A Microstrip Dual-Band Bandpass Filter with Reduced Size and Improved Stopband Characteristics

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***Abstract* — A novel compact microstrip dual-band bandpass filter(BPF) is developed with remarkably improved stopband characteristics. Two square open-loop resonators are embedded in a U-shaped resonator to achieve a significant size-reduction of the filter. Meanwhile, a cross-coupling between nonadjacent resonators is exploited to produce multiple transmission zeros in the stopbands of the filter. As a consequence, wide stopbands with sharp and large attenuations are obtained. Theoretical and measured frequency responses of the designed filter show a good agreement.**

***Index Terms* — cross-coupling, dual-band filter, open-loop resonator, transmission zero.**

1. INTRODUCTION

The rapid advances in the wireless communication industry demand novel designs that can be used in more than one frequency band. One example is that in the global systems for mobile communications (GSMs), RF transceivers must be able to operate concurrently at both 900MHz and 1800MHz. Lin *et al.* [1] developed a tri-band transceiver module for GPRS mobile applications. Three transceivers for tri-bands were realized in one module. The module was large and complicated because each band of the transceivers had its own signal path and was realized by independent components. To reduce the overall size of systems in such applications, dual-band or multi-band components, such as antennas, amplifiers, and filters, are demanded so that two or more RF front ends can be easily incorporated into one module [2]. In [3], Miyake *et al.* reported a method to realize dual-band bandpass filters (BPFs) by connecting two different BPFs in parallel. The circuit configuration was large, and excess external impedance matching networks were required at the input and output of the filters. Quendo *et al.* [4] and Lee *et al.* [5] realized dual-band BPFs by using microstrip transmission lines and open-stubs, but the stopband characteristics of the filters were very poor.

Sun *et al.* [6] proposed a low profile stepped impedance resonator (SIR) dual-band BPF using parallel coupled microstrip line. However, the stopband characteristic of the filter is poor. To improve the attenuation characteristics in the stopband of a dual-band filter without using a large order filter, thus avoiding the increase of both the size and the insertion loss of the filter, one effective method is to introduce extra cross-coupling between nonadjacent resonators and thus produce transmission zeros in the stopbands.

In this letter, a novel three-pole filter for dual-band application is proposed. Microstrip resonators with different geometrical shapes are arranged in a compact configuration, and a cross-coupling between non-adjacent resonators is introduced. The cross-coupling as well as microstrip open stubs are utilized to produce four transmission zeros in the stopbands of the filter. As a consequence, wide stopbands with sharp and large attenuations are obtained. The simulated and measured frequency responses of the filter show a very good agreement.

2. PROPOSED MICROSTRIP DUAL-BAND BPF

Figure 1 shows the geometrical schematic of the proposed three-pole dual-band microstrip BPF. Two square open-loop half-wavelength resonators are embedded in a U-shaped half-wavelength resonator. Both the square open-loop resonators and the U-shaped resonator are designed so that their fundamental modes operate at 0.9GHz, and their first harmonic resonances occur at 1.8GHz, twice that of the fundamental modes. All microstrip lines of the resonators have a width of w=1.2mm. A substrate of Duriod 6010 with a thickness of 0.635mm and a nominal dielectric constant of 10.2 is used in the design.

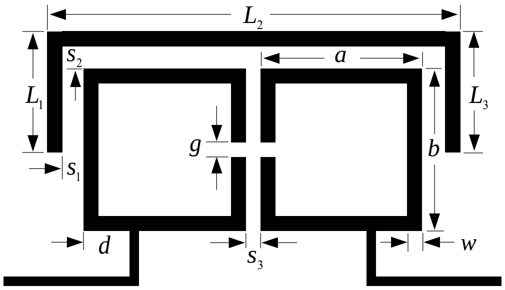

Figure 1. Schematic of the proposed dual-band BPF.

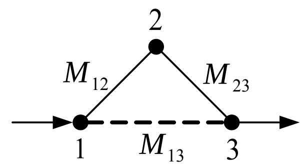

Figure 2. Multi-path coupling diagram of the filter.

Figure 2 indicates the multi-path coupling diagram of the filter. The black dots represent the three resonators. The solid lines express the main coupling paths among the open-loop resonator, the U-shaped resonator, and the open-loop resonator. The dashed line indicates the cross-coupling between two open-loop resonators.

