Compact dual-band bandpass filter based on signal-interference techniques

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Abstract. To realize good isolation between two signal passbands, a dual-band bandpass filter (BPF) in this article was presented using signal-interference techniques, in which five open loop resonators are adopted. The proposed filter topology is made up of two signal transmission paths in parallel, under signal-interference principles, overlap section of two original passbands, decided respectively by two different transmission paths, is selectively removed from the combined passband, as a result, two aim passbands are realized. In addition, good isolation between two aim passbands is established due to two new transmission zeros, produced by adopted signal-interference techniques. At last, good agreement can be observed between simulation and measurement.

1. Introduction

Dual-band bandpass filters (BPFs) have become attractive components in modern wireless communication systems. In recent years, many techniques have been carried out to implement dual-band BPFs. In [1-4], two filters, operating at different frequency bands respectively, are simply combined with common input and output ports. In [5, 6], stepped impedance resonators (SIRs) coupling with each other are used to achieve desirable dual-band passbands, in which resonators are directly connected to 50 $\Omega$ impedance matching line. In [7, 8], single shorted-circuited stub-loaded SIR and single side-coupled shorted lambda/4 SIR are respectively presented to generate two passbands, and several transmission zeros (TZs) are both created to improve selectivity. In [9], a dual-band filter with a mixture of bandpass and bandstop sub-filters is presented, which leads to a very compact size. In [10], to construct dual-band BPF, the input and output ports are connected to each other with a grounded feedline having two via holes located at the tapping point alignments of loading elements. In [11-16], signal interference techniques are adopted to design single-band, dual-band or multi-band BPFs and provide desirable TZs. Hereinto the transversal signal-interference filtering sections are formed by two connected transmission lines, directly connected to I/O feeling ports in [11, 12]. A structure with a short-ended coupled line coupler connected in parallel to a transmission line is introduced in [13]. To reduce size and improve stopband performance, artificial right- and left-handed transmission lines are used in [14]. In [15], a wide passband is constructed using transversal signal-interference technique, resulting in a pair of TZs, where the transversal resonator is used to couple with feedlines connected to I/O ports. In [16], a compact quad-band BPF using square ring loaded resonator is introduced, and multi-transmission zeros are created due to the different propagation paths based on signal interference technique.

In this article, based on conventional structure of miniature open-loop resonator filter [17], a new compact dual-band BPF with two signal transmission coupling paths in parallel has been reported...
based on the signal-interference techniques. Under signal-interference techniques, the overlap section of two original passbands, respectively decided by resonators at two paths is selectively removed. Good isolation between two designed passbands is achieved due to two new transmission zeros, produced by adopted signal-interference techniques. At last, the designed dual-band BPF has been validated by experiment.

Figure 1 (a). The proposed dual-band BPF using signal-interference technique.

Figure 1 (b). Insertion loss characteristics of the proposed BPF under three different weak coupling structures.

Figure 1 (c). Insertion loss characteristics of the proposed BPF under three different signal transmission patterns.
2. The Proposed Dual-band Bandpass Filter and Characteristic Analyses

Figure 1(a) illustrates structure of the proposed dual-band BPF, which is symmetrical about vertical axis. As illustrated, this proposed BPF consists of five open loop resonators with same line width. Tight gap coupling are established between these resonators. Hereinto resonators 3 and 4, 1 and 2 are with same sizes, which are directly connected to the I/O feedline ports. The only difference between resonator 3 and 1 is lengths (L3 and L8) of the open ends.

2.1. Weak Coupling Resonant Characteristics under Different Path Structures

Figure 1(b) shows insertion loss $S_{21}$ characteristics of the proposed BPF under three different weak coupling structures, the adopted parameters in Figure 1(a) are as follow: $W_1=0.5$, $W_2=2.72$, $L_1=10$, $L_2=2.5$, $L_3=5$, $L_4=1$, $L_5=8.25$, $L_6=13.4$, $L_7=7.8$, $L_8=5$, $g_1=0.4$, $g_2=0.55$, $g_3=0.5$, and used substrate is TACONIC TLC-32 with thickness of 1.14 and dielectric constant of 3.2. (Unit: mm in this article)

It is noted for signal transmission path constructed of resonators 1, 2, 3 and 4, there are four resonant frequencies ($f_{12}$, $f_{13}$, $f_{14}$ and $f_{15}$), which represent four different current excitation modes between these four resonators, respectively named as O-S-O, O-O-O, S-S-S, and S-O-O. Hereinto, O and S respectively denote surface currents on symmetrical coupled arms of Figure 1(a) having the opposite direction and the same direction, described in [18]. Similarly, for path composed of resonators 1, 2 and 5, there are three resonant frequencies ($f_{21}$, $f_{22}$ and $f_{23}$), representing surface current modes (S-S, S-S and O-O) between three resonators, respectively. As a result, based on signal interference techniques, two TZs are obtained, hereinto TZ1 is located between $f_{21}$ (S-S) and $f_{12}$ (O-O-O), TZ2 between $f_{22}$ (S-S) and $f_{12}$ (O-O-O), decided by two different transmission paths.

