Miniaturized Wideband Ring-Type Bandpass Filters with Upper Stopband Characteristic

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Abstract—A new class of wideband ring-type microstrip bandpass filter is proposed under smaller size of three quarters waveguide length section. One via hole is placed at perpendicular positions of a squared ring, whereas two short-circuited sections are formed in the ring-type microstrip bandpass filter similar to a dual-mode ring filter in shape, thereby making up a three quarters waveguide length ring-type microstrip bandpass filter. By adjusting the short-circuited sections, the bandwidth of the center frequency can be controlled easily. As a pair of open-circuited stubs is placed between the two ports, two extra resonances can be used to improve the out-of-band performance. Afterwards, a novel microwave microstrip filter has been successfully fabricated with the lower insertion loss S_{21} of

0.48 dB, return loss S_{11} of 30 dB, 3dB bandwidth of 80 %, and central frequency of 2.4 GHz. Simulated and masured results show good wideband filtering performance with widened upper stopband outside the wide passband.

1. INTRODUCTION

Recently, planar filters with the characteristics of low cost, compact size, and wide stopband play an important role in modern filter applications due to easy integration into the printed circuit board (PCB). Moreover, next generation wireless systems and high data-rate communication systems require wideband bandpass filters (BPFs). Broadside coupled structures [1]–[7] enable stronger coupling and filters with these structures exhibit inherently wideband characteristics.

Such filters are realized by parallel-coupled microstrip lines, but this requires smaller coupling gaps in order to enhance the coupling for wider bandwidths [8] and the gap size required to enhance the coupling is limited by the fabrication process. Moreover, many filter structures include coupling gaps between the feed lines and filter circuit. Such a filter suffers from high insertion loss due to the conductor, dielectric, and radiation losses [9]-[14]. To overcome this problem, a direct coupling structure can be used instead of the coupling gaps between the feed lines and filter circuit to reduce insertion losses and create wide passbands. In brief, there are no radiation losses between the feed lines and filter without coupling gaps between them [15]-[16].

On the other hand, much effort has been made to maximize the return loss in the primary passband, e.g., enhanced side-coupling, line-to-ring coupling, and interdigital coupling schemes [17]-[21]. Other techniques such as three-line microstrips [22], multimode resonators [23], and the new coupling scheme in [24] are used to design wideband BPFs. However, the above-mentioned filters may still be large in size or have narrow upper stopband.

To the best of our knowledge, there is no reported work that has developed a wideband ring-type bandpass filter with good low-band rejection by adjusting impedance at two short-circuited sections. The objective of this paper is to present and implement a new class of wideband ring-type bandpass filters with excellent out-of-band rejection. In this paper, resonance behavior of a ring-type bandpass filter with loading of open-circuited stubs will be characterized in a comprehensive way and it will be utilized to constitute a new class of wideband ring-type bandpass filters with compact size, controllable bandwidth, good insertion loss in passband, and improved out-of-band performance.

2. PROPOSED WINDBAND BANDPASS FILTER

Because of its compact size, low insertion loss, wide passband, wide stop band, and low cost are highly desirable, a ring-type microstrip bandpass filtr is proposed to achieve the above desired performances. In this study, miniaturized wideband ring-type bandpass filters are proposed using two λ_g / 4 short-circuitd sections (Z_2, θ_2) and one λ_g / 4 transmission line (Z_1, θ_1) between two sections inserted by input/output feed lines for 50-Ω microstrip lines, as shown in Fig.1.

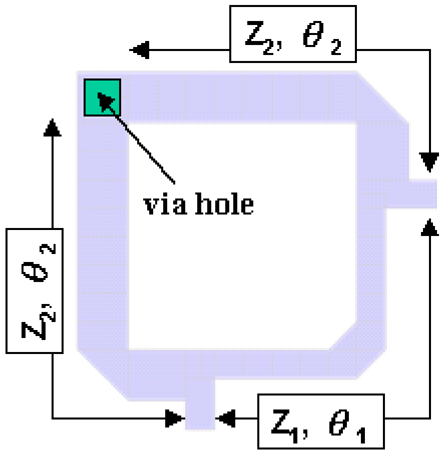

Fig. 1. Schematic diagrams of proposed ring-type bandpass filter.