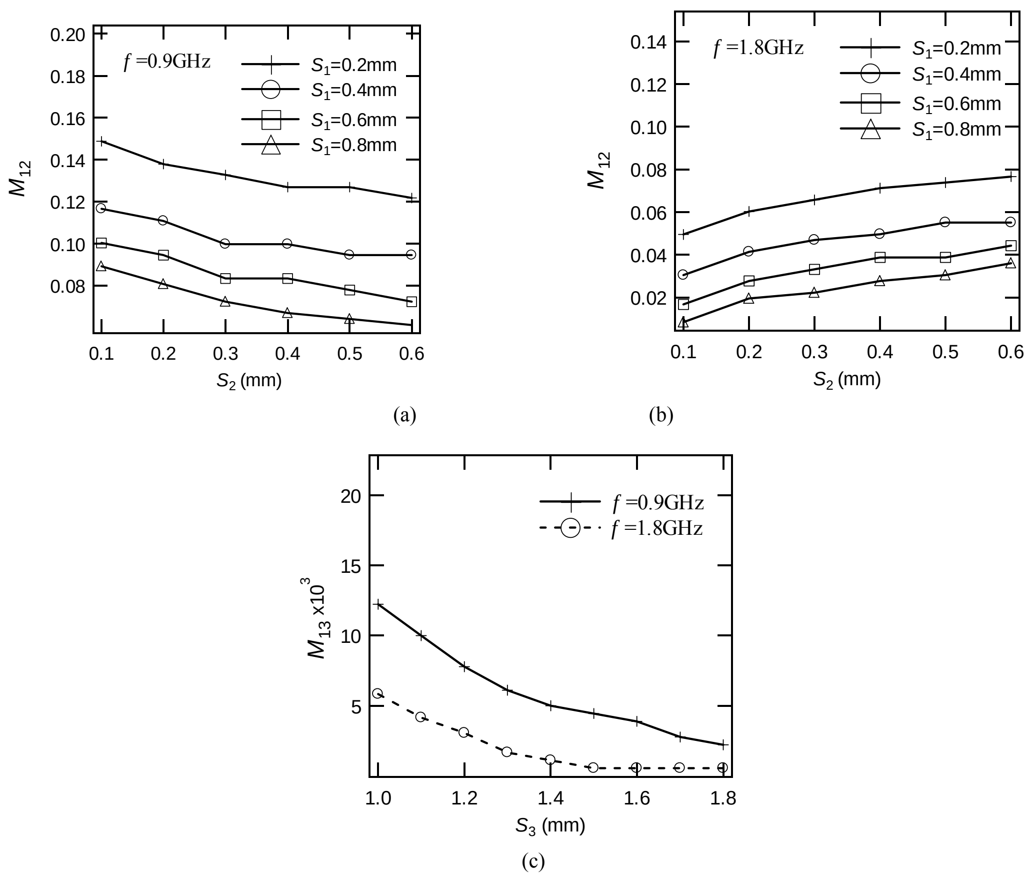

Figure 3. (a) Coupling coefficient M_{12} versus s_1 and s_2 at 0.9GHz, (b) Coupling coefficient M_{12} versus s_1 and s_2 at 1.8GHz, and (c) coupling coefficient M_{13} versus the distance s_3.

The coupling coefficients between two adjacent resonators are computed by employing a full-wave EM simulator, Sonnet em [7]. Figure 3(a) and (b) show the coupling coefficients M_{12} versus the spacing s_1 and s_2 between the open-loop resonator and the U-shaped resonator shown in Figure 1, at 0.9GHz and 1.8GHz, respectively. The coupling between resonators can be controlled by changing s_1 and s_2. Figure 3(c) shows the cross-coupling coefficient M_{13} versus the distance s_3 between the open-loop resonators shown in Figure 1. The cross-coupling M_{13} decreases with the increment of s_3. From the layout of the filter shown in Figure 1 we can see that as to a given L_2, once s_1 is determined, s_3 is determined accordingly.

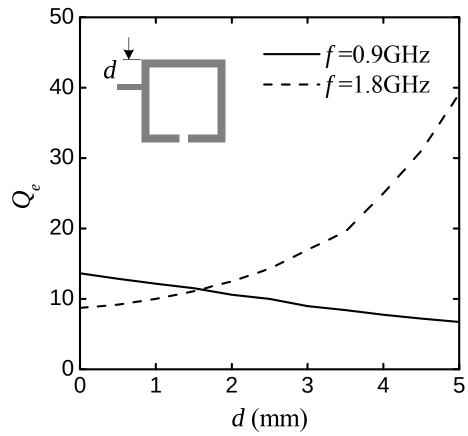

Figure 4. External quality factor Q_e versus the tap-position *d*.

The input/output line of the filter is tap-coupled to the open-loop resonator, as shown by the inset of Figure 4. The variation of the external *Q*-factor of the resonator, Q_e, versus the tap-position *d* is depicted in Figure 4.

