Journal of ELECTRICAL ENGINEERING, VOL 74(2023), NO2, 137–139

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COMMUNICATIONS

Dual mode bandpass filter with switchable response

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A compact dual-mode bandpass filter with independently tunable second passband is proposed based on modified V shaped resonators. By switching the pin diodes at each end of the studied resonators, the second passband is independently tuned without affecting the first passband. A prototype of the dual-mode bandpass filter with a dual-passband of 2.54 GHz and 3.36 GHz or a single passband of 2.54 GHz is designed and verified experimentally.

K e y w o r d s: microstrip filter, switchable, dual-mode, bandpass filter

1 Introduction

Nowadays, the ever increasing demand for compact and low-cost modern wireless communications systems leads to the rapid development of multiband communication systems, which require components that operate at different frequency bands. Dual-band bandpass filter play an important role in the modern multiband communication systems. Accordingly, many researchers have explored several different methods to design dual-band bandpass filters. One of the most popular solutions is based on dual-mode resonators [1]-[3]. However, these filters need two resonators to realize dual-band bandpass responses, which is not easy to achieve compact size and simple physical layout. Thereby, using a single resonator to realize the dual-band performance is necessary to reduce the size and cost of systems. Several dual-band bandpass filters with a single resonator are realized by a patch resonator [4], a slotted circular patch resonator [5], an annular ring resonator [6], a single quadruple-mode resonator [7], and a ring resonator [8]. Nevertheless, all the mentioned filters are not tunable, which cannot satisfy the increasing requirement of modern multiband communication systems. To overcome these problems, electronically tunable and reconfigurable filters are good choice due to their attractive features, i.e., miniaturizing the overall size of systems, easily controlling the spectrum of proposed signals, and relaxing the complexity of systems [9], [10].

In some cases, there is a requirement for controllable dual-band bandpass filter with only one passband tuned. In [11], a dual-band bandpass filter based on E shaped resonators for switchable lower passband is reported. In this paper, we study a dual-mode dual-band bandpass filter for switchable upper passband. The studied bandpass response is realized by two modified V shaped resonators. By switching the pin diodes at each end of the loaded stubs of the modified V shaped resonators, the centre frequency of upper passband is independently tuned without affecting the lower passband. To verify our proposal, a prototype of the dual-mode dual-band bandpass filter was finally designed, fabricated and measured to show the electric performances.

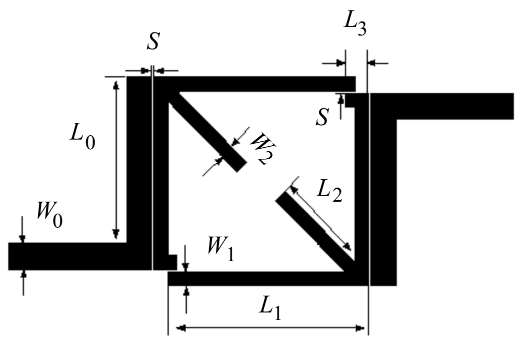

Fig. 1. Topology of the studied dual-mode bandpass filter

2 Filter design

Figure 1 illustrates the layout of the proposed dual-mode dual-band bandpass filter. It consists of two modified V shaped resonators and two feedlines. The substrate has a relative dielectric constant of 2.65 and a thickness of 1 mm. From Fig. 1 we can see that the studied resonator is composed of a uniform transmission line with an open-circuited stub loaded on its centre plane. Based on the even- and odd-mode analysis, two of half circuit models can be formed with an electric wall (E wall) and a magnetic wall (M wall) along the horizontally symmetrical plane, as shown in Fig. 2. Z_i (with $i = 1, 2$) represents the characteristic impedance of each transmission

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https://doi.org/10.2478/jee-2023-0019, Print (till 2015) ISSN 1335-3632, On-line ISSN 1339-309X

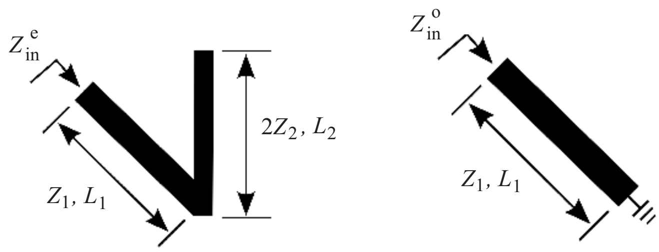

Fig. 2. Even- and odd-mode model. (a) – even-mode circuit model, (b) – odd-mode circuit model

