Broadband Circularly Polarized Fabry-Perot Resonator Antenna

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***Abstract*- The broadband circularly polarized Fabry-Perot resonator (FPR) antenna is presented, which consists of a partially reflective surface (PRS) as cover, a metal-dielectric surface as ground plate and an embedded L-probe coupled rectangular patch as primary radiator. The partially reflective surface covered plate composed of appropriate frequency selective surface (FSS) structure with rectangular patch elements printed on the bottom surface of superstrate. By adjusting the aspect ratio of rectangular patch and the rectangular FSS element, the bandwidth of the circularly polarized (CP) operation can be enhanced. For the proposed antenna, a common frequency bandwidth of 7.7 % for $S_{11} \leq$ -10dB and gain-drop ≤ 3 dB and axial ratio ≤ 3 dB is obtained.**

I. INTRODUCTION

Fabry-Perot Resonator (FPR) antennas with attractive features of high-gain, low-profile, and simple feeding have aroused more and more attention for several years [1-4]. It consists of a primary radiator backed with a metal ground plate and consists of a primary radiator backed with a metal ground plate and a partially reflective covered plate [1]. When the spacing between these two plates is about integer times of half wavelength, the energy from the feed is multi-reflected between the cover and ground plate and then the forward radiation can be enhanced remarkably by means of in-phase bouncing. To design a compact and high gain FPR antenna various methods based on different viewpoints and analysis models such as leaky wave model [5], EBG defect model [6], FP cavity model [1, 2], effective material method [3,7] have been attained and proposed.

On the other hand in several wireless communication system and radar applications, where both high gain and circular polarization (CP) are required, FPR antennas can advantageously reduce the complexity of the feeding structure by using the properties of partially reflecting surfaces (PRS). In summary, there are two ways can be used to realize such type of antennas from the viewpoint of primary source (1) a PRS placed directly above a CP feed antenna [8, 9], (2) a PRS arranged directly above a LP feed antenna [10, 11], where PRS acts as a polarizing transform structure to convert linear polarization (LP) of the feed into CP radiation. However, one of the serious disadvantages of this type CP antenna is that its impedance and axial ratio bandwidth are narrow. In this paper, by using the combined techniques incorporating with appropriate aspect ratio of FSS element and feeding patch design, the broadband circularly polarized FPR antenna can be proposed.

II. PRINCIPLE AND DESIGN

A. Principle

In reference [10], the circularly polarized FPR antenna with linear polarization feed is firstly proposed. According to the EM theory, an incident linearly polarized wave $\vec{E}_{in}$, tilting at 45° with the plates, can be decomposed into two orthogonal components E_{in}^{x} and E_{in}^{y} of equal amplitude, which can be expressed as:

$$\vec{E}_{in} = \hat{x} \cdot E_{in}^{x} \angle\varphi_x + y \cdot E_{in}^{y} \angle\varphi_y \quad (1)$$

At the same time, the radiated wave $\vec{E}_{ra}$ from the upper surface of cover plate can also be written as:

$$\vec{E}_{ra} = \hat{x} \cdot E_{ra}^{x} \angle\theta_x + y \cdot E_{ra}^{y} \angle\theta_y \quad (2)$$

which is relative to the incident wave by

$$\begin{cases} E_{ra}^{x}\angle\theta_x = E_{in}^{x}\angle\varphi_x \cdot T_{ca}^{x}\angle\phi_x \\ E_{ra}^{y}\angle\theta_y = E_{in}^{y}\angle\varphi_y \cdot T_{ca}^{y}\angle\phi_y \end{cases} \quad (3)$$

where the T_{ca}^{x} and T_{ca}^{y} are the model of transmission functions of FP cavity with respect to x and y components. Due to deployment of rectangular FSS element, the phases of transmission functions of x and y are different. If the condition

$$\begin{cases} \left|E_{ra}^{x}\right| = \left|E_{ra}^{y}\right| \\ \theta_y - \theta_x = \pm 90^\circ \end{cases} \quad (4)$$

is meet, the circularly polarized radiated wave can be obtained.

