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3-D Printing Dual-Band Cavity Filter With Capacitive Stubs Producing Transmission Zeros

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***Abstract*—This paper presents a dual-band cavity bandpass filter based on basic modes and high-order modes. By adjusting the sizes of the coupling irises between the waveguide ports and cavity resonators, the TE_{101} mode and TM_{120} mode are excited simultaneously at different frequencies. Therefore, the dual-band filter is designed with two modes. Since the isolation of two passbands is not good, the capacitive stubs are introduced to produce transmission zeros (TZs). Three TZs can be controlled by the sizes of the capacitive stubs, respectively. Owing to the six small capacitive stubs, Three TZs are generated to improve the frequency selectivity. Moreover, the first spurious mode is suppressed. The central frequencies of the two passbands are at 4.55 GHz with a fractional bandwidth of 1.11% and 5.00 GHz with a fractional bandwidth of 0.72%. Finally, a 2nd-order dual-band cavity bandpass filter is fabricated by 3-D printing technology.**

Keywords—3-D Printing, high-order mode, dual-band filter, cavity filter, capacitive stubs, transmission zero.

I. INTRODUCTION

Microwave cavity filters are commonly used in base station and satellite communication systems since their low insertion loss and high power capacity. The trend of microwave filter development is miniaturization. The volume of the substrate integrated waveguide filter is competitive, but the insertion loss and power capacity are not satisfactory [1]. On the contrary, the insertion loss and power capacity of metal cavity filters are very competitive, but the size of the metal cavity filter has no advantage. Therefore, it is better to design a filter with multiple functions to save space for other microwave devices in the system. Multimode resonators can be used to design single passband filters, multiple passband filters and multiplexers [2]-[8]. In [2], a triple-mode single passband cavity filter is proposed by a triple-mode resonator. A miniaturized triplexer is designed in [3] by triple-mode resonators. In [4], a multi-mode cavity filter is presented. Moreover, a duplexer is properly designed by using two bandpass filters that are proposed in [4]. Generally, the design and cascade of multi-mode resonators is a common method to design multi-band filters. A dual-band elliptical cavity filter is proposed in [5], two modes of various frequencies are excited simultaneously in each cavity. Besides, four elliptical cavities are cascaded to design a 4th-order dual-band cavity filter. In [6], a dual-band coaxial cavity filter is presented. Since the cylinder of each coaxial resonator is divided into two parts, each of which has a different radius, two various modes are excited in a single cavity. The design method in [6] is similar to [7]. In [7], the helix in each cavity is divided into two parts according to the number of turns and helix spacing. Therefore, there are two different helix resonators in a single cavity. Finally, four dual-mode resonators are cascaded to design a dual-band filter. Two individually frequency tunable dual-band filter and triple-band filter are designed in [8] by using multiple mode resonators.

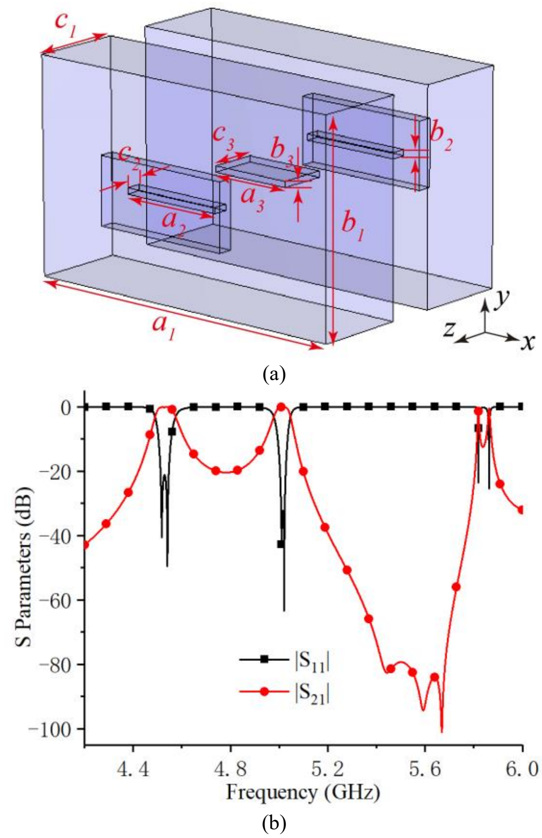
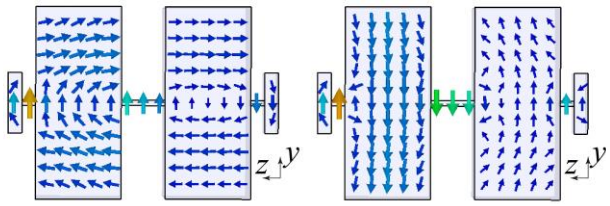