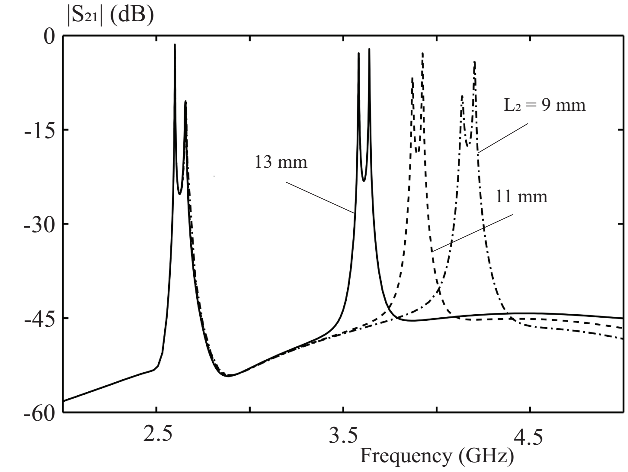

Fig. 3. Frequency responses of dual-mode bandpass filter

line section, whereas L_i (where, $i = 1, 2$) is the corresponding physical lengths. The input impedance of odd-mode is

$$Z_{\mathrm{in}}^{\mathrm{o}} = \mathrm{j}Z_1 \tan\big(\beta L_1\big)\,, \tag{1}$$

where β is the propagation constant. At the resonance, the input impedance is infinity. The odd-mode resonant frequency corresponds to

$$f_{\mathrm{o}} = \frac{c}{4L_1\sqrt{\varepsilon_e}}\,, \tag{2}$$

$$Z_{\mathrm{in}}^{\mathrm{e}} = \frac{1}{j}Z_1\frac{2Z_2 - Z_1\tan(\beta L_1)\tan(\beta L_2)}{2Z_2\tan(\beta L_1) + Z_1\tan(\beta L_2)}\,. \tag{3}$$

The even-mode resonant frequency corresponds to

$$f_{\mathrm{e}} = \frac{c}{2(L_1 + L_2)\sqrt{\varepsilon_{\mathrm{e}}}}\,. \tag{4}$$

From (2) and (4), it is easily found that the resonant frequency of the odd-mode f_{o} is determined by the length of the uniform transmission line and the even-mode f_{e} is determined by both the lengths of the uniform transmission line and the loaded open-circuited stub. Figure 3 illustrates the simulated transmission coefficient S_{21} of a weak coupling resonator according to different lengths of open-circuited stub. As L_2 increases, the odd-mode resonant frequencies are fixed, whereas the even-mode resonant frequencies shift down to lower frequencies. It implies that the length of the uniform transmission line, *ie* L_1, can be adjusted to realize one passband and the loaded open-circuited stub, *ie* L_2, can be adjusted to realize the other passband.

3 Switchable design and results

In order to make the passband to be tuned, two pin diodes are loaded at each end of the open-circuited stub, as shown in Fig. 4 for the layout of the studied filter, where Skyworks pin diodes SMP1345 in a SC79 package are used to connect the open-circuited stubs. Studies show when the pin diodes are the off state, the frequency responses of the proposed tunable filter are of dual passband, while when the switches are on states, a single passband at lower frequency is observed.

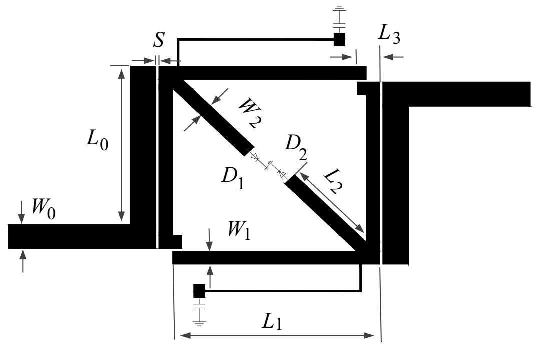

Fig. 4. Layout of the proposed switchable dual-mode bandpass filter with bias line involved

