Compact Dual-Band Filter Using Defected Stepped Impedance Resonator

Bian Wu, Chang-hong Liang, *Senior Member, IEEE*, Pei-yuan Qin, and Qi Li

***Abstract*—This letter presents a novel approach for designing a dual-band bandpass filter by using defected stepped impedance resonator (DSIR). The resonant frequency of the DSIR is found to be much lower than that of the conventional microstrip stepped impedance resonator (SIR), which reduces the circuit size effectively. Two types of second-order DSIR microstrip bandpass filter operating at 1.85 and 2.35 GHz, respectively, are well designed according to the classical theory of coupled resonator filter. Then they are combined to construct a compact dual-band filter with a common parallel microstrip feed line, the measurement results of the fabricated filter have a good agreement with the simulation.**

***Index Terms*—Bandpass filter, compact size, defected stepped impedance resonator (DSIR), dual-band.**

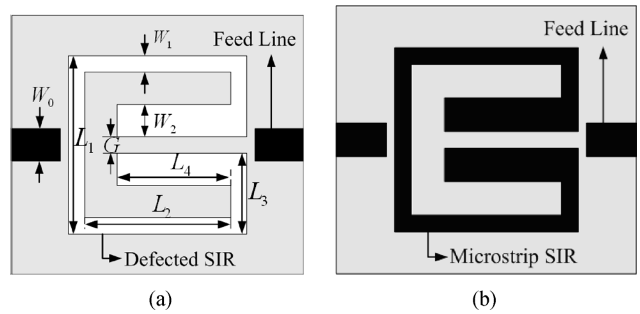

Fig. 1. Structure of microstrip ring resonators. (a) Defected SIR unit. (b) Microstrip SIR unit.

I. Introduction

MORDEN development in wireless communication systems has created an increasing demand for dual-band microwave devices. To meet various application requirements, dual-band filters have been proposed and exploited extensively as a key circuit block in dual-band wireless communication systems [1]–[8]. In [1], a dual-band bandpass filter (BPF) is achieved by a cascade connection of a BPF and a bandstop filter. In [2], a resonator is embedded in another one to obtain two passbands. Dual-band filters can also be realized by combining two sets of resonators with common input and output [3], [4]. Besides utilizing two or more resonators, a dual-band filter can be designed by using a stepped-impedance resonator (SIR) [5]–[8]. Recently, various kinds of defected grounded structures have been presented and found their applications in the design of low-pass, band-pass, and band-stop filters [9]–[11]. In [12], an alternative approach is proposed, in which the DGS themselves are considered as the building blocks of the device and the dual of the split-ring microstrip resonators.

In this letter, a novel dual-band filter based on defected stepped impedance resonator (DSIR) is proposed. The resonant property of DSIR is studied and compared with microstrip SIR. The former is found to have a much lower resonant frequency than the latter, which means a great reduction of circuit size.

Making use of DSIR as the basic resonant unit, two kinds of DSIR filter operating at 1.85 and 2.35 GHz, respectively, are well designed. Then they are combined to construct a compact dual-band filter with a common parallel feed line. An additional transmission zero around 2.9 GHz is created due to the coupling between feed line and nonadjacent resonator, which improves the out-of-band suppression. The measured results validate the proposed design.

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II. Resonant Property of Defected Stepped Impedance Resonator

The configuration of the proposed defected stepped impedance resonator (DSIR) is compared with the conventional microstrip stepped impedance resonator (SIR) as shown in Fig. 1. The substrate used in this letter has a relative dielectric constant of 2.65 and a thickness of 1 mm. A 50 ohm microstrip feed line with a width of $W_0 = 2.8$ mm is located at both of the input and output terminal. The distance from the feed line to the ring is chosen as $S_0 = 0.5$ mm, which results in a weak external coupling. These two resonant units have the same dimension, but the DSIR is realized by etching a folded stepped impedance resonator ring on the ground plane. The folded SIR has two microstrip sections with characteristic impedances of $Z_1 = 85\ \Omega$ ($W_1 = 1.1$ mm) and $Z_2 = 66\ \Omega$ ($W_2 = 1.8$ mm), respectively, so the impedance ratio is $K_{\mathrm{SIR}} = Z_2/Z_1 = 0.776$. Other parameters are $L_1 = 12$ mm, $L_2 = 7.8$ mm, $L_3 = 5.8$ mm, $L_4 = 6$ mm, $G = 0.4$ mm. The DSIR may be thought as a folded slotline and has opposite impedance characteristic as the SIR. Which means a narrow W_1 results in a lower impedance, while a wide W_2 resulting in a higher impedance. So, the impedance ratio is $K_{\mathrm{DSIR}} = 1/K_{\mathrm{SIR}} = 1.288$.

