Novel Dual-Band Filter Incorporating Defected SIR and Microstrip SIR

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

***Abstract*—This letter presents a novel approach to design dual-band bandpass filter by using defected stepped impedance resonator (DSIR) and microstrip stepped impedance resonator (MSIR). A pair of MSIRs on the upper plane forms a cross coupled filtering passage, and a pair of DSIRs at the lower plane constructs a linear phase filtering passage. Both of them are fed by a common T-shaped microstrip feed line with source-load coupling. Then they are directly combined to construct a compact dual-band filter with two passbands centering at 2.35 GHz and 3.15 GHz, respectively. The measurement results agree well with the full-wave electromagnetic designed responses.**

***Index Terms*—Bandpass filter (BPF), defected stepped impedance resonator (DSIR), dual-band, microstrip stepped impedance resonator (MSIR).**

I. Introduction

RECENT developments in wireless communication have created a need for dual-band operation for radio frequency (RF) devices. For example, RF communication transceivers are fabricated for both global system for mobile communications (GSM) and wireless code-division multiple-access (WCDMA) purposes. Dual-band antennas are designed for receiving signals at 0.9/1.8 GHz and at 2.4/5.2 GHz [1], [2]. In addition, various kinds of dual-band filters have been proposed and exploited extensively as a key circuit block in dual-band wireless communication systems [3]–[8]. In [3], a dual-band bandpass filter (BPF) is achieved by a cascade connection of a BPF and a bandstop filter. In [4], 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 [5], [6]. Besides utilizing two or more resonators, a dual-band filter can be designed by using a stepped-impedance resonator (SIR) [7], [8]. Recently, various kinds of defected grounded structures have been presented and find 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 defected ground structure (DGS) themselves are considered as the building blocks of the device and the dual of the split-ring resonators.

In this letter, first, two types of two-pole bandpass filters are proposed. One makes use of defected stepped impedance resonator (DSIR) as the basic resonator, while the other is based on the conventional microstrip stepped impedance resonator (MSIR). Then an analysis of the equivalent circuits for these two filters is made, which shows the two filters take on cross coupled filtering property and linear phase filtering property, respectively. They are directly combined to construct a compact dual-band filter with a common T-shaped microstrip feed line. Finally, a synthesis procedure is achieved and a practical dual-band filter is designed and fabricated. The measured results validate the proposed design.

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The authors are with the National Key Laboratory of Antennas and Microwave Technology, Xidian University, Xi'an 710071, China (e-mail: bwu1981@gmail.com).

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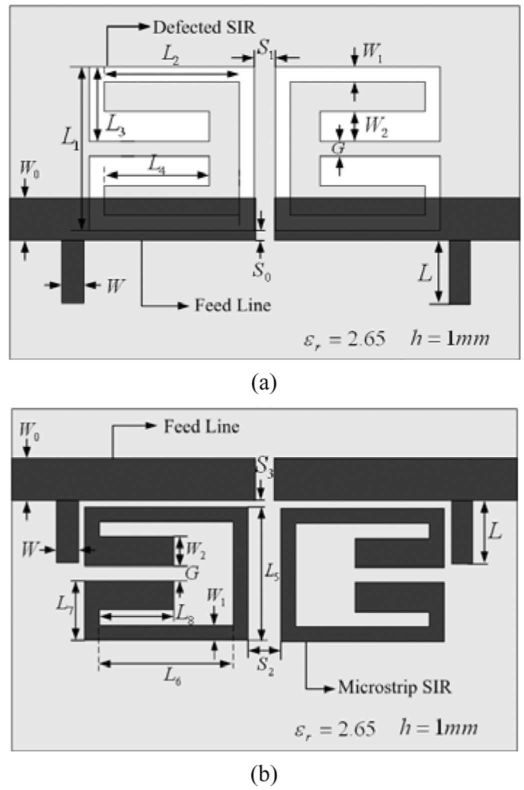


Fig. 1. Geometry of (a) DSIR linear phase filter and (b)MSIR cross coupled filter.

II. Analysis of Two Types of Filters

Fig. 1 depicts two different types of two-pole bandpass filters making use of a pair of folded DSIRs and a pair of folded MSIRs, respectively. Unlike the conventional MSIR, the folded DSIR is obtained by etching a folded stepped impedance resonant ring on the ground plane. Both of the folded SIRs have a middle section with the characteristic impedance of Z_1 and two open-ended sections with the characteristic impedance of Z_2 symmetrically cascaded at both sides of the middle section.

