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COMMUNICATIONS

Dual-mode resonator filter with improved feed-lines for dual-band applications

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An improved feedline configuration for dual-mode resonator filter is investigated in this paper. Based on the introduced topology, a dual-mode dual-band bandpass filter with center frequencies of 1.8 and 2.4 GHz is optimally designed, fabricated and tested. The introduced dual-band bandpass filter has simple structure and enables high selectivity to be realized due to two pairs of transmission zeros located near to the lower and upper passband, respectively. Both measured and simulated performances are presented with good consistency.

K e y w o r d s: dual mode, dual band, bandpass, filter.

1 Introduction

The ever increasing demand for modern wireless communications necessitates efficient utilization of more and more frequency channels, which enables RF transceivers operating in multiple separated frequency band such that users can access various services with a single multimode handset. In such systems, dual or multi band filters play an important role. In [1], a dual-band filter was initially reported, where two single band bandpass filters (BPFs) are stacked together, one on the upper four layers and the other on the lower four layers with each filter having its own input and output ports. Based on slotlines, H. Zhang *et al* [2] etched slotlines on the edge sides of the substrate integrated cavities to achieve dual band, V. Nocella *et al* [3] designed a dual band filter, centered at 4.25 and 4.55 GHz respectively, by using TM dielectric loaded dual mode cavities. Further design for this kind of filters is based on the stepped impedance resonators (SIRs) [4-6]. One of the advantages for SIR filters is that the positions of the dual band can be tuned conveniently with the help of SIRs' inherent properties. Using magnetically coupled SIR, A. Lahmissi *et al* introduced this kind of topology [4]. Also, by using the common grounded via hole and the folded $\lambda/4$ SIRs, a high selectivity dual-band filter has been realized [5]. By applying defected split-ring resonators and irregular SIRs, a dual-band filter is reported in [6], where three transmission zeros are, respectively, located near to the two pass-band thus greatly improving the selectivity.

On the other hand, the dual mode microstrip resonators, as we known, are attractive since each of dual mode resonators can be used as a double tuned resonant circuit, therefore, the number of resonators required for a given degree filter is reduced by half, resulting in a compact filter topology. Hence, P. Ma *et al* [7] introduced this kind of dual-mode dual-band filters with hairpin resonator. However, observing these dual-band filters, drawbacks are suffered. For example, the filter in [1] needs extra matching networks, whereas the in-band or out-of-band performance is not so good [3-7].

Thus, in this Letter, we investigate a dual-mode resonator filter designed for dual band applications. After simply analyzing the introduced basic topology, a dual mode dual band filter, centered at 1.8 and 2.4 GHz, respectively, is optimally designed, fabricated, and tested. Meanwhile, two pairs of transmission zeros, located near to the lower and upper passband, respectively, enable the introduced filter having high selectivity. The measured performances for the fabricated filter show good consistency with the simulated results.

2 Design of the dual mode resonator filter

As compared to the conventional dual-mode loop resonator filter, seen Fig. 1(a), the basic schematic diagram for the investigated filter topology is shown in Fig. 1(b), where a pair of feed-lines is symmetrically and spatially separated on the resonator. Thus in-line input and output (I/O) ports are realized this can increase the design flexibility. Though the I/O ports are not separated by 90°, two degenerate modes, here corresponding to TM^z_{100} TM^z_{010} fundamental mode applications (where z is perpendicular to the ground plane), can be also excited and coupled to each other due to the perturbation element

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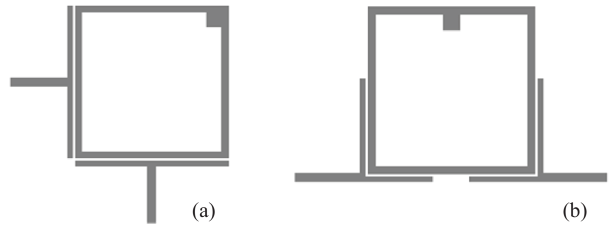

Fig. 1. Dual-mode loop resonator filter (a) – conventional topology (b) – introduced topology

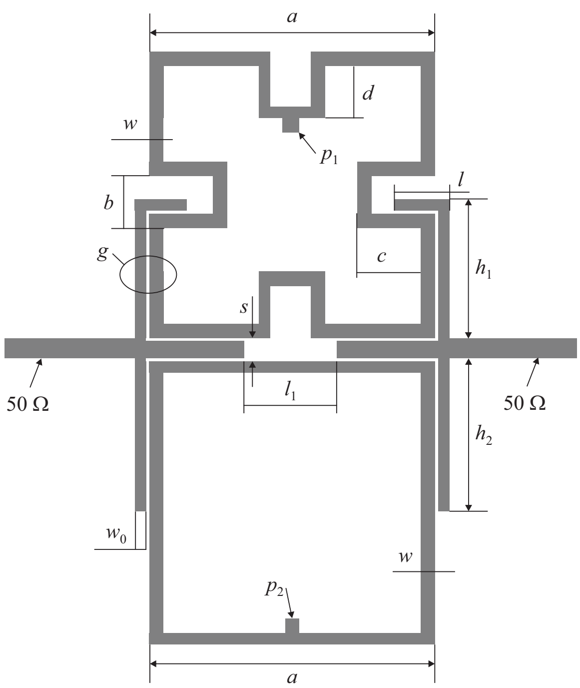

Fig. 2. Schematic diagram for the investigated dual-mode dual-band resonator filter passband performances; and (c) – upper passband performances.

within the resonator. The resonance for both cases can be established when the mean circumference L of the resonator is equal to an integral multiple of a guided wavelength, given by

$$L = n\lambda_g \,, \tag{1}$$

where n is the mode number and λ_g is the guided wavelength.