Fig. 2 shows the transmission curves of these two resonant units with and without the wider section L_4. As can be observed, the DSIR has a resonant peak at about 2.1 GHz. This frequency is much lower than the resonant frequency 4.3 GHz of the SIR. When the wider section L_4 is removed, both of the resonant units become uniform impedance resonators (UIRs), and

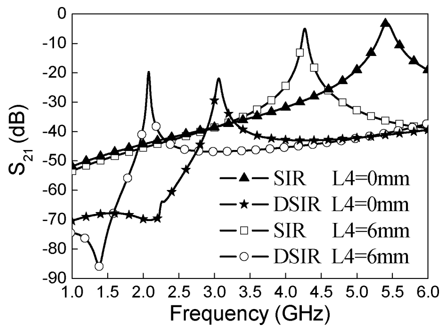
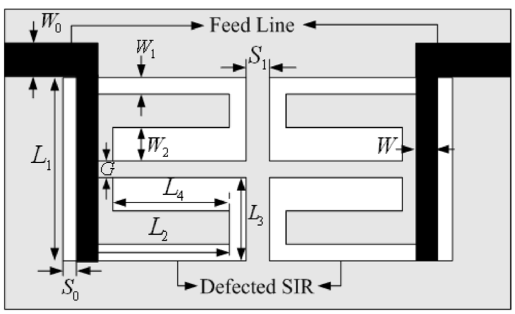
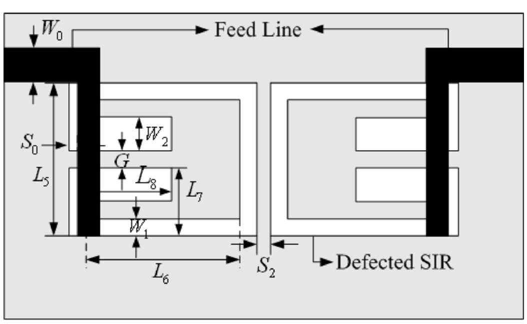


Fig. 2. Resonant property of DSIR and SIR with and without middle loaded stubs. ($W_0 = 2.8$ mm, $W_1 = 1.1$ mm, $W_2 = 1.8$ mm, $L_1 = 12$ mm, $L_2 = 7.8$ mm, $L_3 = 5.8$ mm, $G = 0.4$ mm).



(a)



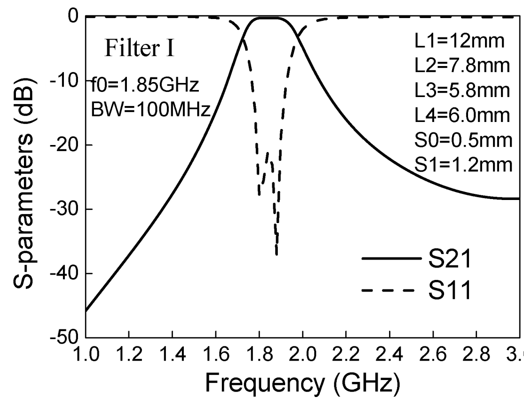
(b)

Fig. 3. Configuration of two types of bandpass filter. (a) Filter I. (b) Filter II.

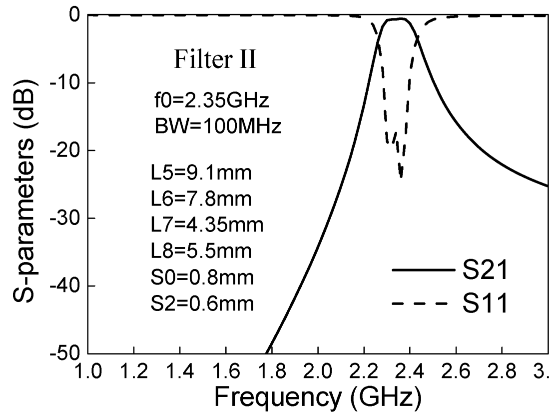
the resonator frequencies increase to about 3.1 and 5.4 GHz, respectively. So the DSIR has the most compact structure, which means a smaller physical size for the same resonant frequency. In addition, with the same distance S_0 from the feed line, the resonant peak value of DSIR is about -20 dB, which is smaller than -5 dB of SIR due to a weaker external coupling. In order to achieve a required external quality factor of a filter, the feed line usually has an overlapped part with DSIR ring.

III. Two Types of DSIR Bandpass Filter

For dual-band filter design, first we have to investigate the design of bandpass filter using DSIR unit. Two types of configurations of second-order bandpass filter are presented as indicated in Fig. 3. Two adjacent DSIR rings with opposite orientation are used as the basic resonant structure. Unlike the microstrip ring, the magnetic field maximum of DSIR is located at the split side while the electric field maximum is located at its opposite side, so the filter in Fig. 3(a) has a magnetic interior coupling while the one in Fig. 3(b) has an electric interior coupling.



(a)



(b)

Fig. 4. Simulated results of (a) Filter I and (b) Filter II.