The electrical lengths are $\theta_1 = \theta_2 = \lambda_g/4$ and λ_g is the guided wavelength at the center frequency. The internal open-circuitd stubs are with $L_{S1} = L_{S2} = \lambda_S/4$ and λ_S is the guided wavelength at the stopband frequency. The g values and fractional bandwidth (FBW) of the bandpass filter are selected as $g_0 = 1$, $g_1 = 0.631$, $g_2 = 3.262$, FBW = 80%. The characteristic impedances Z_1 and Z_2 are calculated as follows [25]：

$$Z_1 = Z_0\left(g_0\sqrt{\frac{2g_1}{g_2}} \right)^{-1} \quad (1)$$

$$Z_2 = Z_0\left(\sqrt{g_0{}^2\left(\frac{2g_1}{g_2}\right)+\left(g_0 g_1 \tan\theta\right)^2} - g_0\sqrt{\frac{2g_1}{g_2}}\right)^{-1} \tag{2}$$

$$\theta = \frac{\pi}{2}\left(1-\frac{FBW}{2}\right) \tag{3}$$

Simulated frequency response of the bandpass filter centered at 2.4 GHz with fractional bandwidth of 80% on a FR4 substrate (permittivity = 4.4, thickness = 0.8 mm) is shown in Fig. 2.

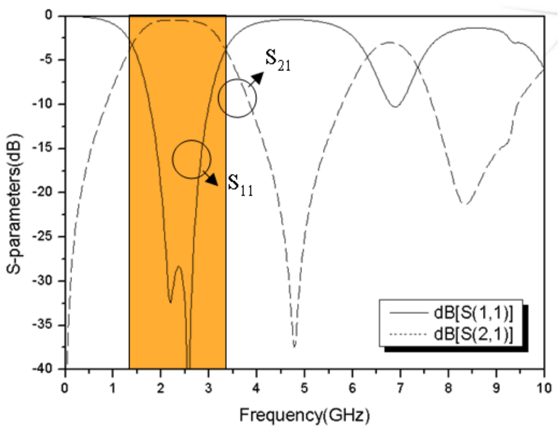

Fig.2. Simulated frequency response of the proposed ring-type BPF.

The proposed ring-type bandpass filter is made by inserting a via hole to create two short-circuited sections, resulting in three quarters waveguide length section. Wideband ring-type microstrip filters of three quarters waveguide length are small in size compared to other filter technologies, such as multi-order filters, although limited in the degree of miniaturization possible due to physical wavelengths at lower operating frequencies and compromises in electrical performance for realizing wideband. Even though meandering the transmission lines of filters can miniaturize microstrip filters, nevertheless, for some meanderd transmission lines generally lead to increased dissipation losses for a given circuit substrate material and, hence, reduced performance. Additionally, we can get a fine tuning of the passband bandwidth by adopting the impedances of two short-circuited sections. In Fig. 3, the magnitude of S_{21} (dB) for the wideband bandpass filter are plotted as a function of the impedances of two short-circuited sections (Z_2). According to formulas (2) and (3), as the width decreases, the equivalent characteristic mpedances of two short-circuited sections (Z_2) increases to result in the fractional bandwidth increases. The proposed techniques are very simple and useful on designing good suppression broadband bandpass filters with compact dimensions and similar band performance.

Fig. 4(a) and (b) depicts layout configurations of the two ring-type bandpass filters with/without the internal open-circuited stubs between the two excited ports, respectively. It is obvious that wide stopband is achieved by using the internal open-circuited stub between the input/ output ports, as shown in Fig.5.

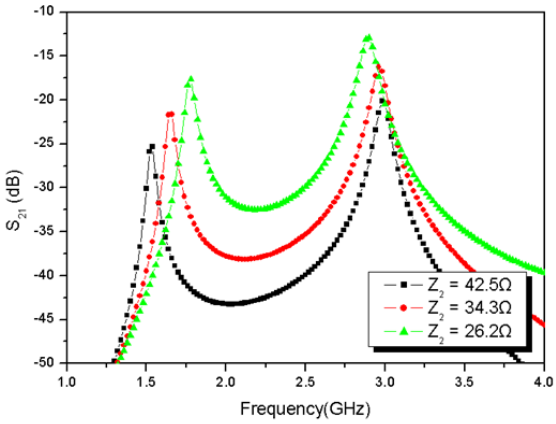

Fig. 3. Frequency response of S_{21} under varied impedance of short-circuited stubs (Z_2).

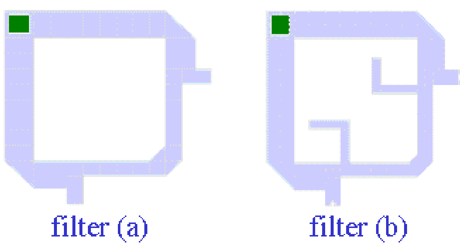

Fig. 4. Schematic diagrams of the proposed ring-type bandpass filtrs (a) without the internal open-circuited stubs and (b) with the internal open-circuited stubs.

The proposed filter is ideally suited for use in communications systems such as satellites and mobile communications equipment due to good insertion loss, controllable bandwidth, good out-of-band performance and small size.

