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A wideband bandpass filter with improved out-of-band performance

José L. Olvera-Cervantes[a), Alonso Corona-Chavez, D. V. B. Murthy, and Humberto Lobato-Morales

Large Millimeter Telescope, Instituto Nacional de Astrofísica Óptica y Electrónica, Luis Enrique Erro 1, Puebla 72000, México

a) *jolvera@inaoep.mx*

Abstract: A novel compact wide bandpass filter is proposed by cascading two square-ring resonators, a quarter wave length short-stub and a quarter wavelength open-stub. This filter offers wide passband, with high out-of-band rejection and suppression of second spurious harmonic. Design procedure of a filter at 1 GHz with 50% fractional bandwidth is presented showing good agreement between simulation and experimental results.

Keywords: microwave filters, bandpass filters, resonator, microstrip filter

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Wide bandpass filters, whose fractional bandwidths are larger than 20%, are important in many different applications such as radio transceivers, measure-

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ment instruments, satellite systems, ultra-wideband (UWB) systems, wireless personal area networks (WPA), advanced imaging of the human body, ground penetrating radar (GPR), wall penetrating radar, secure communications and precision position/tracking [1, 2, 3].

Ring resonators are a good candidate for wide passband filters as shown in [2, 3, 4, 5] due to their attractive features. Hsieh and K. Chang [4] have proposed a ring-resonator bandpass filter, in which the feeding line is connected directly to a dual-mode ring resonator with addition of two tuning stubs making the structure larger. In addition input and output lines are at 90° angle, hence decreasing flexibility when several resonators need to be cascaded. An improved circuit, with more compact size, lower insertion-loss, and smoother passband was proposed in [2]. However, these filters suffer of poor rejection performance in a frequency range out-of the desired passband. In [3] a microstrip bandpass filter based on a dual-mode ring resonator with spur-line structures placed at the input and output ports was proposed. However, this filter suffers from very low rejection in a frequency range below the desired passband. Moreover, the complexity of fabrication increases because the spur-lines are embedded in 50 Ω transmission lines (TLs). In [5] a new class of wideband microstrip bandpass filters using a capacitive coupling scheme at the excitation ports is proposed under multiple resonances of an asymmetric ring resonator; these class of filters improve the out-of-band performance. Nevertheless difficult manufacturing arises due to the required interdigital coupled lines.

In this letter a novel wide passband filter is proposed. The filter is designed by cascading two square-ring resonators, a quarter wave length short-stub and a quarter wavelength open-stub. The proposed filter offers wide passband, is easy to fabricate as no spur lines or interdigital capacitances are required, improved out-of-band performance, offers miniaturization and it can easily be integrated in series with more resonators.

To provide verification of the proposed structure, a prototype filter is designed at a center frequency of 1 GHz and 50% fractional bandwidth and results are confirmed in experiment.

2 Design procedure and experimental results

Fig. 1 (a) shows the configuration of proposed bandpass filter (BPF) which is divided in two subcircuits named as SUB1 and SUB2. Input and output ports of SUB1 are connected to a square ring resonator at electrical lengths of 0° and 180° respectively. Then a $\lambda/4$ short stub is connected at 90° while the ring resonator is shunted at 270°. On the other hand, input and output ports of SUB2 are connected in the same way as SUB1 while a $\lambda/4$ open stub is connected at 270°. We have connected the stubs inside of the ring resonator to provide compact size. Furthermore, the output port is connected at an electrical length of 180° with respect to the input port to facilitate interconnection of multiple series resonators.

Fig. 1 (b) and Fig. 1 (c) show the simulated response for SUB1 and SUB2

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respectively. For this analysis lossless normalized impedances to 50 Ω TLs are used. A normalized frequency range to double the center frequency is used, such that the fundamental frequency is $f_1 = 0.5$ and the second harmonic is $f_2 = 1$. These figures indicate that both SUB1 and SUB2 provide wideband passband response; however SUB1 exhibits poor selectivity while and SUB2 shows unsuitable out-of-band performance. Moreover, from these figures it can be seen that SUB1 has high attenuation at the frequencies 0 and 1 where SUB2 does not. Furthermore, SUB2 presents two transmission zeroes at normalized frequencies of 0.36 and 0.64 which improves the skirt response. Therefore, the complementary interaction of both subcircuits is expected to offer very high performance.