By adjusting the dimension of DSIR ring, the resonant frequency can be optimized to the required center frequency. The interior coupling changes with the ring-space S_1 (S_2), and the inserted length S_0 of parallel feed line to DSIR ring can be tuned to obtain a suitable external quality factor. Once given the specification of a desired filter, the coupling matrix and external quality factor can be extracted according to the filter synthetic procedure; then the structure and the size are obtained with the previous method. Here, two filter examples are proposed based on the proposed structure.

Filter I has a specification with center frequency of 1.85 GHz, bandwidth of 100 MHz, and return loss of -20 dB. According to the proposed structure and method, the structure parameters and the S-parameter curves of this filter are obtained by using the EM simulator IE3D software as shown in Fig. 4(a).

Filter II has a specification with $f_0 = 2.35$ GHz, bandwidth of 100 MHz and return loss of -20 dB. Using the same design and optimum method, the filter parameters and transmission curves of this filter are depicted as Fig. 4(b).

IV. Dual-Band Filter Using Defected Stepped Impedance Resonator

By combining these two filters and making use of a common parallel feed line, a dual-band filtering property can be achieved. The configuration and the size of the proposed dual-band filter are illustrated in Fig. 5, and the substrate has a permittivity of 2.65 and a thickness of 1 mm. Signals operating at different

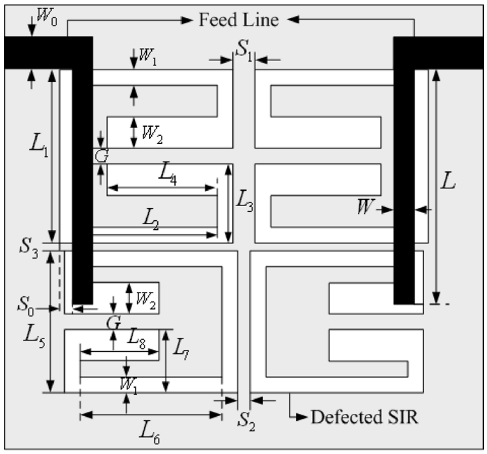


Fig. 5. Configuration of the proposed DSIR dual-band filter.($W_0 = 2.8$ mm, $W_1 = 1.1$ mm, $W_2 = 1.8$ mm, $W = 1.0$ mm, $L = 16$ mm, $L_1 = 12$ mm, $L_2 = 7.8$ mm, $L_3 = 5.8$ mm, $L_4 = 6$ mm, $L_5 = 9.1$ mm, $L_6 = 7.8$ mm, $L_7 = 4.35$ mm, $L_8 = 5.5$ mm, $G = 0.4$ mm, $S_0 = 0.5$ mm, $S_1 = 1.2$ mm, $S_2 = 0.6$ mm).

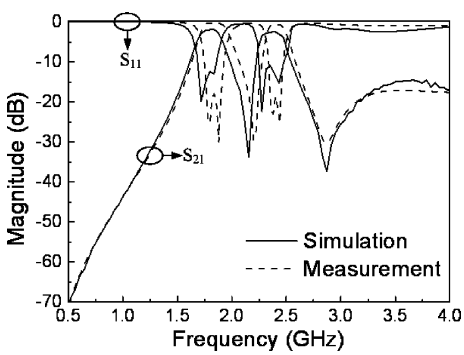


Fig. 6. Simulated and measured results of the proposed DSIR bandpass filter.

frequencies will travel on the different channels above or below separately, but pass through the common feed structure for the energy input and output. The total length L and width W of the feed line as well as the inserted length S_0 can be adjusted to achieve an optimum dual-band transmission property.

Simulation and measurement were carried out using Zeland IE3D software and Agilent's 8719ES network analyzer, respectively. The simulated and measured results are illustrated in Fig. 6. The two passbands centered at 1.85 and 2.35 GHz, are designed to have the fractional bandwidth of 5.5% and 4.5%. The simulated insertion losses are 0.5 and 1 dB at the lower and upper passbands. A transmission zero located at 2.9 GHz is created due to the presence of a cross coupling. The fabrication error leads to a discrepancy between simulation and measurement results that the two center frequencies are shifted 0.3 GHz $\sim$ 0.5 GHz towards the lower frequency. Due to the dielectric loss and radiation loss, the experimental insertion loss is larger than the analytical results by about 1.5 dB. This planar filter can be placed inside a conductive enclosure with four metal posts at each corner of the ground to reduce the radiation loss.

V. Conclusion

In this letter, a novel approach has been presented to design dual-band filter. By comparing the resonant property of DSIR unit and SIR unit, we find the former has a much lower resonant frequency with the same dimension. This compact structure is then applied to design two types of second-order bandpass filters with different center frequencies. Finally, these two filters are combined to achieve a dual-band filter with a common input/output feed line. As a new resonant unit, the DSIR can be found its application in the miniaturized microwave device design of the wireless communication system. The DSIR filter with higher order will be introduced in another research paper.

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