B. Design

Circularly polarized FPR antenna fed by simple dipole with linear polarization is presented in reference [10], but its bandwidth of axial ratio is narrow. In order to improve the property of the bandwidth, an L-probe coupled rectangular patch is proposed as primary radiator, in which the combined techniques incorporating with appropriate aspect ratio of FSS element and coupled rectangular patch are used. Fig.1 shows the geometry of the proposed FPR antenna. The cavity is made of a metal ground plate and a PRS composting of rectangular FSS elements. Both the superstrate of cover and substrate of base have the same relative permittivity ε_r =3.2 and thickness t. The distance between two parallel planes is D. The L-probe coupled patch placed at a distance $\boldsymbol{h}$ from the ground plate. And the L-probe tilts at 45 angle with respect to x direction and the distance between L-probe and coupled patch is h_1. The periodicity of FSS in x and y direction is p_x and p_y respectively. The side length of unit cell of FSS in x and y direction is l_2 and w_2 respectively. As shown in fig.1, the side length of coupled rectangular patch in x and y direction is l_1 and w_1 respectively. A 45°polarized excitation generated by L-probe can be decomposed into two orthogonal x- and y-components with equal magnitude and phase. But when these two components coupled to the rectangular patch, the different response is occurred due to different side length of rectangular patch, which results in that the radiated wave from coupled rectangular patch is an elliptical polarization. By adjusting the aspect ratio of FSS element and coupled rectangular patch, that is to say, adjusting the transmission function T_{ca}^{x} and T_{ca}^{y}, finally the broadband circularly polarized FPR antenna can be obtained.

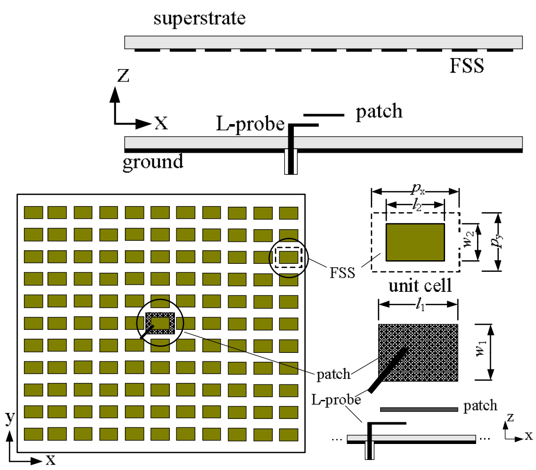

Figure 1. Geometry of proposed antenna

III. SIMULATION RESULTS

Table 1 show the parameters of geometry of proposed circularly polarized FPR antenna, which has been obtained through the simulation with CST Microwave Studio. The cavity height D is set at 10mm in order to obtain a working frequency around 14 GHz. In simulation, the $w_1/\ l_1$ is set to aspect ratio τ_1 and the $w_2/\ l_2= p_y/\ p_x$ is set to aspect ratio τ_2. Figure 2 presents the frequency responses of axial ratio and gain with respect to the parameters list in Table 1. It is illustrated that the bandwidth of axial ratio lower than 3dB reaches from 13.35 to 14.42GHz. More importantly, the bandwidth of the 3dB gain drop ranges from 12.9 GHz to 14.45GHz, in which the peak value of gain approaches 17.0 dBi at 13.7GHz. The frequency response of reflection coefficient of proposed antenna is shown in Figure 3, where the bandwidth of S_{11} with -10dB threshold is ranged from 13.1 to 15.7GHz. It means that the common or overlapped bandwidth for axial ratio, gain drop and the impedance matching is about 7.7%.

TABLE I
value of proposed antenna parameters

Parameter	Dimension (mm)	Parameter	Dimension(mm)
l_1	7.5	p_x	6
w_1	4.8	p_y	3.6
h	3	l_2	4.5
h_1	1	w_2	2.7
D	10	t	1.6

