Fabry-Perot Resonator Printed Antennas Employing EBG and AMC Substrate*

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Abstract: *In this paper, the prototype of Fabry-Perot resonator antenna with double-layer superstrate and U-slotted patch radiator surrounded by high impedance surface as artificial magnetic conductor is proposed, designed and tested. It performs higher directivity, lower side- lobe level, and low profile, wide bandwidth for VSWR but narrower bandwidth for directivity.*

Key words: *Fabry-Perot resonator, Printed antenna, Electromagnetic Band Gap (EBG), High Impedance Surface (HIS), Artificial Magnetic Conductor (AMC).*

1. Introduction

Several references [1-5] had pay attention to different structures of cover (superstrate) for enhancing the directivity of microstrip patch antenna, which may be treated as a Fabry-Perot (F-P) resonator printed antenna [6]. The original model of F-P antenna consists of a printed radiator, a conductive ground plate, and a dielectric cover with thickness of a quarter of wavelength in dielectric (λ_ε /4), and spacing of half a wavelength in air (λ_0/2) from the plate (Fig.1). However, all its technical performances of directivity (*D*, or aperture efficiency η_A), side-lobe-level (SLL), and bandwidth for impedance matching are not satisfactory; in addition, the structural thickness and weight of cover are unacceptable, especially for lower frequency application.

In this paper, three schemes of improvement for Fabry-Perot (F-P) resonator printed antenna are developed and compared. Firstly, the thick cover is replaced by a double-layer sheets (solid dielectric upper layer and dielectric EBG lower layer, or reversed) or a patch-type Frequency Selective Surface (FSS); Secondary, a broadband radiator of stripline-fed wide-slot (Fig.2) or probe-fed U-slotted patch is employed and optimized (Fig.3) under the effect of cover; finally, the radiator is surrounded by patch-type High Impedance Surface (HIS) (Fig.4) acting as Artificial Magnetic Conductor (AMC) for thinning the structure.

According to individual simulation and design for various prototypes with the same aperture area at 14 GHz, it can be summarized as: (1) The model of FSS-cover, wide-slot feed without HIS achieves highest directivity (19.6 dBi) and aperture efficiency (87 %), and also thin structure; but narrow common bandwidth (3.7 %) for both VSWR (<2:1) and directivity (−3 dB drop). (2) The model of dielectric/EBG-cover, U-slotted patch feed without HIS possesses widest common bandwidth (7.7 %); but lower directivity. (3) A second model with HIS can performs most thin structure (17 mm) and most weak SLL (−15.5 dB), moderate bandwidth (5.6 %) and maintain the same *D* as that without HIS.

2. The Scheme for Cover [7]

There are four kinds of dielectric cover constructed as (upper-/lower- layer with gap): (a) both are solid dielectric sheets---which results in stronger SLL and backward diffraction due to multiple inter-reflection. (b) both are dielectric EBG sheets with higher permittivity---which could not decrease the thickness of cover due to lower effective permittivity. (c) solid/EBG or (d) EBG/solid can effectively suppress the lateral wave and edge diffraction. In comparison, (c) provides higher directivity; but (d) forms wider bandwidth and higher radiation ratio of forward to backward *F*/*B*.

A typical design of (c) with optimized wide-slot radiator without HIS (Fig.5a) performs: *D*=18.6 dBi (η_A =68 %), *F*/*B* =20.6 dB, SLL= −13.0 dB; bandwidth for VSWR is 19.7 %, for *D* is 5.9 %, and then 5.3 % (13.7~14.5 GHz) for common bandwidth; which total thickness is 26.4 mm.

On the other side, a typical design of (d) with same radiator and without HIS (Fig.5b) performs: *D*=18.4 dBi (η_A =66 %), *F*/*B* =21.9 dB, SLL= −12.8 dB; bandwidth for VSWR is 21.7 %, for *D* is 7.7 %, and then 6.8 % (13.56~14.52 GHz) for common bandwidth; which total thickness is 24.9 mm.

Besides, a FSS printed on a thin dielectric sheet with lower permittivity can also be used as a thin cover (Fig.5c), its metal part in cover may enhance the directivity but decrease its bandwidth. A typical design with same radiator as above give out the performances: *D*=19.6 dBi (η_A =87 %), *F*/*B* =21.2 dB, SLL= −15.0 dB; bandwidth for VSWR is 19.5 %, for *D* is 5.7 %, and then only 3.7 % (13.87~14.4 GHz) for common bandwidth; which total thickness is 18.4 mm.