Assume that the fractional bandwidths of the first and the second passband of the dual-band filter are FBW_1 and FBW_2, respectively. For the n-th (n=1, 2) passband, the relation between the coupling coefficients and bandwidth is given by [8]

$$(Q_e)_n = \frac{1}{(g_0)_n} \cdot \left(\frac{(g_1)_n}{FBW_n} + \frac{(B_1)_n}{2}\right) \tag{1}$$

$$(M_{ij})_n = \frac{FBW_n \cdot (J_{ij})_n}{\sqrt{((g_i)_n + FBW_n \cdot (B_i)_n/2)((g_j)_n + FBW_n \cdot (B_j)_n/2)}} \tag{2}$$

where *g*, *J* and *B* are the element values of the prototype low-pass filter.

A dual-band Chebyshev BPF is designed with midband frequencies of f_1=0.9 GHz and f_2=1.8 GHz, passband ripples of 0.01dB, and equal-ripple fractional bandwidths of FBW_1=7.4% and FBW_2=4.3%. From Figure 3(a)-(c) and Figure 4, we choose the dimensions of the filter shown in Figure 1 as follows: L_1=L_3=13mm, L_2=39.3mm, *a*=*b*=17.2mm, *g*=0.8mm, *w*=1.2mm, s_1=0.4mm, s_2=0.55mm, s_3=1.7mm, and *d*=3.1mm. The input and output lines are of 50 Ω with a width of 0.6mm.

3. EXPERIMENTAL RESULTS

The filter designed above is fabricated and then measured by using a network analyzer HP8722ES. Figure 5 is a photograph of the fabricated dual-band BPF, and Figure 6 provides a comparison of the simulated and measured characteristics of the filter. The solid lines are the measured response of the filter, and the dashed lines are the simulated curves using Sonnet em. In the simulation, we have taken into account both the dielectric and conductor losses by using a loss tangent of 0.0023 of the dielectric substrate and a conductivity of $\sigma = 5.8\times10^7$ S/m of the copper films. Moreover, we used a measured dielectric constant of ε_r=11.3 instead of the nominal value of 10.2 from the provider of the substrate, because we found that the measured frequency response of the filter shifted downward approximately 50MHz from the simulated one. To find out the reason for the frequency deviation, we measured the dielectric substrate by using our well-established cavity method and automatic measurement system with a high precision. We got an averaged value of ε_r=11.3. The simulated filter response using ε_r=11.3 is drawn in Figure 6 by dashed lines, and agrees well with the measured solid lines. The measured insertion loss in the first and second passband of the filter is 1.3dB and 3dB, respectively. Larger attenuations greater than 45dB are obtained in the frequency range 1-1.6GHz and 1.95-2.3GHz.

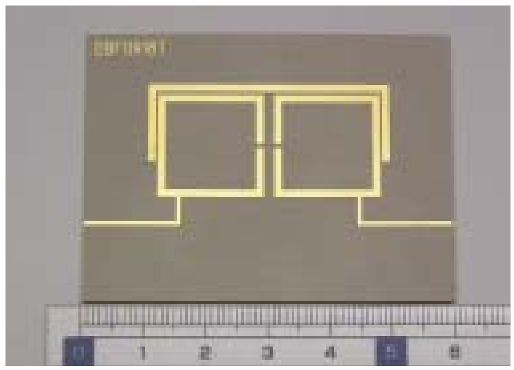

Figure5. A photograph of the fabricated dual-band BPF.

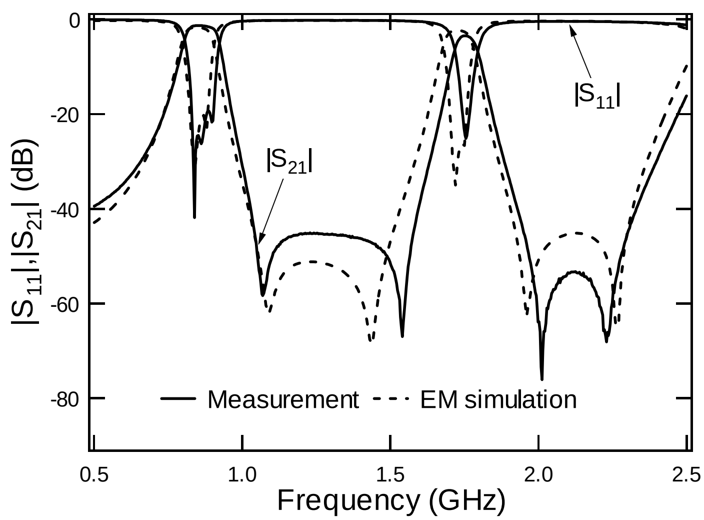

Figure6. Comparison between simulated and measured responses of the filter.

4. CONCLUSION

A novel compact microstrip dual-band BPF is proposed. The three-pole filter is compact because it occupies approximately the same area of a two-pole open-loop resonator filter. Transmission zeros are realized due to the introduction of cross-couplings between non-adjacent resonators. As a result, wide stopbands with sharp and large attenuations are obtained. The simulated characteristics of the filter are verified well by the measured results.

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