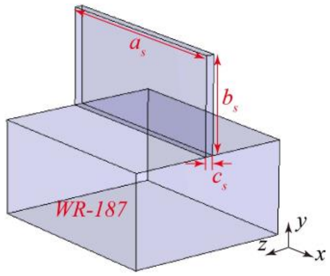
Fig. 1. (a) Perspective view of the initial dual-band filter. (b) Simulation results of the filter.

In this paper, a dual-band cavity filter is presented. One passband is at 4.55 GHz with a fractional bandwidth of 1.11% and the other is at 5.00 GHz with a fractional bandwidth of 0.72%. The filter consists of two dual-mode cavity resonators, TE_{101} mode and TM_{120} mode are excited in a single cavity. In addition, three pairs of capacitive stubs are made to generate three TZs and suppress the first spurious mode. Finally, since

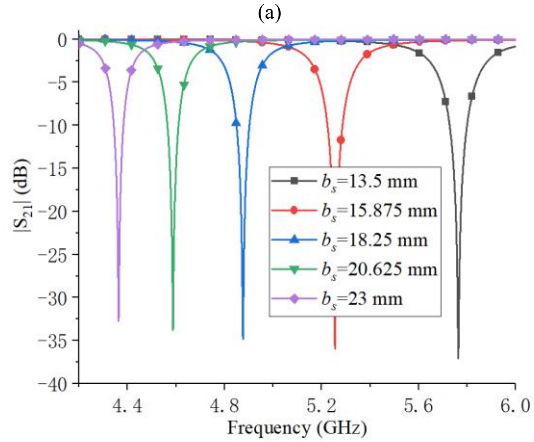


(a) (b)

Fig. 2. (a) Side view of electric field distribution in 4.53 GHz. (b) Side view of electric field distribution in 5.01 GHz.



(a)



(b)

Fig. 3. (a) Three-dimensional (3-D) view of the stubs. (b) Different $|S_{21}|$ with the changes of the b_s.

the structure of the filter is simple, the proposed filter is fabricated by 3-D printing technology.

II. DESIGN OF DUAL-BAND FILTER WITH TZS

Fig. 1(a) illustrates the perspective view of the initial dual-band filter, it can be seen from fig. 1(a) that the initial filter consists of two cavity resonators and three coupling irises. The structure is symmetrical along the center of the structure. Two standard waveguides (WR-187) are used as input/output ports. The proposed structure is simulated in commercial software CST. It is depicted in fig. 1(b) that the proposed filter is a dual-band filter whose passbands are at 4.53 GHz with a fractional bandwidth of 1.81% and 5.01 GHz with a fractional bandwidth of 1.35%. The first spurious mode is at 5.82 GHz and there is no TZ between the two passbands.

Fig. 2 shows the side view of the electric field distribution in 4.53 GHz and 5.01 GHz. The TE_{101} mode and TM_{120} mode are excited simultaneously in each cavity resonator. From Fig. 2, it can be found that the TM_{120} mode in the cavity is

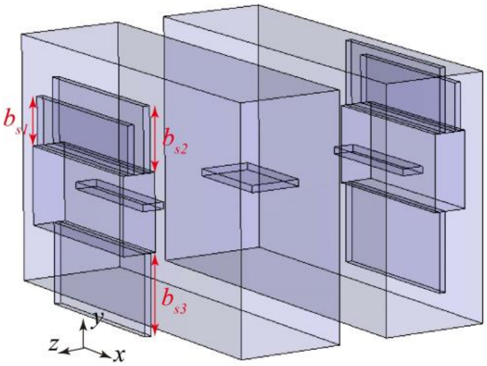
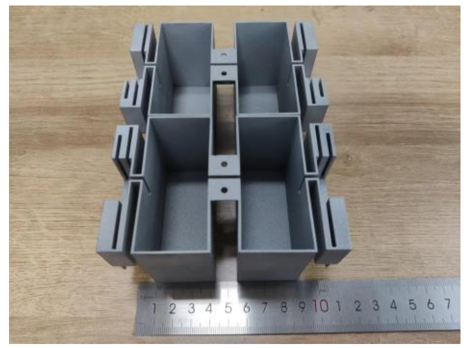
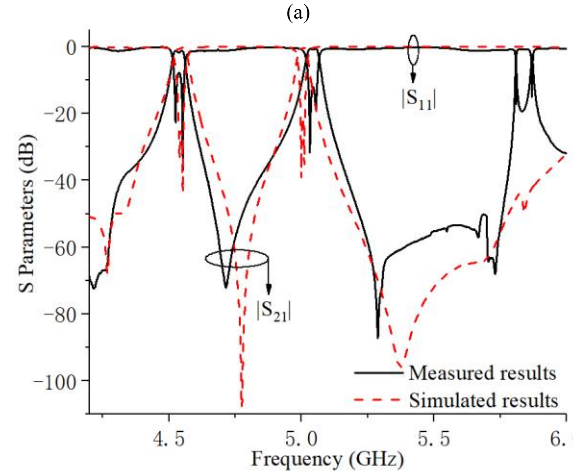


