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Miniaturized microstrip bandpass filter designed using rectangular dual spiral resonator

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ABSTRACT

A miniaturized microstrip bandpass filter based on a rectangular dual spiral resonator (DSR) is proposed in this paper. The rectangular DSR bandpass filter is centered at 3.65 GHz to suit for Wireless LAN (IEEE802.11y) application. The proposed filter offers transmission zero at the high side of out-of-band response. Across the bandwidth, the measured minimum insertion loss is about 1.7 dB, while the measured return loss is better than 19 dB. Measurement results are good agreement and closed to the simulated ones. The total circuit size of the miniaturized bandpass filter is about 0.145λ_g by 0.135λ_g, where λ_g is the guided wavelength at 3.65 GHz.

1. Introduction

Nowadays, there is a growing interest in the wireless communication applications. Wireless LAN has become one of the most popular methods for Internet Access [1]. Microwave filters, especially bandpass filters, are essential to the operation of this technology. However, the most significant keys to succeed in development of WLAN modules are excellent performance, low cost and small size. That is why new approach in miniaturized bandpass filter is necessary. To miniaturize microstrip bandpass filters may be achieved by using high dielectric constant substrates, a change in the geometry of filters is required and therefore numerous new filter configurations become possible. Recently, several research works on miniaturized microstrip bandpass filters have been reported such as pseudo interdigital filter [2] and Microstrip hairpin bandpass filter [3]. Miniaturized dual-mode resonator filters have also been proposed to miniaturize circuit area, such as back-to-back spiral-shaped and interdigital spiral-shaped filters [4], bandpass filter using a dual-mode microstrip meander loop resonator and bandpass filter using a single dual-mode open-loop resonator [5]. However, some filters proposed above occupy still a fairly large circuit area. On the other hand, compact S and U-type spiral resonator bandpass filters have been reported to reduce the size of the bandpass filters [6,7] and some perfect performance have been obtained. Furthermore, many compact resonators, such as Y-shaped dual-mode and multiple-mode resonators [8,14], Stepped-Impedance and Meander-Loop resonators [9–11], modified SIR and open-loop [12,13], dual-Log spiral resonator and Ring resonators [15–17] have also been attempted to construct the miniaturized filters. And in [18–24], compact filters have been also reported.

In this paper, the rectangular dual spiral resonator (DSR) is investigated for reducing circuit area of bandpass filters. In this work, a miniaturized microstrip bandpass filter for wireless LAN (IEEE802.11y) application is proposed by using the presented rectangular DSR. The compactness in circuit size and the symmetry of the filter topology are the characteristic of the proposed filter using the rectangular DSR compared to the conventional spiral resonator proposed in [25–27]. For demonstration purposes, a compact wide-stopband bandpass filter using DSR is designed, fabricated, and measured. The measured results show that the fabricated filter has a fractional bandwidth of 8.2% at a central frequency of 3.65 GHz.

2. Analysis of the proposed rectangular DSR

The presented rectangular DSR is shown in Fig. 1. It consists of two quarter-wavelength spiral microstrip lines and is denoted by its physical length ($L = \lambda/4 + \lambda/4 = \lambda/2$) and width ($W$). It can be seen that the presented rectangular DSR is symmetric, which will greatly benefit the filter design when the filter is constructed by using the presented rectangular DSR.

Fig. 2 shows the comparison of symmetric coupling characterization for the filter using rectangular DSR and conventional spiral resonator. It can be seen that the filter is symmetric when the

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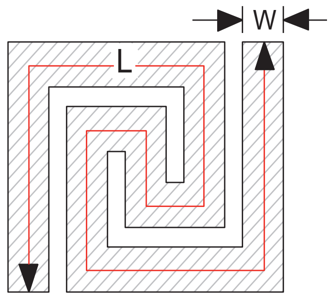

Fig. 1. Structure of the presented rectangular DSR.

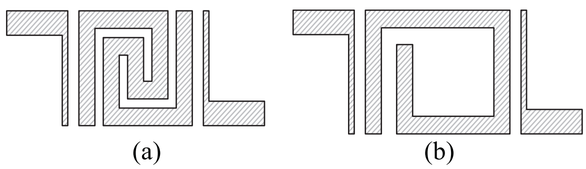

Fig. 2. Comparison of symmetric coupling characterization: (a) DSR and (b) conventional spiral resonator.

filter is constructed by using any number of rectangular DSR. However, the filter using conventional spiral resonator is symmetric only when the number of the conventional spiral resonator is even. Moreover, the coupling characterization of the presented rectangular DSR is also different with that of previous dual spiral resonator in [6].

