Compact multiband bandpass filters based on parallel coupled split structure multimode resonators

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Abstract

In this letter, a novel sext-band bandpass filter (BPF) using two split-type multiple-mode resonators is proposed. The filter is composed of two sets of resonators which are respectively designed to realize Filter 1 with two passbands and Filter 2 with quad passbands. Then the two BPFs are combined by parallel coupling feed lines for sext-band responses, and each of the six centre frequencies in the proposed sext-band BPF is able to be controlled due to the design freedom. To validate the design and analysis, a prototype filter has been fabricated with six passbands centered at 1.88/2.59/3.48/5.26/5.82/6.75 GHz. The measured result of the fabricated filter agrees well with the simulation, which shows that the proposed structure is a good candidate for sext-band BPF designs and validates the proposed design flow well.

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Introduction: In the recent years, developments in microwave multi-band bandpass filters (BPFs) have been gaining much attention for multi-service wireless communication systems, such as GPS, WLAN, WiMAX and RFID applications. However, it is still a challenge to carry out high-performance multi-band BPFs with compact size, closely spaced passbands, low insertion loss, high return loss and sharp skirt to satisfy the whole WLAN application demands.

Recently, many approaches to multi-band BPF design have been reported to address that problem[1]–[6]. In [1], Yan T F used two sets of short-stub-loaded E-Type resonators to realize a quad-band BPF. In [2], Bukuru D investigated quad-mode stepped impedance resonator (QMSIR) to achieve a compact quad-band bandpass filter. In [3], Li X realized novel quad- and sext-band bandpass filters on a basis of multimode resonator (MMR) using SIRsloaded tapered-line (SIRTL). In [4], Kamma A used T-shaped stubs loaded with a modified ring resonator (MRR) to realize a quad-band BPF. In [5], Chen F C used six pairs of semi-lumped resonators to achieve a sext-band BPF. In [6], Hsu K W realized a quint-band BPF using five tri-mode stub-loaded SIRs among the common input/output (I/O) ports. These papers show good electrical performance, but because of the use of many pairs of resonators, the size is relatively large.

In this letter, a novel sext-band bandpass filter (BPF) using two split-type multiple-mode resonators is proposed. The filter is composed of two sets of resonators which are respectively designed to realize Filter 1 and Filter 2. Filter 1 generates two passbands, meanwhile, Filter 2 generates other four passbands. The proposed filter has compact size, low insertion loss. Moreover, there are multiple coupling paths between different stubs, resulting in controllable bandwidths.

Filter design procedure: Fig. 1 shows the equivalent transmission line model for the proposed sext-band BPF.

Fig.1. *The equivalent transmission line model for the proposed sext-band BPF*

Fig.2 shows that Filter 2 generates four passbands. And Filter 1 generates two passbands obviously. The two BPFs are then combined by parallel coupling feed lines for sext-band responses.

Fig.2. *EM simulated frequency response of quad-band Filter 2*

Fig. 3 displays the equivalent transmission line model for the proposed three-band BPF in Filter 2.The center frequencies of the three passbands are f_1, f_2 andf_3, respectively.

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Fig.3. *The equivalent transmission line model for the proposed three-band BPF in Filter 2*

The variation in frequency with different L_1 andL_{s1} is shown in Fig. 4 (a) and Fig. 4 (b), respectively. It shows that with the increase of the parameterL_1, the center frequencyf_1 of the first passband is basically unchanged, while the center frequencies f_2 andf_3 of the second and third passbands move to the lower frequency, and the variation speed of f_3 is obvious faster than f_2.