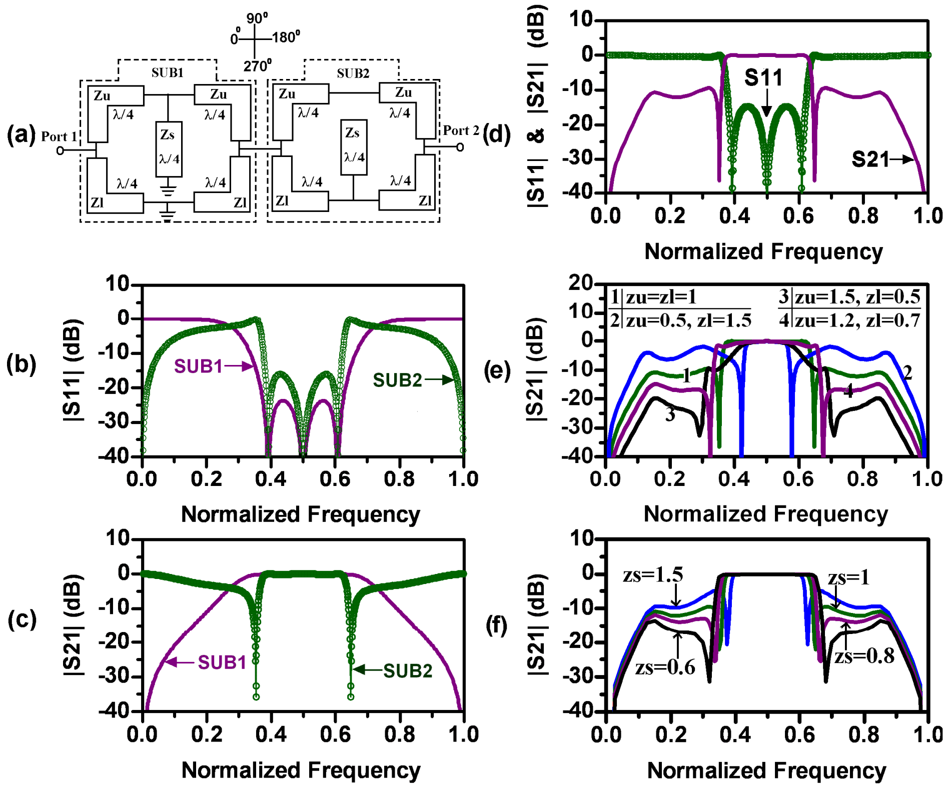

Fig. 1. (a) Proposed filter; (b) Return and (c) insertion losses of each subcircuits; (d) response of proposed filter; (e) filter response when z_u and z_l are varied; (f) filter response when the stub impedance is varied.

The complete filter is obtained by cascading SUB1 and SUB2. Simulations with [6] are shown in Fig. 1 (d). This figure shows that the filter has good selectivity, wideband passband response, low insertion losses, high out of band attenuation and suppression of the second spurious harmonic.

Moreover, we have found that with different normalized impedances $z_u(=Z_u/Z_0)$, $z_l(=Z_l/Z_0)$ and $z_s(=Z_s/Z_0)$ the filter exhibits changes in the bandwidth. Fig. 1 (e) shows the analysis when $z_s = 1$ and z_u and z_l are varied; from this figure it can be seen that narrow bandwidths are obtained

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when $z_u > z_l$ on the other hand when $z_u < z_l$ the bandwidth is increased but the out-of-band rejection worsens.

Fig. 1 (f) shows the case when $z_u = z_l = 1$ and z_s is varied. From this figure it can be seen that the out-of-band performance is improved when the impedance stub is decreased. For the analyzed cases the fractional bandwidth can be tuned from 35% to 70% for an out-of-band performance better than -10 dB.

To prove the proposed procedure we have designed a filter with central frequency of 1 GHz and fractional bandwidth of 50%. The calculated

Fig. 2. Designed and built BPF.

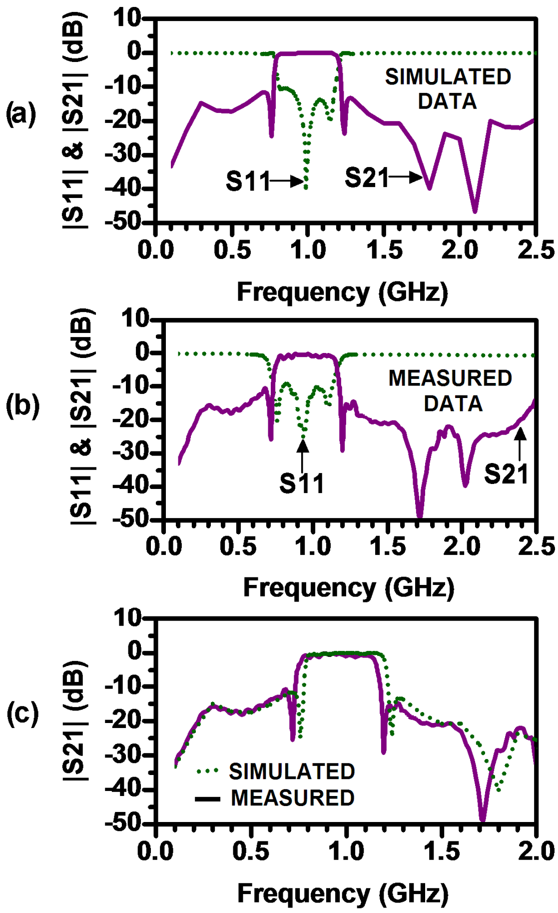

Fig. 3. (a) Simulated and (b) measured response of proposed filter; (c) comparison of simulated and measured data.

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denormalized impedances are $Z_u = 57.5\,\Omega$, $Z_l = 30.7\,\Omega$ and $Z_s = 36.8\,\Omega$. The filter was designed using the RT-Duroid 6010 substrate ($\varepsilon_r = 10.8$ and $h = 1.27$ mm).

Measurements were performed using Agilent PNA Series microwave Vector Network Analyzer (E8361A). Photograph of the proposed filter is shown in Fig. 2. For construction of the filter the shorts are achieved by means of via holes.

Fig. 3 depicts simulated and measured data where good agreement can be seen between them. The experimental center frequency is at 0.95 GHz and the fractional bandwidth is 52%. The out-of-band rejection is lower than −10 dB from 0.1 GHz to 0.701 GHz, and from 1.22–2.5 GHz,. The position of transmission zeros are at 0.7 GHz and 1.225 GHz. In addition, it is clearly seen that the second spurious harmonic expected at around 2 GHz has been fully suppressed.

3 Conclusion

A generalized design procedure for wide bandpass filter with fractional bandwidth from about 35% to about 70%. The filter consists of two square ring resonators with $\lambda/4$ short-circuited and open circuited stubs. This filter is is easy to fabricate as no spur lines or interdigital capacitances are required. It offers wide passband response with improved out-of-band rejection and suppression of the second harmonic resonance. Moreover, very sharp skirt response can be obtained due the addition of two transmission zeroes. Using the proposed design a microstrip BPF was fabricated with central frequency at 1 GHz and 50% BW. Good agreement between measured and simulated results was obtained.

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