2.2. Resonant Characteristics under Three Different Signal Transmission Patterns

Based on same parameters above, Figure 1(c) shows $S_{21}$ of the proposed BPF under three different signal transmission patterns, which verifies that overlap section of two original passbands, decided by two different transmission paths, is selectivity removed due to signal interference techniques. Two new passbands with two TZs are achieved. Due to coupling pattern differences, positions of TZ1 and TZ2 are shifted a little in Figure 1(c), different from ones in Figure 1(b). Note that $L_3=L_8$ in simulation about Figure 1(b) and Figure 1(c).

![Figure 2 (a). The insertion loss and return loss characteristics with $L_3=4.5$ and varied $L_7$.](image)

![Figure 2 (b). Insertion loss and return loss characteristics with $L_7=7.8$ and varied $L_8$.](image)

2.3. Dual-Band Characteristics with Varied $L_7$ or $L_8$

To adjust dual-band bandwidths, parameters $L_7$ and $L_8$ are utilized to realize this aim. Figure 2(a) and Figure 2(b) show $S_{21}$ and return loss $S_{11}$ of the proposed BPF with varied $L_7$ or $L_8$, respectively. Other parameters in Figure 1(a) are given as follows: $W_1=0.5$, $W_2=2.72$, $L_1=10$, $L_2=2.5$, $L_3=5$, $L_4=1$, $L_5=8.25$, $L_6=13.4$, $g_1=0.4$, $g_2=0.55$, $g_3=0.5$. (Unit: mm)

Figure 2(a) is $S_{21}$ and $S_{11}$ characteristics with $L_8=4.5$ and varied $L_7$. When $L_7$ decreases, the upper side of the second passband and TZ3 are almost fixed, and the second passband bandwidth with $S_{11}=-10$ dB only varies a little. Whereas the first passband bandwidth obviously decreases with $L_7$ decreased,
which can be carefully adjusted to desirable bandwidth. In addition, TZ₁ and TZ₂ affected evidently, stopband bandwidth between two new passbands increases in a certain range when L₇ decreases.

Figure 2(b) provides S₂₁ and S₁₁ characteristics with L₇=7.8 and varied L₈, it can be observed that when L₈ decreases, the lower-side of the first passband is almost fixed, and the first passband bandwidth below S₁₁=-10 dB is affected only a little, whereas the second passband bandwidth and TZ₃ can be adjusted in a large range to desirable values. TZ₁ and TZ₂ are affected evidently, the stopband bandwidth between two passbands decreases when L₈ decreases. Especially, when L₈= 4.25 mm, TZ₁ and TZ₂ are shifted and combined into one transmission zero.

2.4. Dual-Band Optimized Characteristics with Varied L₇ And L₈
Figure 3(a) and Figure 3(b) respectively show optimized S₂₁ and S₁₁ characteristics of the proposed dual-band BPF with varied L₇ and L₈, here L₃= L₈. In which the four resonators except of resonator 5 own same sizes. It can be observed that when L₇ and L₈ decrease, the center frequencies of two passbands both increase, and three TZs also move towards higher frequency region.

2.5. Summary
Based on the simulations and analyses above, it is verified that the proposed BPF can achieve a dual-band passbands due to signal interference technique. Hereinto, overlap part of original two passbands, decided by two different transmission paths respectively, is selectively removed, and two new passbands with two TZs, produced by signal-interference techniques, are obtained. In addition, two passband bandwidths can be carefully adjusted by changing lengths (L₇ or L₈), observed in Figure 2(a) and Figure 2(b). At last center frequencies of two passbands can be simultaneously adjusted and optimized, which is verified in Figure 3(a) and Figure 3(b).

3. Experimental Results
A microstrip dual-band BPF is designed, fabricated, and measured to validate the proposed concept. The substrate TACONIC TLC-32 used in article is with a relative dielectric constant of 3.2, a thickness of 1.14 mm, and loss tangent of 0.003. The BPF is designed and optimized using HFSS software, and Figure 4 is the photograph of the fabricated BPF. It has a size of 28×12 mm², Figure 5 shows the simulated and measured results of the proposed dual-band BPF, the fabricated dual-band BPF in Figure 4 has two passbands below S₁₁=-10 dB from 3.18 to 3.58 GHz and from 4.17 to 4.90 GHz respectively, and one transmission zero at 3.87 GHz between two passbands is obtained. Difference between simulation and measurement is due to the fabricated error and unperfected ground, and it can be improved by more careful fabrication technology.
4. Conclusions
A compact dual-band BPF based on signal interference technique is proposed in this article, overlap part of two wideband passbands, decided respectively by two different signal transmission paths, is selectively removed from the combined passband, and two new passbands are achieved. Due to the used signal-interference techniques, good isolation between two aim passbands is realized with two introduced transmission zeros. Experimental results are in good agreement with predicted results. Because of design flexibility and good performances, the proposed dual-band BPF is attractive for wireless wideband bandpass systems.

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6. References
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