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A Miniaturized Cavity-Backed Slot Third-Order Filtering Antenna Using Multiple Mode Resonator

Shuqing Zhang1, Sai-Wai Wong1*, Yejun He1
State Key Laboratory of Radio Frequency Heterogeneous Integration,
College of Electronics and Information Engineering, Shenzhen University, 518000, China
Email: wongsaiwai@ieee.org

Abstract—A novel miniaturized cavity-backed slot filtering antenna is presented. The antenna consists of a cavity with three metallic cylinders. The cavity filter of the proposed multiple-mode resonator filtering antenna has only one cavity compared to a traditional 2nd-order coaxial filter, with an additional resonance mode within the passband. Moreover, two pairs of capacitive stubs, are used to achieve a third-order-filtering response. The proposed antenna operates at 8.1 GHz central frequency with a fractional bandwidth of 4.9% (S_{11} less than -10 dB). The E-field distribution of the proposed antenna is plotted to further understand its filtering mechanism. The simulation results reveal that the proposed antennas exhibit good radiation characteristics in the passband and frequency selectivity as well, and effectively reject the out-of-band frequencies.

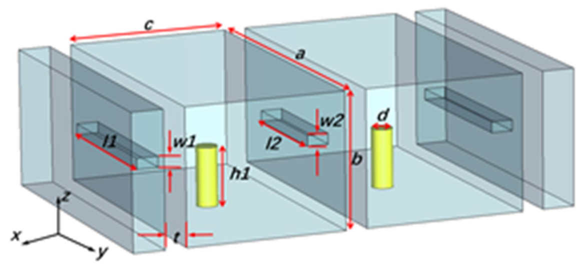
Index Terms—software define radio, whip antenna, broadband, low profile.

I. Introduction

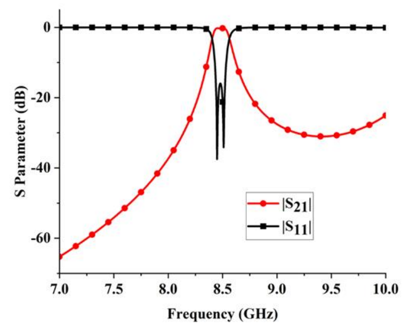
Filtering antennas in the wireless communication industry are widely used because of their high performance and multi-functional features. Due to the current high spectrum occupancy, filters are important as they can filter out unwanted electromagnetic interference. The antenna is an indispensable device in modern communication systems. Traditionally, the filter and antenna are two independent components, which makes them occupy a lot of space with additional power losses. To overcome the above problem, a filtering antenna is a more suitable candidate [1]–[4].

Many techniques have been reported in the literature to design filtering antennas. In [5], a filtering dielectric resonator antenna is proposed by designing an open stub on the microstrip feedline to obtain transmission zeros (TZs) and to achieve better filtering performance. An omnidirectional dielectric resonator antenna in [6] is designed by adding three sets of shorting metal posts. A parallel-scheme filtering antenna in [7], consists of three elements, which can generate radiation cancellation and provide two TZs. In another study in [8], the antenna is the last resonator of the filter, the first half of this filter antenna is the quarter resonator, and the second half is an antenna.

Another design technique is the cavity-based filtering antenna. The cavity is a highly efficient and easy-to-use structure to improve antenna performance. There are many papers using it as a filter [9], and there are also many works using it as an antenna or filtering antenna [10]–[12]. In [10], a filtering cavity slot array is investigated, it uses high-order modes in the cavity and slots in a suitable position to achieve high gain and suppress harmonics.