3. The Scheme for Radiator

To replace the stripline-fed wide-slot radiator by probe-fed U-slotted patch for the cover of type (d), it can extend the common bandwidth to 7.7 % (13.51~14.59 GHz) from 5.3 %, and reduce the total thickness to 19.4 mm from 26.4 mm simultaneously. The sizes of U-slotted patch are optimized under the effect of cover, hence quite different from isolated one [8]. Both two different radiators are used in prototypes (Fig.6) for testing.

4. The Scheme for Base

In order to reduce the total thickness furthermore, the HIS can be utilized surrounding the radiator [9]. Various types of HIS structure are compared: mushroom type, UC-PBG type, square-patch type and square-ring type, for their frequency response of reflection phase under the arbitrary incident angle. As shown in Fig.7, the UC-PBG is fight off due to its high frequency sensitivity, the square-patch is best, the mushroom has almost same response but more complicated in fabrication [10].

A sample of EBG/solid dielectric cover and U-slotted patch radiator surrounded with square-patch type of HIS is compared to that without HIS, it reduces thickness to 17.0 mm, and slightly improves the SLL, but its common bandwidth become narrower as 5.6 % (13.71-14.50 GHz).

5. Experimental Verification

All the simulation work is run on CST Microwave Studio. Two prototypes of Fabry-Perot resonator printed antenna are fabricated and tested respectively. Fig.8 shows the comparison between the measured and simulated curves for improved F-P printed antenna with/without HIS. The measured curves have move leftward deviate from that of simulated, it is caused by the error of dielectric constants; the radiation patterns are with good agreement.

6. Conclusions

The structure of Fabry-Perot resonator can be used to enhance the directivity of printed antennas, but the thickness in structures profile is relatively large. The improved structures are proposed in this paper. By using a probe-fed U-slotted patch radiator, the thickness of antenna is obviously reduced, the bandwidth is enlarged, and the side-lobe level is decreased. It can be further improved by high impedance surface surrounding the patch radiator; however it results in narrower bandwidth. The further efforts should be coordinating the design of cover and radiator, to make their bandwidth overlapping as well as possible.

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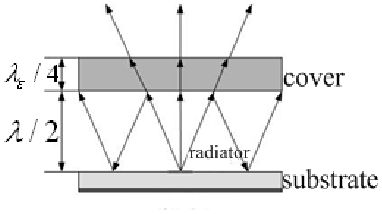


Figure 1 Structure of Fabry-Perot antenna

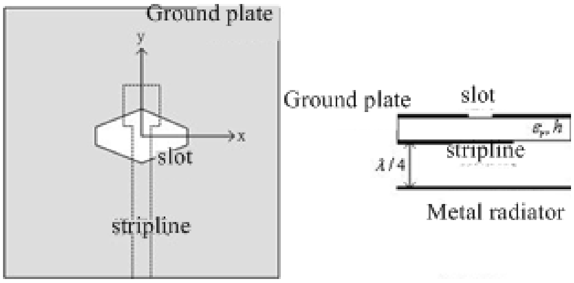
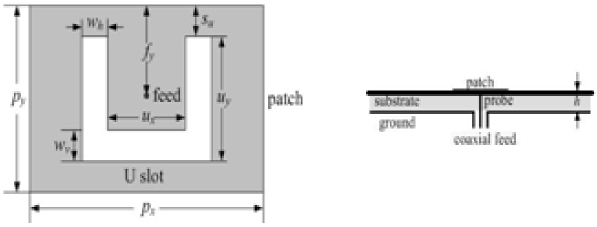


Figure 2 Structure of Fabry-Perot antenna



(a) Top view (b) Front view

Figure 3 Structure of U-slotted rectangular patch radiator

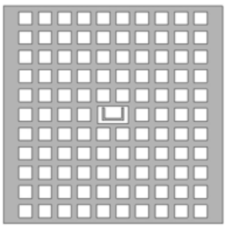
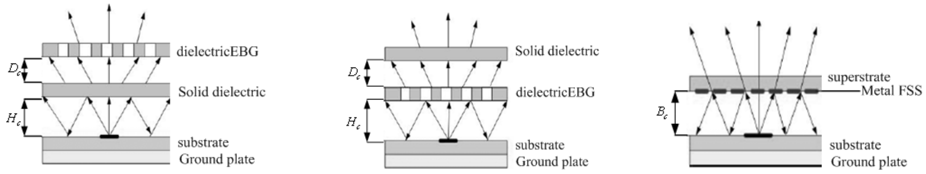
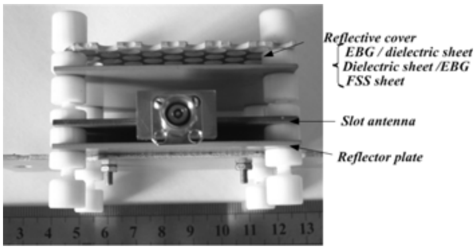