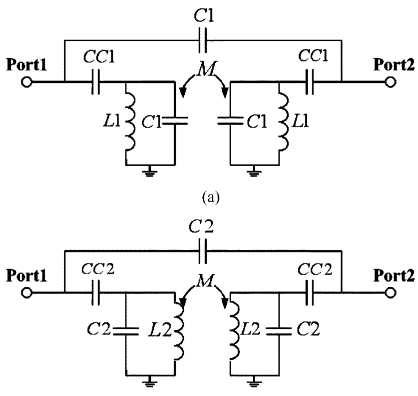


Fig. 2. Equivalent circuit of (a) DSIR linear phase filter and (b)MSIR cross coupled filter.

The impedance ratio of SIR is $K = Z_2/Z_1 = 0.62$. The T-shaped feed structures used in these two filters have the same dimension. In order to achieve a required external quality factor of a filter, the feed line has an overlapped area with DSIR. In addition, an open-circuit stub is loaded in the feed line to increase the external coupling with MSIR.

The equivalent circuits of the above filters are shown in Fig. 2. Each folded resonant ring is equal to a LC resonant tank, and they have capacitive external couplings with the feed lines. A capacitive source-load coupling is created due to the small gap between a pair of microstrip feed lines. The maximum electric field appears at the adjacent sides between a pair of DSIRs as shown in Fig. 1(a) and leads to an electric coupling, which has the same sign as the source-load coupling, so a linear phase filter is formed. While in Fig. 1(b), the maximum magnetic field is located at the adjacent sides between a pair of MSIRs and leads to a magnetic coupling, which has the opposite sign to the source-load coupling, then a cross coupled filter is achieved.

The simulated frequency responses of these two filters are illustrated in Fig. 3. It can be obviously found that the transmission response of MSIR filter takes on cross coupled filtering property and a pair of transmission zeros are symmetrically located outside the passband at about 2.95 GHz and 3.4 GHz. Furthermore, the phase values of the DSIR filter vary linearly with frequencies around the center frequency $f_0 = 2.35$ GHz, which means a linear phase filtering characteristic.

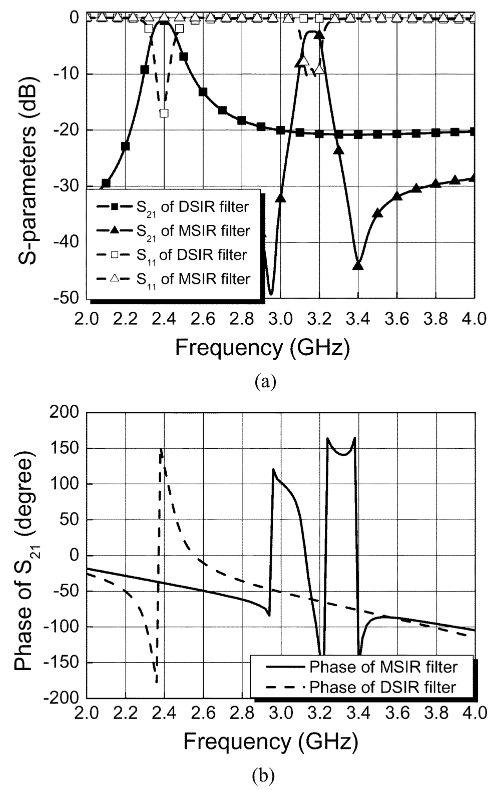


Fig. 3. Frequency responses of two filters: (a) magnitude of S-parameters and (b) phase of S_{21}. Geometric parameters of the filters are $W_0 = 2.8$, $W = 1.5$, $L = 4.2$, $W_1 = 0.5$, $W_2 = 1.5$, $G = 0.6$, $L_1 = 9$, $L_2 = 6$, $L_3 = 4.2$, $L_4 = 5.5$, $L_5 = 7.4$, $L_6 = 6$, $L_7 = 3.4$, $L_8 = 2.5$, $S_0 = S_1 = 1$, $S_2 = 2$, $S_3 = 0.3$. All are in mm.

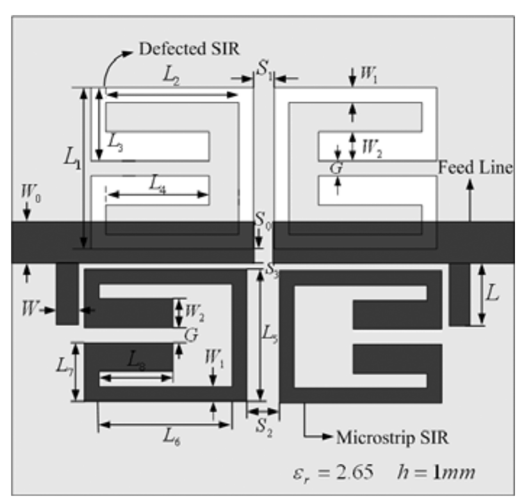
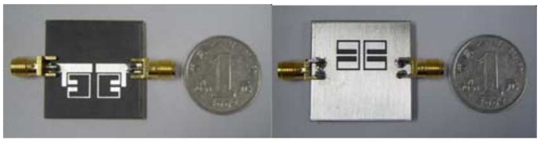


Fig. 4. Configuration of the proposed dual-band filter with DSIR and MSIR. All the geometric parameters are the same as depicted in Fig. 3.