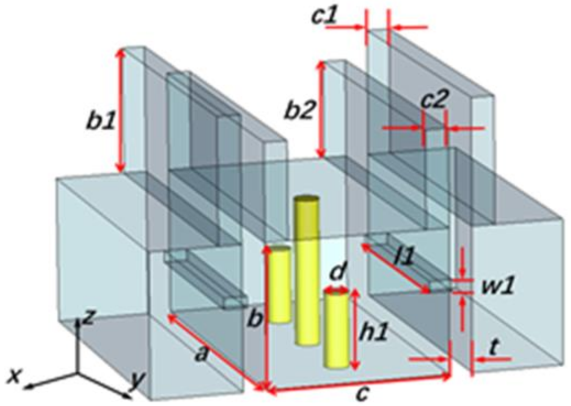
(a) 3-D view



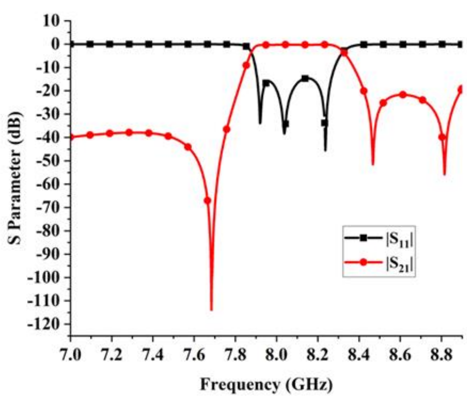
(b) Simulation results of the fliter

Fig. 1. Configuration of the traditional 2nd-order coaxial filter.(a) 3-D view. (b) Simulation results of the filter.

In this paper, a novel cavity-backed slot filtering antenna is presented. It uses a single metallic coaxial cavity to accomplish an additional resonance mode as an advantage over the traditional second-order coaxial filter. Furthermore, two pairs of capacitive stubs are incorporated in the design to generate TZs and improve the filtering performance. Finally, a total of three TZs are obtained on both sides of the passband and have flat gain within the passband. The rest of the paper is summarized as sections II and III explaining the design description and results and discussions. Finally, section IV concludes the paper.



(a) The proposed filter



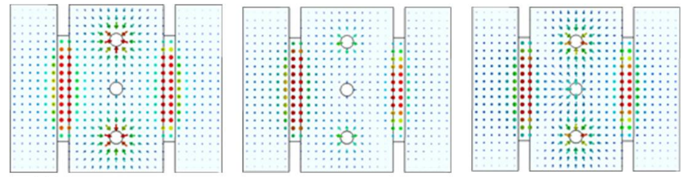
(b) Simulation results of the fliter

Fig. 2. (a) The proposed filter. (b) Simulation results of the filter.

II. Antenna Design And Working Principal

Fig.1(a) shows the design configuration of a traditional 2^{nd}-order coaxial filter. It can be seen from Fig.1(a) that the traditional coaxial filter consists of two coaxial cavities and three irises. The filter is symmetrical along the y-z plane, and two standard waveguides (WR-112) are used as two ports. Figure 1(b) illustrates the response of 2nd-order coaxial filter. It is clear from the Fig.1(b) that there are two resonance modes at 8.45 and 8.51 GHz frequencies with a fractional bandwidth of 1.2% (8.43 - 8.534 GHz). However, there are no TZs exist out-of-band.

Figure 2(a), shows the configuration of the miniaturized coaxial filter, compared with the traditional coaxial filter, the proposed filter puts two metal posts into the same cavity, the volume of the filter can be reduced, and at the same time, there is an additional resonant mode, which increases the bandwidth and the filtering order. There are three resonant modes as shown in Fig. 2(b). The traditional filter in Fig.1 has no TZs. Two pairs of capacitive stubs on the basis of the miniaturized filter are incorporated to improve its filtering performance and frequency selectivity as shown in Fig. 2(a). Two capacitive



(a)Mode 1 at 7.92 GHz (b)Mode 2 at 8.037 GHz (c)Mode 3 at 8.237 GHz

Fig. 3. (a)Mode 1 at 7.92 GHz. (b)Mode 2 at 8.037 GHz. (c)Mode 3 at 8.237 GHz.

