Simple Thin Partial Reflective Surface for Dual-band Fabry-Parot Resonator Antennas

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Abstract

A simple thin partially reflective surface with the periodic structure is developed for dual-band, dual-polarization Fabry-Perot resonator antennas. Using the developed partially reflective surface and an electric conductor ground, a dual-band resonant cavity in both polarization can be formed and hence a dual-band, dual-polarization resonant cavity antenna can be designed. The method to design the partially reflective surface is described and positive simulated results are obtained.

Keywords : Electromagnetic band-gap, partially reflective surface, Fabry-Perot resonator antennas, directive antennas, EBG resonator antennas

1. Introduction

Fabry-Perot resonator, originally used in optical region, have been applied to enhance the gain of small antennas for the past two decades [1,2]. Recent progress in photonic band-gap (PBG) and electromagnetic band-gap (EBG) materials inspired the study on Fabry-Perot resonator antennas. High-gain, wideband or multiband directive Fabry-Perot resonator antennas were developed [3-9] using various EBG materials in the microwave region. Advantages of such kind of antennas include structure simplicity, low cost, ease of fabrication and integration.

Recently, a new design approach was developed [6-8] to design dual-band Fabry-Perot resonator antennas. Using this approach, a simple partially reflective surface (PRS), composed of a single thin dielectric slab with one or two specially-designed metallic coating arrays on one or both of its sides, is able to be easily designed for the dual-band operation [6-8]. In this paper, a PRS for dual-band, dual-polarization operation is presented. Details of the design procedures are given and simulated results verify the design target.

2. Design Principle of PRS for Dual-Band Operation

It is known that objects exhibit significantly different electromagnetic properties at resonance. We have found from our investigations that the magnitude and phase of the transmission and reflection of a PRS vary significantly in a frequency band that is close to the PRS resonance frequency [6-9]. This phenomenon has been applied to design wideband [9] and dual-band [6-8] Fabry-Perot resonator antennas. All the PRSs we investigated for wideband and dual-band Fabry-Perot resonator antennas are composed of a single dielectric slab, with a large size, and one or two arrays of periodic elements printed on one or both of its surfaces. Several element geometries, such as dipoles, slots, patches, rings, etc., have been investigated for this purpose. In [6], a dielectric slab with an array of slots on its bottom surface is designed for dual-band, single-polarization Fabry-Perot resonator antennas. To design such a PRS for dual-band, dual-polarization operation, the geometry of the PRS should be symmetrical in its both dimensions. A dielectric slab with an array of square-patch pairs is designed here for this purpose.

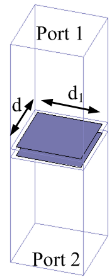

Figure 1: A unit cell PRS for dual-band, dual-polarization operation.

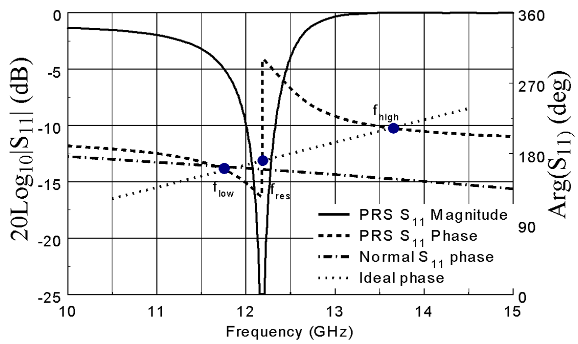

Figure 2: Reflection magnitude and phase of the proposed PRS.

A unit cell of the proposed PRS is shown in Fig. 1, which is composed of a square dielectric and two same square metallic patches printed on the two sides of the unit dielectric. The side length and thickness of the unit cell are *d* and *t*, respectively. The side length of the two patches is d_1. The reflection magnitude and phase of the proposed PRS can be computed using the model in Fig. 1. As can be seen, two ports are set up at the top and bottom surfaces of the unit cell. Periodic boundary condition is applied to the four side surfaces. For normal incidence, the periodic boundary condition on the four sides can be replaced by PEC and PMC boundaries. For example, sides 1 and 3, as shown in Fig. 1, use PEC boundary and sides 2 and 4 are set to PMC boundary. In the example design presented in this paper, the dielectric layer uses FR4/Epoxy material, which has a dielectric constant of about *4.4* and a thickness of *0.8 mm*. The parameters *d*, *t* and d_1 are taken *6 mm*, *0.8 mm* and *5.3 mm*, respectively. Using commercial software CST Microwave Studio, the reflection from the surface of the PRS can be obtained. The computed reflection magnitude and phase are plotted in Fig. 2. One can see that the PRS resonates at *12.2 GHz*, due to the array of the square patch pairs. The reflection phase decreases with frequency at most frequencies, while at the resonant frequency, the phase has a steep increase that can be taken advantage of to generate dual-band operation when the PRS is applied to form a Fabry-Perot resonator antenna. The reflection phase from a normal PRS, which can only generate a single-band operation when form a Fabry-Perot resonator antenna, is also plotted in Fig. 2, for comparison.

The resonance condition of a Fabry-Perot cavity, formed by a PRS and a PEC ground, is given by [4]

$$\phi_P + \phi_G - \frac{2\pi}{\lambda} 2h = 2k\pi, \quad k = 0, \pm 1, \pm 2 \cdots \qquad (1)$$

where ϕ_P and ϕ_G are reflection phases of PRS and the ground, respectively. When this condition is satisfied, the leaky waves on the surface of the PRS are in phase and maximum directivity can be obtained in the broadside of the PRS. The reflection phase of a PEC ground plane is always *180°*. When the cavity height *h* is fixed and taken a value of *12 mm*, the ideal phase ϕ_P, which ensures that condition (1) is always satisfied with frequency, is plotted in Fig. 2. As can be seen, there are total three cross points between the ideal phase and the reflection phase from the proposed PRS, exhibiting that the cavity can satisfy the resonance condition at three frequencies (f_{low}, f_{res} and f_{high}). However, as described in [6-8], the PRS is almost transparent at its resonant frequency, f_{res} at this case. Hence the transmission through the PRS is strong, resulting in a smaller antenna aperture and less or even no gain increase at f_{res}. Therefore the gain enhancement only occurs at f_{low} and f_{high} bands.

