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Design of 7th Order Bandpass Filter Based on Series Cascaded Rings and Coupled-Lines

S. K. M. Khanfar*, M. K. M. Salleh, Z. Awang

Microwave Technology Centre(MTC), Faculty of Electrical Engineering, University Teknology Mara(UiTM), 4050 Shah Alam, Malaysia

Abstract

This paper presents a very selective wideband-bandpass filter topology, which is more compact, compared to a conventional coupled line filter and requires much lesser adjustment of parameters. The new topology consists of two identical one-wavelength rings that are combined with four identical quarter-wavelength coupled-lines, resulting in 7th order bandpass response. The use of the rings allows larger bandwidth with lower coupling level of the coupled-lines. The filter is simulated and fabricated using microstrip technology on FR4 epoxy glass substrate and the measurement results are found to be in good agreement with the simulation results.

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Keywords: microwave; ring; wideband; bandpass filter; coupled-line; conventional

1. Introduction

Microwave and wireless systems make extensive use of parallel coupled line bandpass filters due to their ease of design and synthesis, as well as, the low cost by which they can be fabricated [1-6]. In fact, quarter wavelength parallel coupled line filters result in a more compact circuit size, and better performance as compared to half-wavelength parallel coupled lines filters [7]. While ring resonators bandpass filters support dual frequency resonance, ring resonator implementations, on the other hand, have been used to miniaturize the topology of the filter. And

* Corresponding author.
E-mail address: samehkhanfar@gmail.com
cascading two cells of the same topology will lead to a higher order filter with a high order of selectivity and better out of band rejection [8-9].

The topology proposed in this paper consists of two series-cascaded 3rd order filter that has been presented in [10]. The final circuit which contains only two rings and four quarter wavelength coupled lines, manages to produce a 7th order response; while it requires 8 coupled lines in conventional coupled lines to attain the same result. Therefore, the new topology offers more compact size and less control parameters, since the cascaded filter has four identical coupled lines and two identical rings, limiting to only three control parameters to control the filter response; where the characteristics impedances of the rings are represented as $Z_r$, even mode as $Z_{oe}$, and odd mode as $Z_{oo}$. The conventional coupled lines will require eight control parameters.

The initial topology from [10] consists of a one wavelength ring, which is placed in between two identical quarter-wavelength coupled lines. Such configuration will give birth to a 3rd order bandpass response, which is easy to control via the impedances of its lines.

2. 7TH Order Series Cascaded Ring Filter

Cascading two cells of the topology in series will result in 7th order filter, while using the conventional line requires cascading eight coupled line to achieve the same. The overall topologies of the two filters are shown in Fig. 1 (a) and 1 (b). Characteristics impedances of the conventional coupled line and the proposed filters for the same bandwidth response are listed in Table 1, where the conventional coupled line has eight controlling parameters and the proposed design only has three, which facilitate controlling the response of the filter.

![Fig. 1. Topologies of 7th Order Filters (a) Conventional Coupled Lines (b) Series-Cascaded-Ring-Filter](image1.png)

Fig. 1. Topologies of 7th Order Filters (a) Conventional Coupled Lines (b) Series-Cascaded-Ring-Filter

![Fig. 2. Series-Cascaded-Ring-Filter Versus Conventional Coupled Lines](image2.png)

Fig. 2. Series-Cascaded-Ring-Filter Versus Conventional Coupled Lines
Table 1. Control parameter of the conventional coupled line filter and ring-integrated coupled line filter

| Type of Design | Section 1      | Section 2      | Section 3      | Section 4      |
|----------------|----------------|----------------|----------------|----------------|
| Conventional  | $Z_{oe1}=148$, $Z_{oo1}=30$ | $Z_{oe2}=128$, $Z_{oo2}=21$ | $Z_{oe3}=117$, $Z_{oo3}=20$ | $Z_{oe4}=130$, $Z_{oo4}=27$ |
| Proposed      | $Z_{oe}=138$, $Z_{oo}=39$ | $Z_r=55$       |                |                |

The ideal responses of the conventional and proposed design are shown in Fig. 3(a) and 3(b), respectively, while the insertion loss response of the proposed design versus the conventional coupled line is shown in Fig. 4. Practically, the values of the conventional coupled line requires very tight coupling and very minimum line spacing which are very difficult to realize because of the constraints of microstrip fabrication, while the values of the ring-integrated coupled line simply can be realize by general microstrip fabrication. Moreover, a wide bandwidth has been achieved, since the new topology increases the coupling between the microstrips.