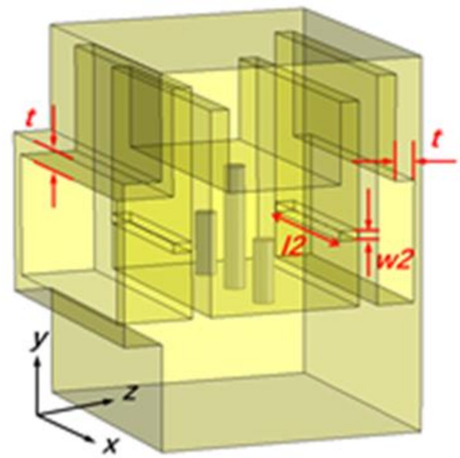
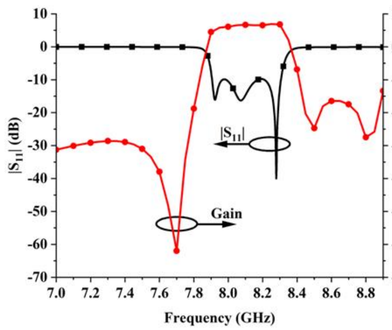


Fig. 4. Perspective view of the proposed antenna.

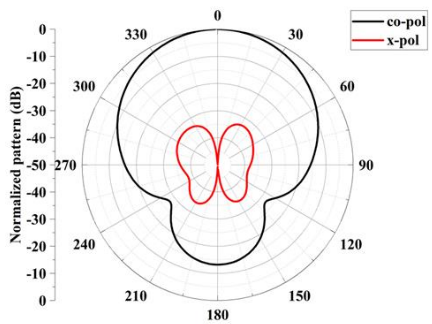
stubs result in three transmission zeros at 7.682 GHz, 8.463 GHz, and 8.811 GHz respectively, as shown in Fig. 2(b). The first TZ at the lower stopband is generated by the longer capacitive stubs, controlled by its height b2. The last two TZs at the upper-stopband are produced by longer capacitive stubs, controlled by their height b1.

Figure 3 shows the E-field of the three modes in Fig. 2(b) at the x-y plane. All the modes are generated by the metal post on which the E-field is concentrated on. At mode 1, the E-field at the input/output ports and the E-field of the metal posts reach the maximum and minimum values almost concurrently, and the E-field at the two ports is in phase. Moreover, at mode 2, the phase difference between the E-field at the input port and the E-field at the output port is 90°, and the output port is the minimum value when the E-field at the input port reaches the maximum value, and vice versa. The E-field at the input port reaches a maximum and minimum at the same time as the electric field on the metal post. At mode 3, the E-filed at the input/output ports and the E-filed on the metal posts reach a maximum and minimum at the same time, but the E-field phase difference between the two ports is 180°.

Then open a port, and rotate it to radiate towards the z-axis, so that electromagnetic waves radiate into free space to form a cavity-backed slot filtering antenna. Fig. 4 gives the three-dimensional(3-D) view of the proposed filtering antenna. It integrates the good filtering characteristics of



(a) S-parameter and gain



(b) pattern at 8.1 GHz

Fig. 5. Simulated results of the proposed antenna. (a)S-parameter and gain. (b)pattern at 8.1 GHz.

the proposed filter and has three TZs out of the band and flat gain in the wanted frequency.

III. Simulation Results

When the proposed filtering antenna is excited, three resonances at 7.922 GHz, 8.072 GHz, and 8.275 GHz are observed. It is centered at 8.1 GHz and has a fractional bandwidth of 4.9%. Figure 6(a), illustrates the S-parameter response of the proposed antenna and exhibits good performance in the desired frequency band.

At the same time, Fig. 5(a) also shows the curve of the proposed antenna gain changing with frequency. It has three TZs located on both sides of the passband, two of which are high-frequency TZs. 6.6 dB gain in the passband and 29 dB out-of-band rejection.

Fig. 5(b) shows the radiation patterns of the proposed antenna and illustrates that there are stable radiation patterns in the passband and extremely low cross-polarization characteristics.

IV. CONCLUSION

This article presents a compact cavity-backed slot-filtering antenna. The antenna comprises a single cavity having three metallic cylinders and two pairs of capacitive stubs which are employed to obtain an additional resonance mode. It is observed from the results that the proposed antenna operates at 8.1 GHz frequency and manifests a fractional bandwidth of 4.9%, along with three TZs on both sides of the operation band, and achieves an out-of-band rejection of 29dB. Thus, the anticipated antenna is a good candidate for wireless filtering applications.

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