A Wideband Fabry-Pérot Cavity Filtering Antenna

Shu-Qing Zhang, Sai-Wai Wong*, Yejun He, Zhonghe Zhang
State Key Laboratory of Radio Frequency Heterogeneous Integration
Sino-British Antennas and Propagation Joint Laboratory, Ministry of Science and Technology of China
Guangdong Engineering Research Center of Base Station Antennas and Propagation
Shenzhen Key Laboratory of Antennas and Propagation
College of Electronics and Information Engineering, Shenzhen University, 518060, China
Email: 2100432054@email.szu.edu.cn, wongsaiwai@ieee.org, heyejun@126.com, 2150432016@email.szu.edu.cn

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***Abstract*—This paper presents a wideband Fabry-Pérot Cavity (FPC) filtering antenna, which consists of a cavity filtering antenna as the feed antenna, exciting the FPC structure above it. The top partially reflective surface (PRS) exhibits a positive reflective phase gradient within the operating frequency range. The proposed antenna achieves a -10 dB impedance bandwidth of 24.3%, with a maximum gain of 14 dB within the passband. It also features a radiation null in the low-frequency stopband and high-frequency stopband, achieving out-of-band suppression of 33 dB and 21 dB, respectively.**

***Index Terms*—FPC antenna, filtering antenna, out-of-band suppression, radiation null, broadband antenna.**

I. Introduction

Filtering antennas have become a hot topic in modern .microwave device research. Thanks to their multifunctionality, filtering antennas combine the filtering performance of filters with the radiation performance of antennas. This makes them potential alternatives to the combination of filters and antennas in RF front-end systems, aligning with the trend of high integration in modern communications. In practical applications, important metrics for filtering antennas include size, out-of-band suppression, operating bandwidth, and gain.

Recently, there has been a lot of research on various types of filtering antennas, including microstrip patch filtering antennas [1]-[2], dielectric resonator filtering antennas [3]-[4], and cavity filtering antennas [5]-[11], etc. Cavity antennas, due to their inherent characteristics, inherently have certain filtering properties, and their metallic structures can withstand relatively high power, making them popular in satellite communication and certain military applications. However, they typically have a narrow bandwidth due to their high Q values. In reference [8], a high-order mode cavity filtering antenna using wavefront phase compensation is introduced. This antenna corrects the phase of radiation fields with opposite phases in high-order modes by adjusting the height of radiation slots and grid-slotted patches. Finally, a CQ structure is introduced at the feed point to form two radiation nulls in the high and low frequencies, achieving excellent frequency selectivity. However, its operating bandwidth is only 3%. In reference [9], a bandwidth-enhanced high-gain filtering slot antenna array is proposed. By bringing two cavity modes close together to enhance the bandwidth, and replacing the traditional single radiation slot with four radiation slots, the antenna achieves increased gain without increasing its volume. However, it still only has a peak gain of 11dB and an impedance bandwidth of 6.2%.

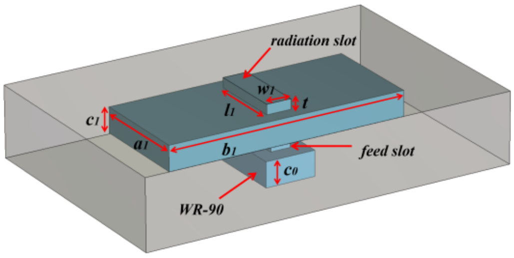

Fig. 1. The structure diagram of the feeder antenna (The grey portion represents brass, while the blue portion represents vacuum, c0 = 15, a1 = 21, b1 = 48.6, c1 = 5, l1 = 15, w1 = 5, t = 2, unit: mm)..

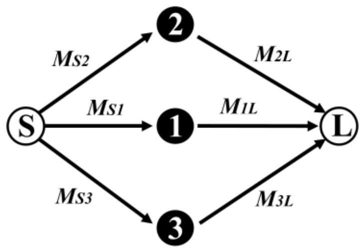

Fig. 2. The topology diagram of the feeder antenna (mode 1: slot mode; mode 2: T E120; mode 3: T E130).

In this article, a broadband FPC filtering antenna is proposed. By utilizing a PRS with a positive-negative phase gradient, the antenna achieves a wide gain bandwidth. Additionally, filter characteristics are designed on the feeding antenna, enabling the proposed antenna to exhibit strong out-of-band suppression without introducing additional filtering circuits.