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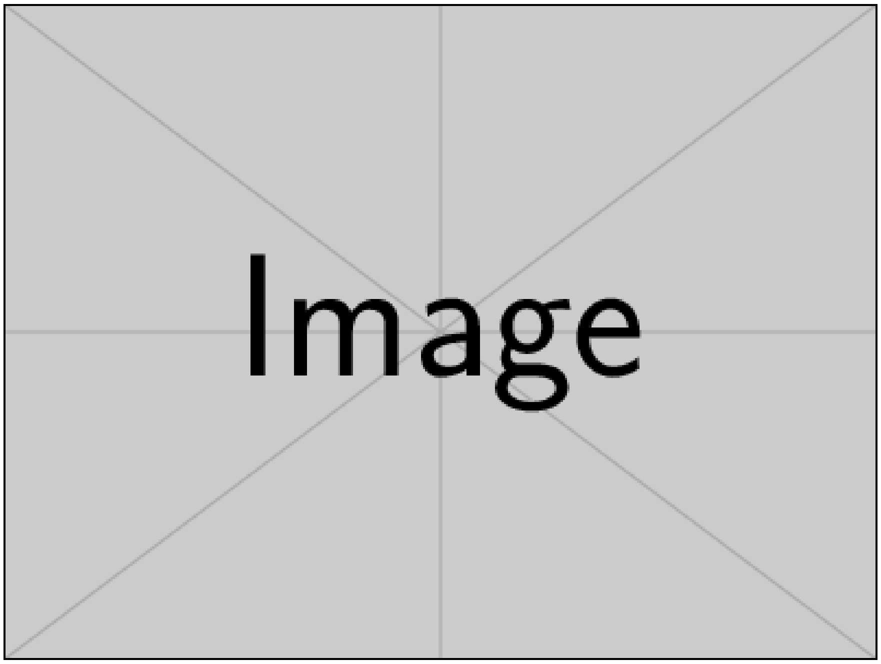

(b)

Fig.4. *Variation of frequency with different parameters..*

a Variation of frequency with different L_1

b Variation of frequency with different Ls_1

As shown in Fig. 4 (b), with the increase of parameterL_{s1}, the position of center frequencyf_2 of the second passband is basically unchanged, while the center frequencies f_1 andf_3 of the first and third pass bands move to the lower frequency, and f_3 moves faster thanf_2, so center frequency of the passband can be controlled by parameters L_1 andL_{s1}.

Experimental results: The structure of the proposed sext-band BPF is shown in Fig.5.

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Fig. 5. *Structure of the proposed sext -band BPF.*

To validate the proposed design flow, an example sext-band BPF is fabricated on a Rogers TMM10 (relative dielectric constantϵ_ρ =9.20, loss tangent tanδ=0.0022) substrate with thickness of 1.00 mm as shown in the inset plot of Fig. 6.