Figure 4 U-slotted patch radiator surrounded by HIS

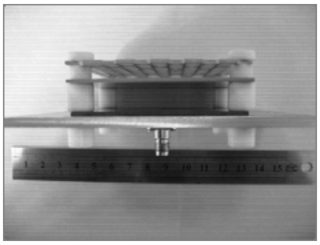


(a) solid/EBG dielectric sheets (b) EBG/solid dielectric sheets (c) superstrate with FSS

Figure 5 Three kinds of cover structure

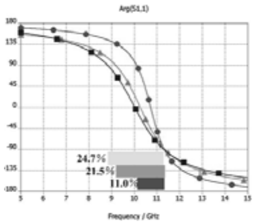


(a) Prototype fed by wide-slot

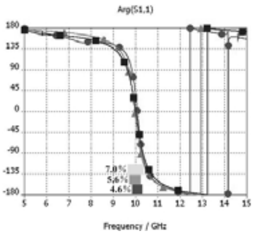


(b) Prototype fed by U-slotted patch

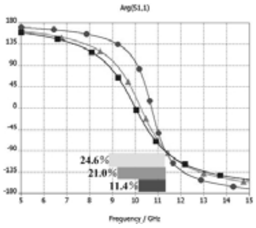
Figure 6 Prototypes for testing



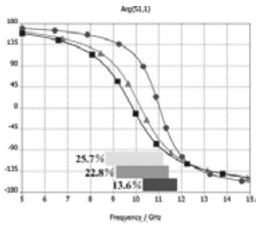
(a) Mushroom type



(b) UC-PBG type



(c) Square-patch FSS type



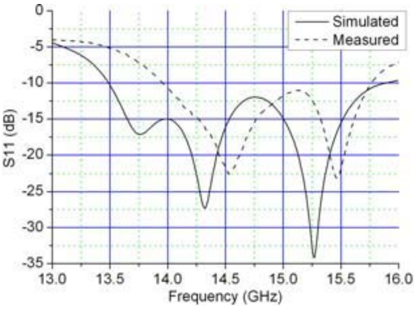
(d) Square-loop FSS type

0° Normal incidence:

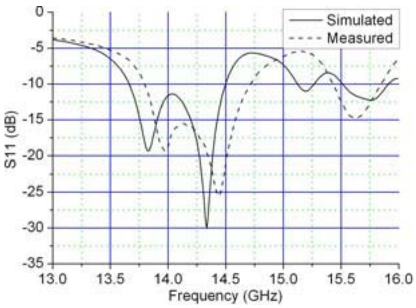
30° oblique incidence:

60° oblique incidence:

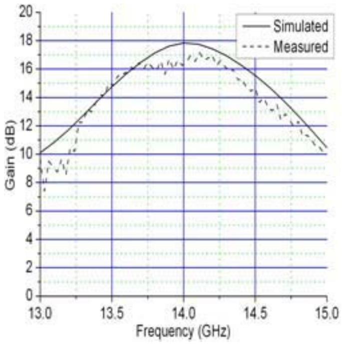
Figure 7 Frequency response of reflection phase under different incidence



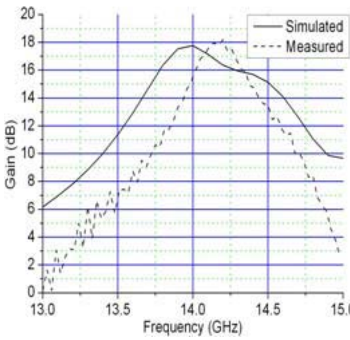
(a) Returned loss for the case without HIS



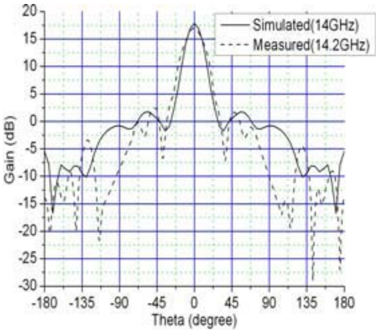
(b) Returned loss for the case with HIS



(c) Directivity for the case without HIS



(d) Directivity for the case with HIS



(e) H-plane pattern without HIS

Figure 9 Measured and simulated curves for improved F-P printed antennas