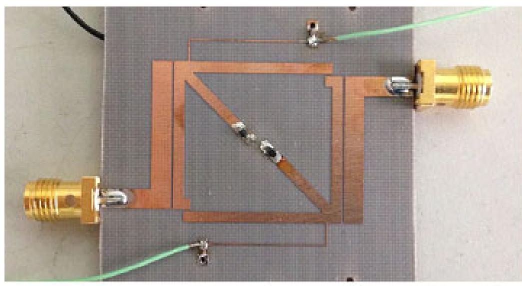

Fig. 5. Photograph of the developed dual-mode bandpass filter

As one example, a dual-mode dual-band bandpass response is realized at $W_0 = 2.8\,\mathrm{mm}$, $L_0 = 21\,\mathrm{mm}$, $W_1 = 1.7\,\mathrm{mm}$, $L_1 = 22\,\mathrm{mm}$, $W_2 = 1.7\,\mathrm{mm}$, $L_2 = 12\,\mathrm{mm}$, $L_3 = 2.2\,\mathrm{mm}$, and $S = 0.3\,\mathrm{mm}$ in Fig. 4, Based on this, the studied filter is further built and Fig. 5 shows the photograph of the developed filter. The measured centre frequency of the lower passband is 2.54 GHz, whereas the upper passband is centred at 3.36 GHz when the switches are the off states, as shown in Fig. 6. The measured fractional bandwidths (FBWs) of the lower and the upper

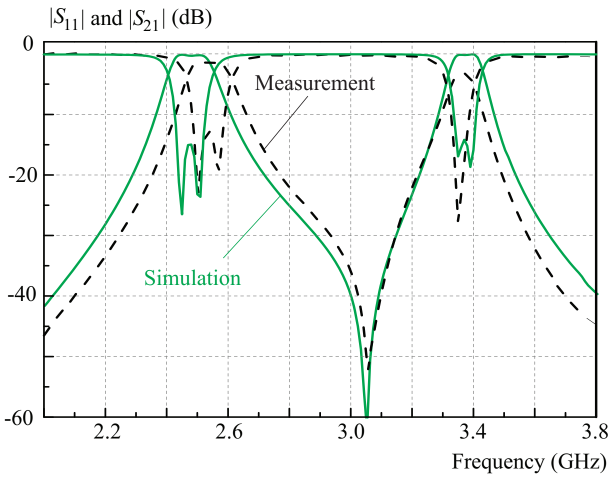

Fig. 6. Simulated and measured results of developed filter corresponding to switches being off states

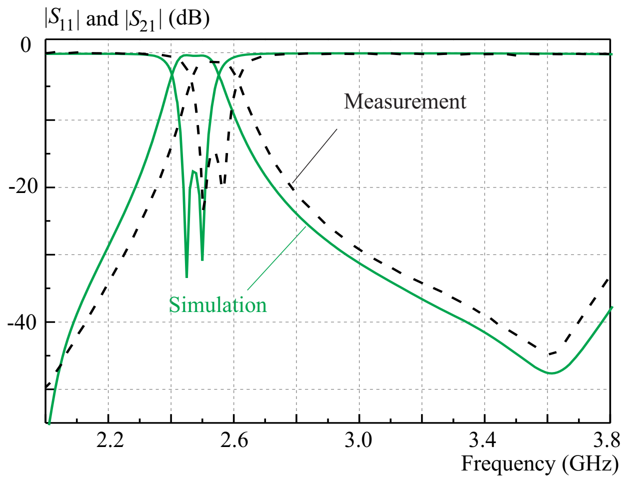

Fig. 7. Simulated and measured results of developed filter corresponding to switches being on states

passbands are about 6. 3% and 2. 7%, respectively. Both of the return losses of the two passband are > 10 dB. In addition, a transmission zero appears at 3.06 GHz. Further, the switches are of on states are investigated, and Fig. 7 shows the measured S parameters in this case. It can be seen that the proposed filter has a single passband at 2.54 GHz, meaning a lower passband, where the measured fractional bandwidth is 6.3%. It is seen no difference in the lower passband between the on and off states of the switches.

4 Conclusion

A novel dual-mode band-switchable bandpass filter has been studied based on V shaped resonators, where one passband can be conveniently tuned without affect the other passband. As an example, one tunable dual-mode dual-band bandpass filter is designed, implemented, and measured. The proposed filter behaves compact in size and easy to fabricate. It is expected that this kind of configuration can be further developed toward microwave multiband system applications.

Acknowledgment

This work was supported in part by the Key Fundamental Research Project under Grant no. 2019-JCJQ-ZD-262-00.

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Received 7 March 2023