II. Antenna Design

A. Feeder Antenna

Fig. 1 shows the structure of the feeder antenna, which consists of a metal cavity and two slots. It has a very simple structure and is fed by standard waveguide WR-90. The filtering principle of the antenna is shown in Fig. 2, and its topology is a transverse coupling structure. Mode 1 is the slot mode, mode 2 is the TE_{120} mode of the metal cavity, and mode 3 is the TE_{130} mode. When the coupling

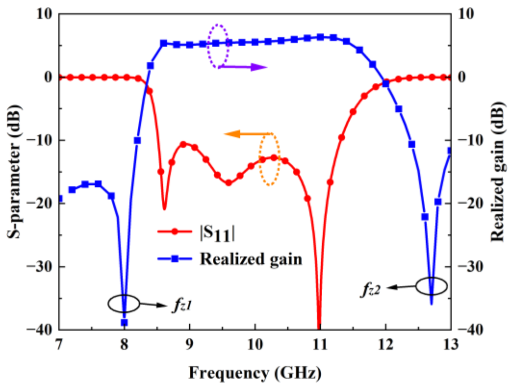

Fig. 3. Simulation S-parameter and gain curve of the feeder antenna.

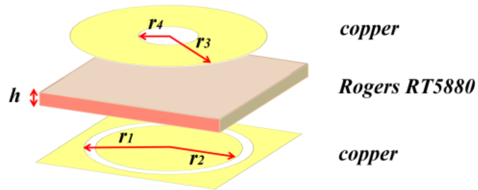

Fig. 4. The schematic diagram of the structure of PRS, the yellow part represents brass and the brown part represents the dielectric substrate (r1 =2.898, r2 = 2.52, r3 = 3.25, r4 = 1, h = 0.787, unit: mm).

coefficients between the three modes satisfy $M_{S1}M_{1L}M_{S2}M_{2L} < 0$ and $M_{S1}M_{1L}M_{S3}M_{3L} < 0$, they can produce two radiation nulls. Fig. 3 shows the simulation results of the feeder antenna. As shown in the Fig. 3, the antenna achieves a -10 dB impedance bandwidth of 28.35%, and there is a radiation null in the low-frequency stopband and and another in the high-frequency stopband, achieving out-of-band suppression of -22 dB and -16 dB, respectively. The maximum gain within the band is 5.6 dB.

B. PRS Units

Fig. 4 shows the PRS unit cell structure. The PRS unit consists of a circular gap at the bottom and a metal ring structure at the top. The design utilizes Rogers RT5880 as the substrate material with a thickness of *h*=0.787 mm, relative permittivity of 2.2, and loss tangent of 0.0009. In traditional FPC antennas, the reflection phase decreases as the frequency increases.

$$f = \frac{c(\varphi_1 + \pi)}{4\pi h_c} \quad (1)$$

$$D_{PRS} = 10\log\frac{1+|S_{11}|}{1-|S_{11}|}(dB) \quad (2)$$

With a fixed cavity height, according to the resonance condition (1), *c* is the speed light, φ is the reflection phase of the PRS, *hc* is the height of FPC. (1) is only valid within a small frequency range. As a result, traditional FPC

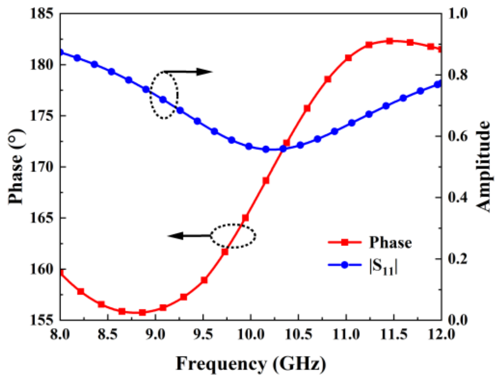

Fig. 5. The simulated S-parameter and reflection phase of the PRS.

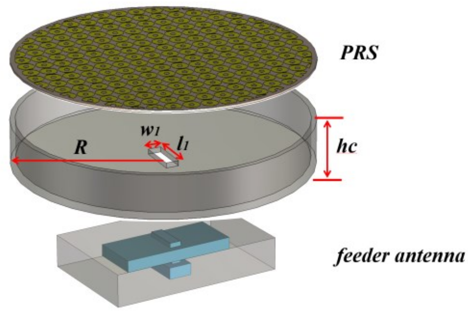

Fig. 6. The schematic diagram of the proposed FPC filtering antenna structure (R = 54.4, hc = 15, unit: mm).

antennas have a narrow gain bandwidth. However, employing a PRS with a positive-negative phase gradient allows the antenna to satisfy the resonance condition over a wider frequency band, enabling a broader gain bandwidth. Moreover, based on (2), the $|S_{11}|$ is the S-parameter of PRS, the directivity coefficient (Dprs) of the PRS indicates that a higher magnitude of reflection coefficient results in higher antenna gain. Fig. 5 illustrates the corresponding simulation results, showing that the unit exhibits a positive phase gradient within the operating

frequency band, with reflection coefficients exceeding 0.5 mm.