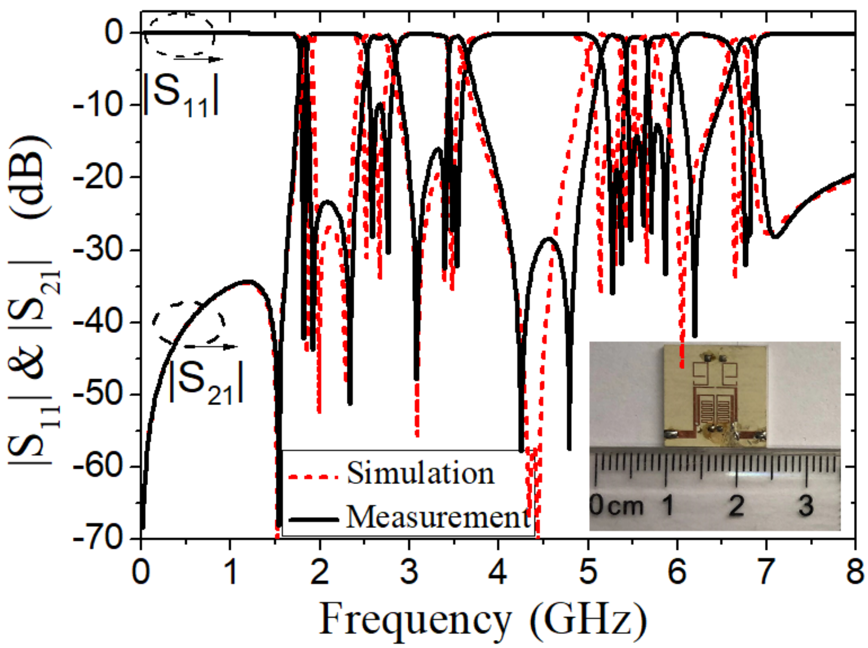

Fig. 6 *Simulated and measured results of sext-band BPF*

The dimension values are summarized as follows (all in mm): L_1=5.80, L_2=12.84, L_3=8.61, L_{p1}=6.29, L_{p2}=2.68, L_{c1}=3.12, L_{c2}=2.58, L_{c3}=2.58, L_{c4}=5.17, L_{c5}=2.56, L_{s1}=0.17, L_{s2}=1.91, S_{c1}=2.00, S_{c2}=0.36, S_{c3}=1.12, S_{c4}=0.18, S_{c5}=0.33, W_{c4}=0.36, . The overall size of the circuit is approximately $0.17\lambda_\gamma \times 0.08\lambda_\gamma$, where λ_γ represents the guided wavelength at the first passband.

Table 1: Comparison with some previous multi-band BPFs

Ref.	Frequency (GHz)	Insertion loss (dB)	Isolation (dB)	Size ($\lambda_g \times \lambda_g$)
[5]	0.59/0.88/ 1.17/1.48/ 1.79	2.79/2.88/ 2.87/2.58/ 2.27	ISO_{12}>27.89 ISO_{23}>29.97 ISO_{34}>35.78 ISO_{45}>26.90	0.51×0.05 (0.0255)
[6]	1.48/2.49/ 3.47/4.49/ 5.78	1.49/1.78/ 0.89/1.18/ 2.47	ISO_{12}>34.77 ISO_{23}>27.91 ISO_{34}>32.98 ISO_{45}>30.88	0.24×0.17 (0.0408)
[7]	0.88/1.19/ 1.37/1.66/ 1.97/2.39	2.28/1.99/ 2.27/2.68/ 2.19/1.97	ISO_{12}>37.98 ISO_{23}>19.87 ISO_{34}>29.80 ISO_{45}>21.92 ISO_{56}>14.85	0.26×0.15 (0.039)
[8]	0.69/1.98/ 3.18/4.49/ 5.77/6.95	1.29/0.58/ 0.79/1.06/ 1.37/2.16	ISO_{12}>52.83 ISO_{23}>44.95 ISO_{34}>51.72 ISO_{45}>41.92 ISO_{56}>37.88	0.16×0.09 (0.0144)

This work	**1.88/2.59/ 3.48/5.26/ 5.82/6.75**	**0.85/1.36/ 0.74/0.98/ 1.14/0.82**	ISO_{12} **>23.34** ISO_{23} **>16.59** ISO_{34} **>28.43** ISO_{45} **>15.31** ISO_{56} **>41.93**	**0.17×0.08 (0.0136)**

Measurement of the fabricated filter is performed using Agilent E8363B network analyzer. Fig. 6 shows the simulated and measured S-parameters of the sext-band BPF, and the photograph of the fabricated BPF is also demonstrated in the inset of Fig. 5. The measured six passbands are centered at 1.88/2.59/3.48/5.26/5.82/6.75 GHz with 3 dB fractional bandwidth of 4.26%/11.97%/6.32%/5.19%/5.17%/2.96%. The minimum insertion losses of each band are 0.85/1.36/0.74/0.98/

1.14/0.82 dB. The band-to-band isolations are above 23.34, 16.59, 28.43, 15.31, 41.93 dB, which generate sharp and deep rejections between the adjacent passbands.

The mismatch between the measured and simulated results may be leaded by the nonuniformity of the relative permittivity of the substrate, the fabrication tolerance and SMA connectors.

In order to evaluate the achieved performance, Table I presents a performance comparison of the proposed sext-band BPF with some previously reported works. The proposed sext -band BPF in this letter exhibits compact size, low insertion and switchable bands.

Conclusion: This letter has presented a miniaturised sext-band BPF by using two split-type multiple-mode resonators. The proposed sext-band BPF features very high design freedom of every single band. The simulated and measured results have a good agreement, which shows that the proposed filter features compact size, low insertion loss, sharp skirt. Owing to these merits, the proposed structure is a good candidate for sext-band BPF design.

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