For dual band applications, we set two resonators with equal side length a, and then put together with a space s, shown in Fig. 2. A common feed line is shared between the resonators and the remains are coupled the upper and lower resonators, respectively. With this arrangement, two pairs of transmission zeros can be realized near to the lower and upper passband, which enhances the filter selectivity. The design procedure for this kind of filter can be summarized as follows: firstly, we design a square loop resonator that has a resonance frequency of 2.4 GHz, and then by meandering or fractal technique, we design another resonator 1.8 GHz. It is worth mentioning that the two resonators have the same side length a, and this is the key point to design this kind of dual-band resonator filter. Finally, we place the two resonators together and introduce the proposed feed-line configurations. Thus, a dual-mode dual-band bandpass filter, as seen in Fig. 2, is realized.

Table 1. Dimension parameters for the proposed dual mode dual band filter

Parameters	(mm)	Parameters	(mm)
a	13.13	g	0.2
b	3.0	s	1.0
c	2.96	l_1	4.45
d	2.46	h_1	6.285
w	0.5	h_2	7.0
p_1	0.65	l	2.26
p_2	0.3	w_0	0.4

3 Simulated and measured results

The investigated dual-band filter has been optimally designed, fabricated, and tested. Its dimension parameters are given in Tab. 1. The simulation is accomplished using Ansoft Ensemble 8.0, a full-wave EM of moment (MoM). Measurements are carried out on an HP8510C network analyzer. Figure 3 shows the simulated and measured performances. The fabricated filter has minimum passband insertion losses of 3.35 and 3.68 dB at the center frequencies of 1.8 and 2.44 GHz, respectively. Two pairs of transmission zeros located at 1.725, 1.97, 2.36 and 2.625 GHz, respectively, have been realized with the attenuation levels over 45 dB. Compared to the results given in [3, 4] and [7], these transmission zeros have greatly improved the filter selectivity, especially, for the upper passband. Though the slight shift in frequency between simulations and measurements due to the fabrication uncertainties, good consistency between them can be observed.

4 Conclusions

Based on the improved in-line feed-line configuration, a dual mode dual-band filter has been investigated in this letter. Centered at 1.8 and 2.4 GHz, respectively, a demonstrator filter has been optimally designed and examined with good consistency between simulations and measurements. Its enhanced selectivity and

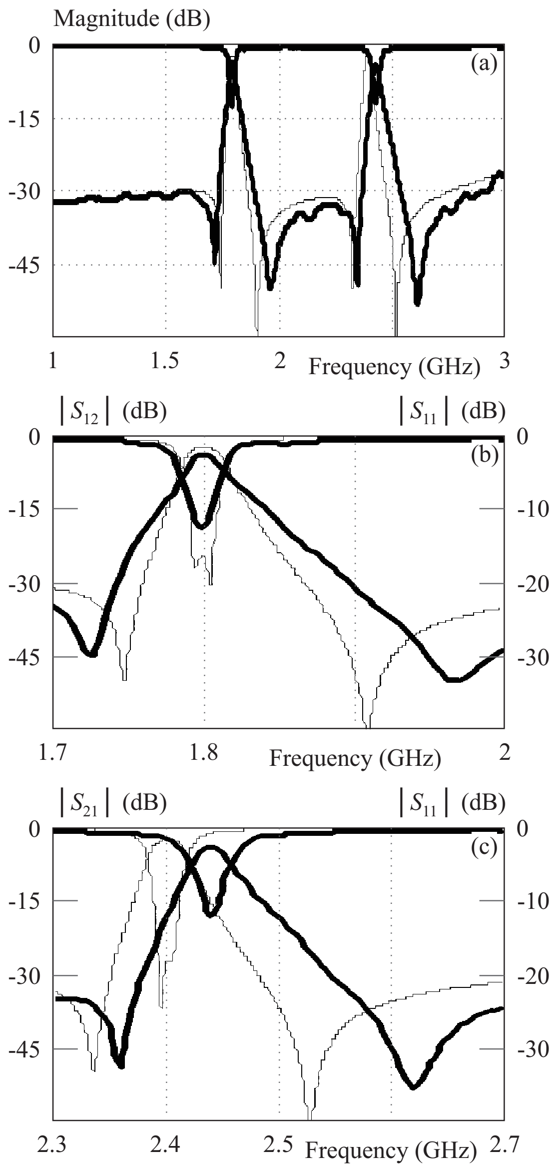

Fig. 3. Measured and simulated performances (measured simulated): (a) – broadband responses; (b) – lower

simple topology are attractive in modern wireless communications. Acknowledgment: This work was supported in part by the National Natural Science Foundation of China (NSFC) (61601063), in part by Open Foundation of State Key Laboratory of Millimeter Waves, the Southeast University (K202121), in part by Open Fund of Sichuan Provincial Key Laboratory of Pattern Recognition and Intelligent Information Processing of Chengdu University (MSSB-2020-08).

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