Fig. 3. Ideal Response of 7th Order Filters (a) Conventional Coupled Lines (b) Series-Cascaded-Ring-Filter

Fig. 4. Insertion Loss of the New Topology Versus Conventional Coupled Lines

To verify the performance of the proposed filter, an example of the implementation of the 7th order filter is performed using FR4 substrate with dielectric constant of 4.1 and a thickness of 1.6 mm at 2 GHz. The overall layout and dimension of the filter are shown in Fig. 5. The full electromagnetic simulation and measurement results are shown in Fig. 8, while Fig. 7 shows the photograph of the 7th order microstrip filter.
The bandpass response is located at 2 GHz with a relative bandwidth around 66%, while the in-band insertion loss is 2.2 dB and the out-of-band rejection level is found above 50 dB at 2 \( f_0 \).
3. Conclusion

A highly selective wideband filter topology was presented in this paper where four identical quarter-wavelength coupled-lines connected to two identical rings each has circumference equal to one wavelength of operator frequency to exhibit a 7th order bandpass response. In addition, a comparison between conventional coupled line and the proposed topology was investigated to prove the flexibility and improvement of the new filter design.

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References

[1] Kuo, J., Chen, S., Jiang, M., Parallel-Coupled Microstrip Filters With Over-Coupled End Stages for Suppression of Spurious Responses, IEEE Microwave Wireless Component Letter, 2003. 13(10):440-442.
[2] Chang, C., Itoh, T., A Modified Parallel-Coupled Filter Structure That Improves the Upper Stopband Rejection and Response Symmetry, IEEE Transaction on Microwave Theory and Techniques, 2002. 59(2):310 – 314.
[3] COHN, S., Parallel Coupled Transmission Line Resonator Filters, IRE Transaction on Microwave Theory and Techniques, 1958. Vol. 6: 223-221.
[4] Avantek, A., High Performance Parallel Coupled Microstrip Filters, 481 Cottonwood Drive Milpitas, CA 95035. 1988.
[5] Cheong, P., Fok, S., Tam, K., Miniaturized Parallel Coupled-Line Bandpass Filter with Spurious Response Suppression. Microwave Theory and Techniques, IEEE Transaction on Microwave Theory and Techniques, 2008. 53(5): 487-490.
[6] Kuo, J., Shih, E., Microwave Stepped Impedance Resonator Bandpass Filter with an Extended Optimal Rejection Bandwidth, IEEE Transactions on Microwave Theory and Techniques, 2003. 51(5).
[7] Deng, P., Lin, Y., Wang, C., Chen, C., Compact Microstrip Bandpass Filters With Good Selectivity and Stopband Rejection, IEEE Transaction on Microwave Theory and Techniques, 2006. 54(2):533 – 539.
[8] Salleh, M., Yassin, I., Baharom, R., Hamzah, M., Prigent, G., Series-Cascaded Ring Resonators for Compact Microwave Filter with High Rejection, IEEE Symposium on Industrial Electronics and Applications, 2010.p. 518 – 521.
[9] Salleh, M., Ali, M., Hamzah, M., Prigent, G., Series Coupled Microwave Ring Resonators, IEEE International Conference on System Engineering and Technology (ICSET), 2011.p.125-127.
[10] Khanfar, S., Salleh, M., Wahab, N., Awang, Z., Combination of One-Wavelength Ring and Coupled-Lines for Compact and Selective Bandpass Filter, IEEE Symposium on Wireless Technology and Applications, 2012. p. 92 – 94.