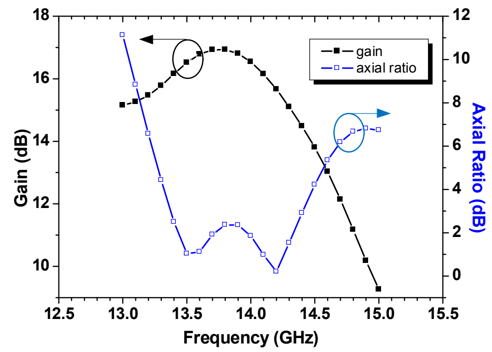

Figure 2. Frequency response of gain and axial ratio

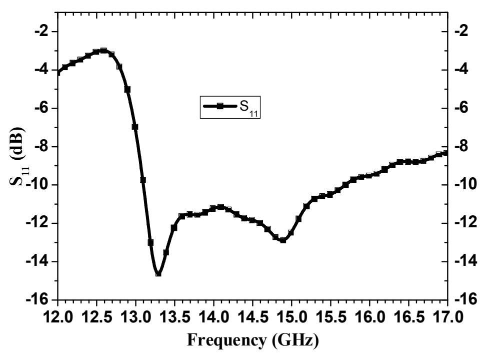

Figure 3. Frequency response of reflection coefficient

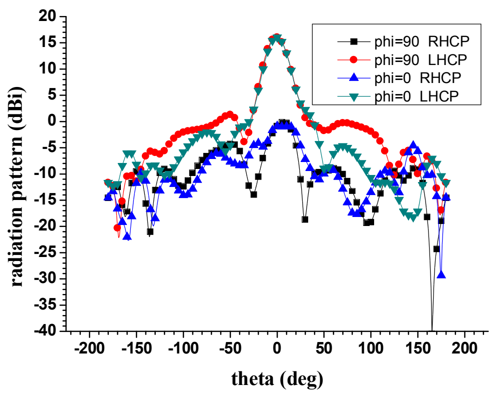

Figure 4. Radiation pattern at *f*=13.4GHz

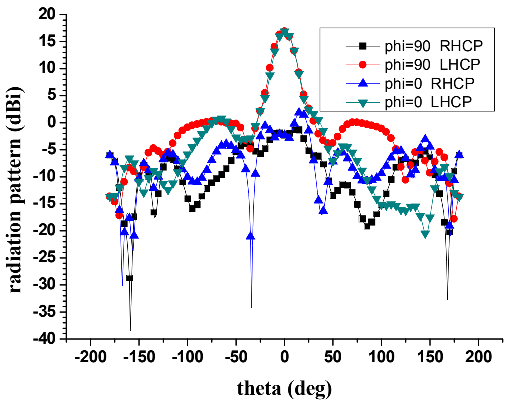

Figure 5. Radiation pattern at *f*=13.7GHz

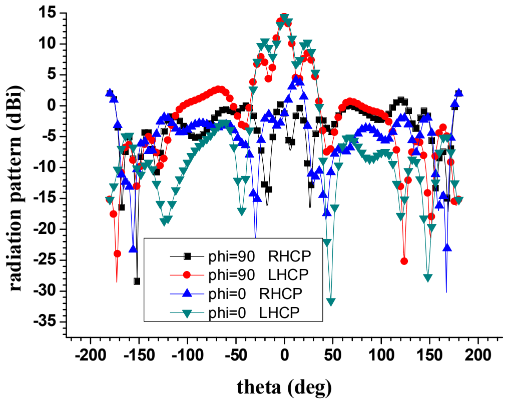

Figure 6. Radiation pattern at *f*=14.4GHz

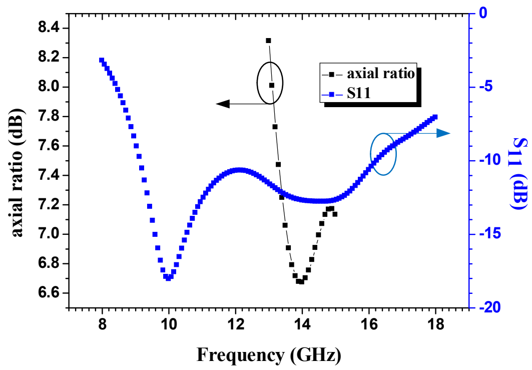

Figure 7. Frequency response of axial ratio and reflection coefficient of L-probe coupled rectangular patch

Figure 4 and Figure 5 show the simulation results of radiation pattern at frequency 13.4GHz and 13.7GHz respectively. At frequency 13.7GHz, the side-lobe level is better as -17.0dB in E and H plane. The -20dB cross-polarization-level (XPL) at broadside and better than 16 dB within half-power beamwidth can be obtained. Figure 6 also shows the radiation pattern at side frequency 14.4GHz, where the gain approach 15dBi, but the side-lobe-level is only about -5dB.

In order to validate the excited polarization property of the single L-probe coupled rectangular patch, the FPR antenna directly removed the superstrate under the same condition is simulated. Figure 7 shows the simulated result of frequency response of axial ratio and reflection coefficient. It is illustrated that in the common bandwidth the polarization excited by single feed is an elliptical polarization EM wave other than circular polarization, where the minimum axial ratio is 6.65dB. At same time, in the common bandwidth the reflection coefficient is lower than -10dB. From the above statement, it is demonstrated that the combined techniques incorporating with appropriate aspect ratio of the FSS element and the coupled rectangular patch to enhance the bandwidth of circular polarization FPR antenna are in effect.

IV. CONCLUSION

In this paper, a broadband circularly polarized Fabry-Perot resonator antenna fed by single L-shaped probe coupled rectangular patch and integrated by rectangular FSS element is proposed based on the idea of polarization transform. The bandwidth of axial ratio can be enhanced by adjusting the aspect ratio of rectangular patch and rectangular FSS element, which results in that the excited elliptical polarization EM wave can be transformed into the circular polarization in broad bandwidth.

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