Fig. 4. Perspective view of the proposed dual-band filter.



(a)



(b)

Fig. 5. (a) Internal view of the filter. (b) Comparison between simulated and measured results.

resonating at 4.53 GHz. Besides, the TE_{101} mode is resonating at 5.01 GHz, which makes the higher passband.

Some TZs need to be generated to improve the frequency selectivity. A capacitive stub in parallel on the sidewalls of the waveguide is a method to generate a TZ [9] for the proposed filter. Fig. 3(a) gives the three-dimensional (3-D) view of the proposed capacitive stub. Obviously, the volume of a capacitive stub is very small. Moreover, fig. 3(b) illustrates the $|S_{21}|$ of the proposed capacitive stubs with various length of the structure. By changing the b_s of the capacitive stub, various bandstop resonators can be designed. Therefore, three pairs of capacitive stubs are added to the proposed initial dual-band filter in fig. 1(a). Fig. 4 shows the perspective view of the proposed dual-band filter with three pairs of capacitive stubs producing three TZs and suppressing the first spurious mode.

III. Experimental Results

A second-order dual-band cavity filter is fabricated using AlSi10Mg based on metal 3-D printing technology. The parameters of the filter are given as follows: a_1 = 114.00, b_1 = 70.20, c_1 = 31.25, a_2 = 35.00, b_2 = 2.00, c_2 = 6.40, a_3 = 26.20, b_3 = 2.00, c_3 = 15.00, a_{s1} = 47.55, b_{s1} = 13.75, c_{s1} = 2.00, a_{s2} = 47.55, b_{s2} = 18.50, c_{s2} = 2.00, a_{s3} = 47.55, b_{s3} = 23.00, c_{s3} = 2.00 (all in mm). Fig. 5(a) gives the internal view of the proposed dual-band filter. Besides, fig. 5(b) depicts the frequency responses of the measured and simulated results. It can be found in fig. 5(b) that there are some differences between the simulated results and measured results, which is caused by the fabrication. The simulation results are as follows: the first passband is at 4.55 GHz and the fractional bandwidth of the first passband is 1.11%; the second passband is at 5.00 GHz of a fractional bandwidth of 0.72%. The measured insertion loss of the first passband is around 1.20 dB, and it is around 0.70 dB for the second passband. Compared with the initial filter in fig. 1(a), the frequency performance of the proposed filter in fig. 4 is better because of the three pairs of capacitive stubs, which is shown in fig. 5(b). Two TZs are generated below the first passband and one TZ is designed between the two passbands to improve the frequency selectivity. In addition, two stubs that are resonating at the frequency where the first spurious mode resonates. Therefore, the first spurious mode is suppressed in simulation, which makes the frequency performance better. In the measured results, the reason why the first spurious mode is not suppressed may be that the manufacturing error causes the capacitive stubs not to resonate at the frequency, which is similar to the three TZs.

IV. Conclusion

A dual-band cavity filter with capacitive stubs producing TZs is proposed and fabricated based on metal 3-D printing technology, two modes are excited in a single cavity. By using the capacitive stubs, four TZs are generated and the first spurious mode is suppressed. Finally, there are some differences between measured and simulated results, which proves that there is a certain gap between 3-D printing and traditional CNC in fabrication accuracy. Compared with traditional CNC, 3-D printing still has advantages in fabrication time and fabrication cost, and 3-D printing filter is still a potential research direction.

Acknowledgment

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