3. Design Example

As a design example, we have designed a PRS for a dual-band Fabry-Perot resonator antenna that could operates in two bands, one around 11.5 GHz and the other around 13.5 GHz. The configuration of the antenna is shown in Fig. 3. The PRS, made out of FR4/Epoxy material, forms the dual-band EBG resonator antenna together with a PEC ground and a feed antenna

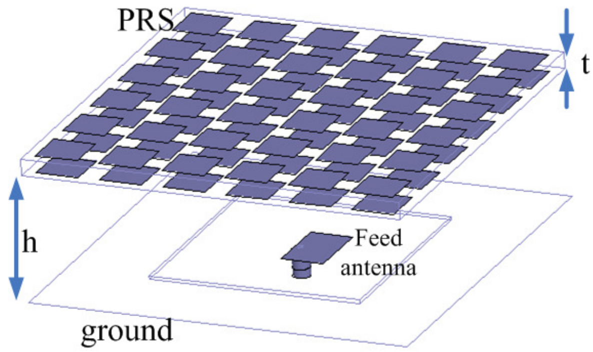

Figure 3: Configuration of the proposed Fabry-Perot resonator antenna.

The parameters (d, t, d_1 and h) of the PRS and the antenna, having been used to demonstrate the design principle of the dual-band operation in the above section, are taken as follows: $d=6\ mm$, $d_1=5.3\ mm$, $t=0.8\ mm$ and $h=12\ mm$. In the antenna design, the PRS has overall dimensions of $90 \times 90\ mm^2$ (about $3.6\lambda \times 3.6\lambda$ at $12\ GHz$ and 15×15 unit cells). The antenna is simulated using the in-house FDTD code. In the simulations, a horizontal electric dipole (HED) (e.g. an x-polarized HED at the centre of the antenna above the ground) was employed to feed the antenna, for simulation simplicity. The computed directivity, plotted in Fig. 4, has two peak values greater than $16\ dBi$ over the two concerned frequency bands. The computed radiation patterns at $11.5\ GHz$ and $13.4\ GHz$ are plotted in Fig. 5.

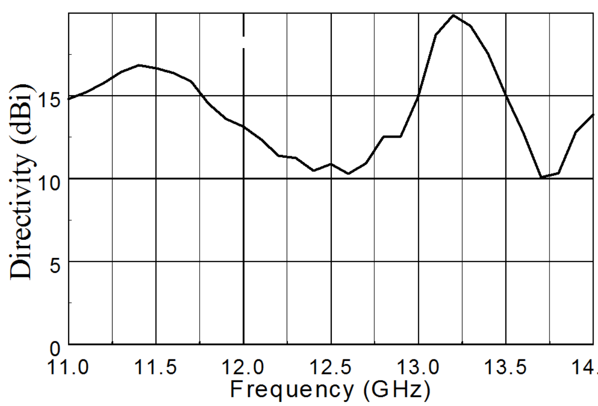

Figure 4: Directivity vs Frequency.

4. Conclusions

A thin, single-layer partially reflective surface is successfully designed for the realization of dual-band, dual-polarization, low-profile Fabry-Perot resonator antennas. The Fabry-Perot cavity, formed by the example partially reflective surface and a PEC ground, exhibits two useful resonance frequencies, at the two sides of the resonance frequency of the PRS, respectively, leading to a dual-band Fabry-Perot resonator antenna. The symmetrical structure of the designed PRS is also suitable for the dual-polarisation operation. Simulations of the formed antenna confirm the high directivity of the antenna in two distinct frequency bands.

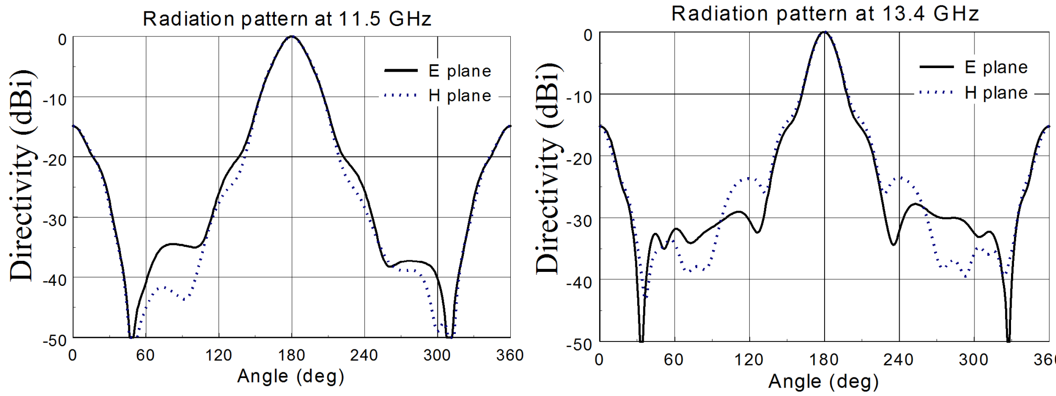

Figure 5: Radiation patterns at 11.5 GHz and 13.5 GHz.

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Acknowledgments

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