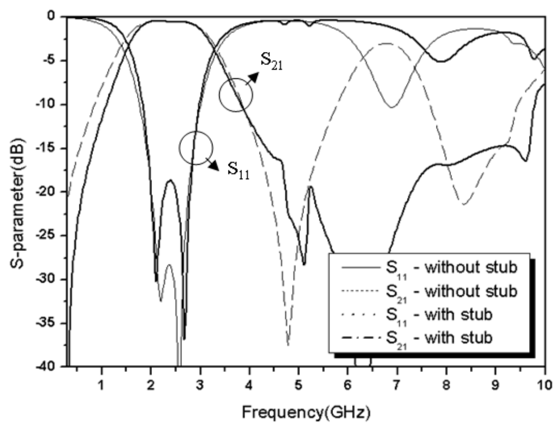

Fig. 5. Simulated frequency response of the proposed ring-type bandpass filters with/without the internal open-circuited stubs.

3. IMPLEMENTATION AND EXPERIMENTAL RESULTS

The proposed filter was designed and fabricated on an FR4 substrate with thickness h = 0.8 mm and relative dielectric constant ε_r = 4.4. The electrical lengths are $\theta_1 = \theta_2 = \lambda_g/4$, λ_g is the guided wavelength at the center frequency. The internal open-circuitd stubs are with $L_{S1} = L_{S2} = \lambda_S/4$ and λ_S is the guided wavelength at the stopband frequency. Fig. 6 shows configuration of the proposed ring-type bandpass filter. After optimization, dimensions of the proposed ring-type bandpass filter are W_1 = 0.5 mm, W_2 = 2.7 mm, L_a = 17.3 mm, L_b = 17.3 mm, $W_{S1} = W_{S2}$ = 0.9 mm, $L_{S1} = L_{S2}$ = 7.1 mm, and W_0 = 1.5 mm.

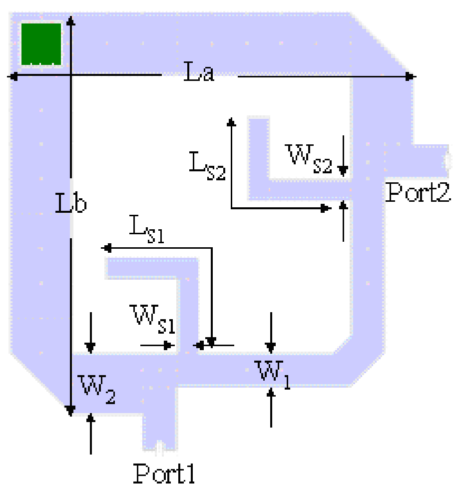

Fig. 6. Configuration of the proposed ring-type bandpass filter.

The performance of the filter was measured by using an Agilent vector network analyzer (VNA). The simulation and measurement results of the proposed filter are shown in Fig. 7. Excellent agreement is obtained and the filter exhibited wideband bandpass performance with lower insertion loss S_{21} of 0.48 dB, return loss S_{11} of 30 dB, 3dB bandwidth of 80 %, 15dB bandwidth of 40%, and central frequency of 2.4 GHz. Some of the additional insertion loss within the passband is due to connector loss and radiation loss. The total size of the proposed filter is 17.3 mm × 17.3 mm, a very compact size only amounting to 0.1875 by 0.1875 guided wavelength at the center frequency, making it suitable for size- and weight- sensitive applications, such as in mobile communications devices and satellite communications systems.

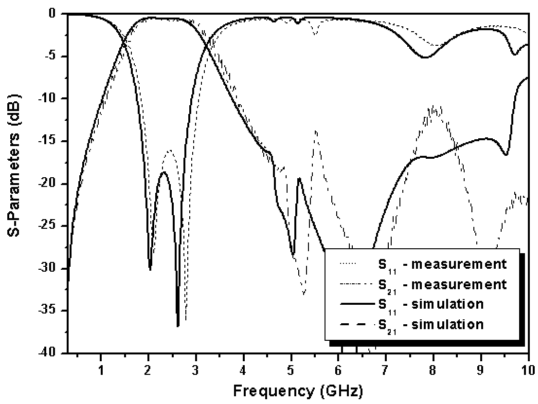

Fig.7. Simulated and measured frequency response of the proposed ring-type bandpass filter.

4. CONCLUSION

A simple planar bandwidth controllable ring-type filter having smaller size of three quarters waveguide length is proposed in this study. Both simulated and measured results demonstrate the good performance as good out-of-band suppression. The fabricated filter exhibited insertion loss S_{21} of 0.48 dB, return loss S_{11} of 30 dB, 3dB bandwidth of 80 %, 15dB bandwidth of 40%, and central frequency of 2.4 GHz. The proposed bandwidth controllable filter can be applied to wireless communication for ISM-band.

ACKNOWLEDGEMENT

The authors are grateful to the National Science Council of the Republic of

China which supported grant under contract No: NSC 97-2221-E-006-239.

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