III. DUAL-BAND FILTER COMBINED WITH MSIR AND DSIR

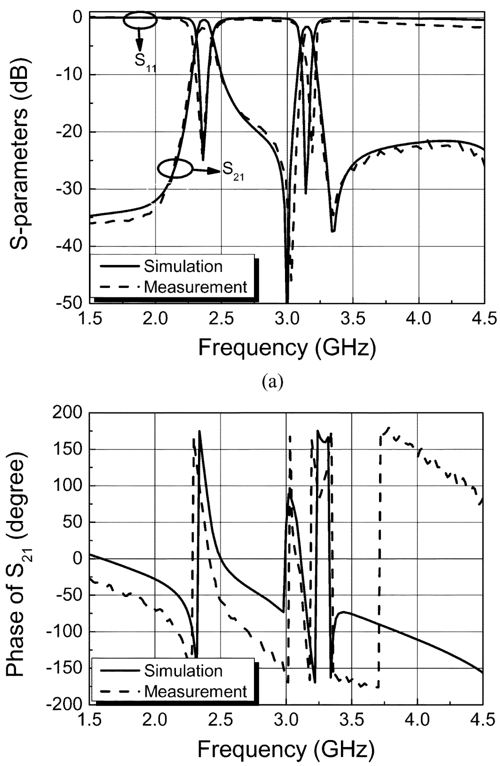
By combining these two filters and making use of a common T-shaped feed line, a dual-band filtering property can be achieved. The configuration of the proposed dual-band filter is illustrated in Fig. 4, which has the same parameter values as given in the previous section. The substrate has a permittivity of 2.65 and a thickness of 1mm. Signals operating at different frequency will travel on the different channels above or below separately, but pass through the common feed structure for the energy input or output. The stub length L and gap width S_3 can be adjusted to achieve a desired external quality factor of the MSIR filtering passage. The external coupling of the DSIR filtering passage can be satisfied by tuning the parameter S_0. The internal coupling is determined by the space of two adjacent rings S_1 (S_2). The design procedure is summarized as follows.

1) According to the dual-band filter specification, find the values of coupling coefficients and external quality factors for each passband making use of the classical filter design theory.
2) Fix the impedance ratio value and the length of the parallel side, determine the size of DSIR by the low passband



(a) (b)

Fig. 5. Photographs of the dual-band filter (a)top view and (b) bottom view.



(a)

(b)

Fig. 6. Simulated and measured results of the proposed dual-band filter: (a) magnitude of S-parameters and (b) phase of S_{21}.

center frequency and the size of MSIR by the high passband center frequency.

3) Extract parameters S_1 and S_2 according to the coupling coefficients, and parameters L, S_0 and S_3 by the external quality factors, then obtain the size of two filters, respectively.
4) Combine the two filters and make a minor tuning to the values of L and S_0 to achieve an optimum dual-band transmission property.

Simulation and measurement are carried out using Zeland IE3D software and Agilent's 8719ES network analyzer, respectively. Fig. 5 shows the photographs of the fabricated dual-band filter, and the simulated and measured results are illustrated in Fig. 6. The two passbands centering at 2.35 GHz and 3.15 GHz, are designed to have the fractional bandwidth of 4% and 3%. The simulated insertion losses are 0.5 dB and 1.5 dB at the lower and upper center passband, respectively. The measured two passbands are centered at 2.355 GHz and 3.16 GHz with the fractional bandwidth of 3.9% and 2.8%. The experimental insertion losses are 1.8 dB and 3.0 dB at the center passbands, which are mainly attributed to the dielectric loss and radiation loss. A pair of attenuation poles outside the second passband is located at 3.0 GHz and 3.35 GHz, which improves the out-of-band selectivity. The total phase response takes on a combined phase property of the two separated filters.

IV. Conclusion

In this letter, a novel approach to design a dual-band filter composed of DSIR and MSIR has been presented. Fed by a microstrip line with capacitive source-load coupling, a pair of MSIRs and a pair of DSIRs can be used to form two types of two-pole bandpass filters. Both the equivalent-circuit analysis and the numerical simulation are made for these filters, which are found to take on cross coupled filtering property and linear phase filtering property, respectively. A compact dual-band filter can be achieved by a directly combining of these two filters. The design procedure of this method is summarized in the letter, and an example dual-band filter centering at 2.35 and 3.15 GHz are well designed and fabricated. Compared with other microstrip dual-band filters, this filter has better selectivity and flexibility but larger insertion loss. The design approach can find its applications in many other areas of the dual-band wireless communication system.

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