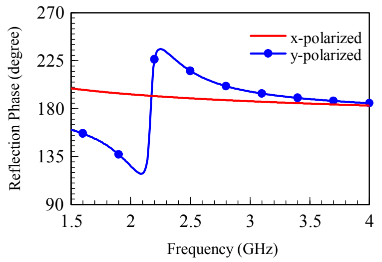

Fig. 3 Reflection phase of the solar cell.

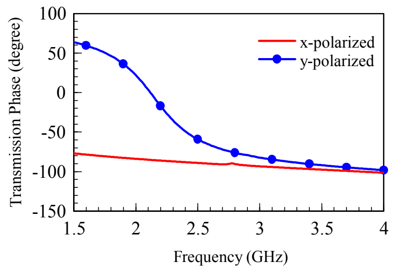

Fig. 4 Transmission phase of the solar cell.

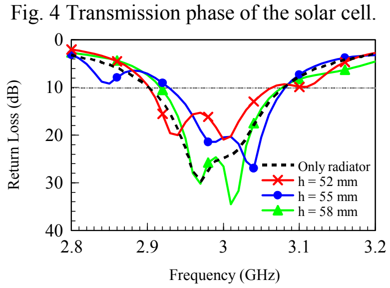

Fig. 5 Simulated return loss by tuning the cavity height *h*.

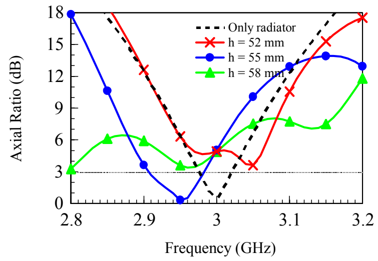

Fig. 6 Simulated axial ratio by tuning the cavity height *h*.

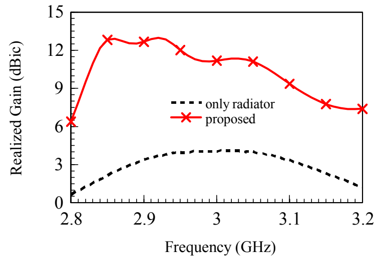

Fig. 7 Simulated gain of the proposed green antenna; h = 55 mm.

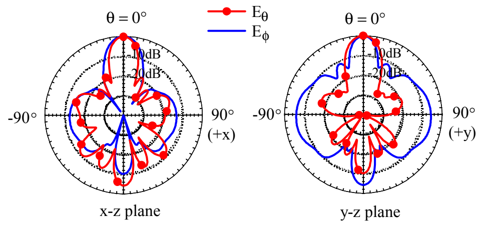

Fig. 8 Simulated radiation patterns at 2.95 GHz for the proposed antenna.

IV. Conclusion

A novel CP green antenna using a solar panel as a frequency selective surface has been successfully implemented and studied. The impedance bandwidth and CP bandwidth of the proposed green antenna are 154 MHz (2.928 ~ 3.082 GHz) and 76 MHz (2.907 ~ 2.983 GHz), respectively. Maximum gain is 13 dBic.

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