C. FPC Filtering Antenna

Fig. 6 depicts the structure of the proposed broadband FPC filtering antenna. The antenna utilizes the aforementioned cavity filtering antenna as the feeding source, with a PRS at a distance *hc* from the metal ground plane. The FPC cavity is circular with a radius *R*. The electromagnetic energy from the feeding antenna enters the FPC cavity and passes through the top PRS to achieve gain enhancement.

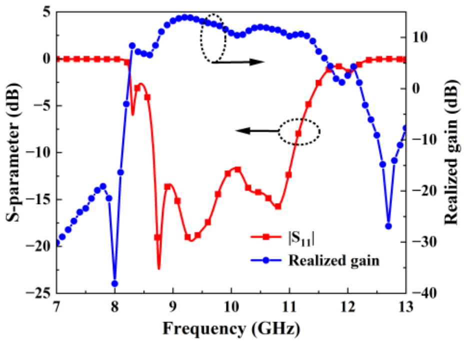

Fig. 7. The simulated S-parameter and gain curve of the proposed FPC filtering antenna

III. Simulation Result

Fig. 7 shows the S-parameter and gain curves of the proposed antenna. The antenna exhibits two radiation nulls in the low-frequency stopband and high-frequency stopband, with out-of-band suppression of 33 dB and 21 dB respectively. It achieves an impedance bandwidth of 24.3% and a maximum gain of 14 dB within the band. Fig. 8 depicts the radiation patterns at three frequency points within the band, indicating good consistency and low cross-polarization of the antenna. These results indicate that the proposed antenna performs well in terms of filtering performance and radiation characteristics.

IV. Conclusion

In this article, a broadband FPC filtering antenna is proposed. The antenna achieves a wide impedance bandwidth, and due to the filtering performance of the feeder antenna, it does not require additional filtering circuits. The proposed antenna features two radiation nulls in both the high-frequency and low-frequency stopbands, respectively, resulting in good out-of-band suppression. Additionally, compared to the feeder antenna, the proposed antenna exhibits significantly improved gain. Moreover, the proposed antenna has a very simple structure and is easy to fabricate, providing a design solution for broadband high-gain FPC filtering antennas.

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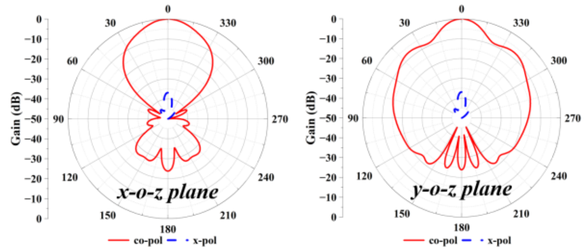
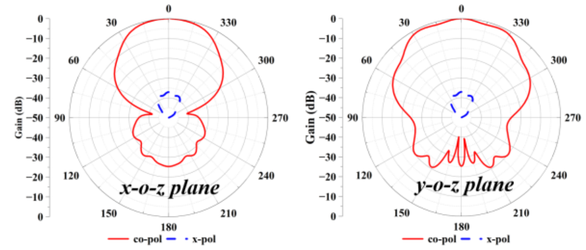
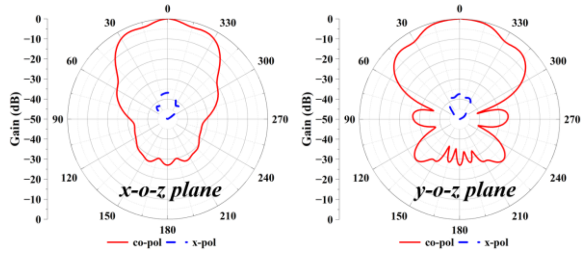


(a)



(b)



(c)

Fig. 8. The radiation pattern within the operating band. (a) 9.2 GHz. (b) 10 GHz. (c) 10.8 GHz.

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