3. Filter design

Fig. 3 shows the feed and coupling scheme at resonant frequency of the proposed DSR bandpass filter. The coupling coefficient between two resonators (R_1 and R_2) can be specified by the two dominant resonant frequencies, which are split off from the resonance condition due to electromagnetic coupling. If f_{P1} and f_{P2} are defined to be even and odd resonant frequencies, respectively, the coupling coefficient can be obtained from [4]

$$K_{12} = \frac{f_{P2}^2 - f_{P1}^2}{f_{P2}^2 + f_{P1}^2} \tag{1}$$

where K_{12} represents the coupling coefficient between the two resonators. It is noted that the coupling coefficient (K_{12}) is related to the gap (S) between the resonators. The coupling can be varied by varying the gap (S) between the resonators as shown in Fig. 4. The resonance frequencies are obtained from the simulated response S21 for two resonators by using HFSS [28] and K_{12} = 0.045 has been obtained. The optimum design condition of S is set as 0.26 mm in this design. The coupling scheme of the proposed filter predicts the transmission zero at the high side of the stopband due to cross-coupling between input/output as shown in Fig. 3.

The initial physical length of the proposed DSR resonator can be determined through the following expression [2]

$$\lambda = \frac{300\ \text{mm}}{f_0\,(\text{GHz})\sqrt{\varepsilon_{eff}}} \tag{2}$$

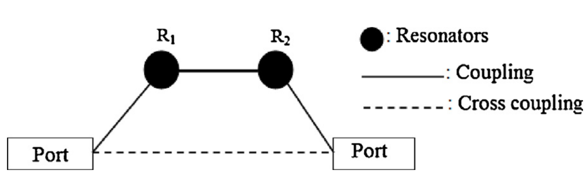

Fig. 3. Feed and coupling scheme of the proposed DSR bandpass filter.

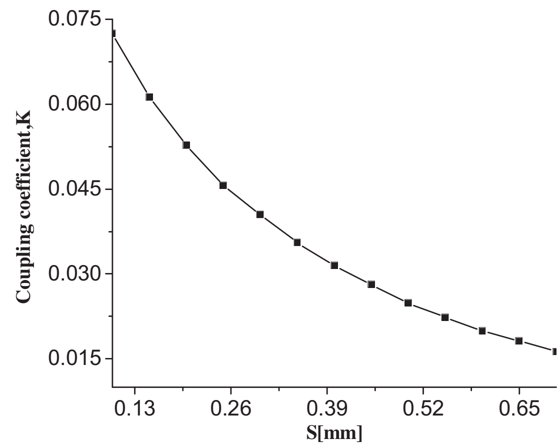

Fig. 4. The calculated coupling coefficient K_{12} between two DSR at 3.65 GHz.

where ε_{eff} = 2.62, W = 0.576 mm, f_0 = 3.65 GHz, and the guided wavelength λ is 50.68 mm. It means the initial physical dimensions of the proposed filter have been known once the guided wavelength of the DSR resonator is obtained. Fig. 5(a) shows the initial configuration of the proposed filter while Fig. 5(b) shows the simulated frequency response of the proposed filter with initial dimensions defined as follows:

$L = \lambda/2 = 25.34$ mm, $W_1 = 1.15$ mm, $W_2 = W_3 = 0.1$ mm, $S = S_2 = 0.26$ mm, $S_1 = S_3 = 0.1$ mm, $L_1 = 10.295$ mm, $g = 0.25$ mm.

The simulation results with initial parameters show the center frequency (3.65 GHz) is shifted to 4.3591 GHz and spurious at 7.56573 GHz in high stopband is detected as shown in Fig. 5(b). In order to make the performance at the high stopband, two open circuit stubs at the input/output are added as shown in Fig. 6(a).

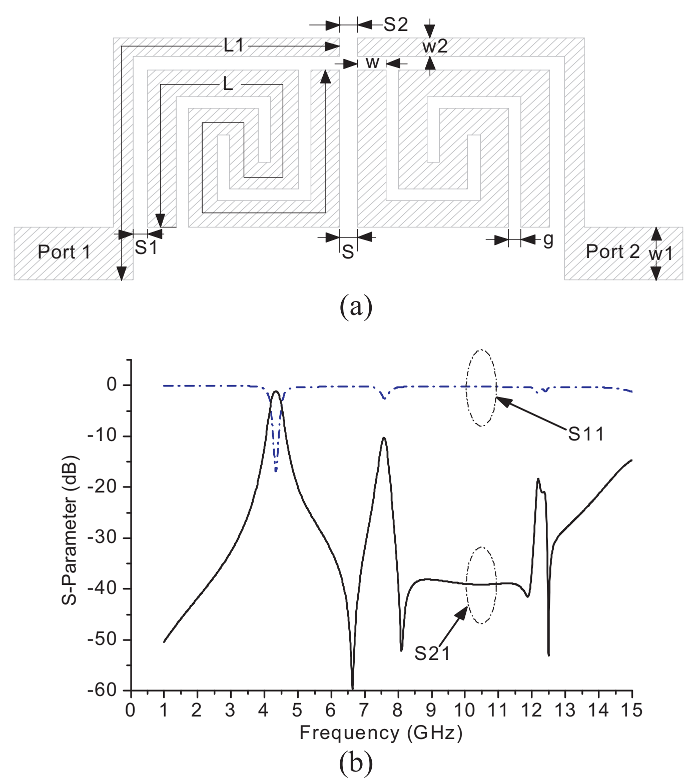

Fig. 5. (a) Configuration of the proposed filter. (b) Simulated frequency response of the proposed filter with initial parameters.