Indonesian Journal of Electrical Engineering and Computer Science
Vol. 17, No. 3, March 2020, pp. 1422~1426
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v17.i3.pp1422-1426

Closed-loop ring resonator topology for bandpass filter applications

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Article Info

Article history:

Received Jun 16, 2019
Revised Sep 15, 2019
Accepted Sep 29, 2019

Keywords:

Bandpass filter
Closed-loop resonator
High selectivity
Microstrip
Transmission zero

ABSTRACT

This paper presents a single mode pseudo-elliptic bandpass resonator based on closed-loop ring topology. The resonator is built from six quarter wavelength transmission lines to form a square closed-loop ring structure. This structure creates transmission zeros at the lower and upper sidebands so that high selectivity bandpass filter response is achieved. The advantage of this topology is that the design is less complex since no perturbation is needed on the ring lines for creation of transmission zeros. Higher-order filters can be constructed by introducing quarter-wavelength coupled-lines, coupled at both input and output of the closed-loop ring resonator. For proof of concept, the filters are designed at 10 GHz up to 3rd order, simulated using full-wave electromagnetic simulator on microstrip substrate, FR-4 with characteristics given as $\varepsilon r = 4.70$, $h = 1.499$ mm and $\tan \delta = 0.012$. The filters are simulated and responses are found to be agreeable with the proposed idea.

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1. INTRODUCTION

Bandpass filters are indispensable components in RF/microwave wireless communication systems [1-5]. Filter is a device that commonly used in telecommunication system. Besides, it also used in radar system. The main function of the filter is to pass the desired frequency band and block those unwanted signal frequencies. In recent years, demand for a low, cost, low loss, and compact size filters arises rapidly. Thus, microstrip band pass filters are becoming more popular because of their low cost and easy to fabricate [6-9].

Until to-date, numerous designs of microstrip filters had been proposed. These filter designs were developed using various method and technologies depending on applications [10-14]. Besides, the response and performance of filters can also be improved by modification of structures or by selection of high performance substrate [15-18].

It is well-known a ring topology may produce high performance bandpass filter with high selectivity [19-23]. Hence, in this work, a single square ring resonator is introduced as a base cell which employs quarter-wavelength coupled-lines, coupled at the input and output of the ring lines. By doing so, higher order filters are created. The response showed the existence of transmission zeros at lower and upper side bands for high selectivity [24-26]. The advantage of this topology is that, transmission zeros are maintain, while increment of numbers of orders are increased by introducing more coupled lines This characteristic is important for high performance of bandpass filter especially when this filter is working at higher frequency above 10 GHz. In terms of its application, these filters are suitable for systems using X-Band frequency range.

2. RESEARCH METHOD

Figure 1 below shows a common structure of filter line on microstrip substrate. There is a conducting line with certain width and thickness that are printed on the top of substrate. The bottom of the substrate is a ground plane. The line and the ground plane are usually made of conducting material, like copper [8]. The line is used to deliver an electromagnetic wave from input port to output port. Bend in filter design is a part of microstrip discontinuities. There are four types of bending which are 45° mitered, the 90° bend, the inner cut-off and the outer cut-off [25]. It is usually used to get a better value of the return loss and the insertion loss [8].

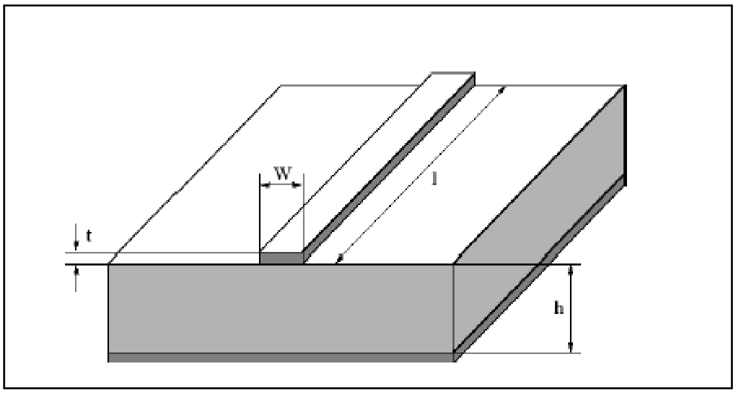

Figure 1. Microstrip filter specifications

Based on these findings, the proposed designs are carried out. The performance of the resonators is measured using Scattering Parameters which are insertion loss, return loss, fractional bandwidth and transmission zero. The proposed designs are simulated using electromagnetic simulator software at 10 GHz using microstrip technology on FR-4 substrate with the properties tabulated in Table 1. Figure 2 illustrates the basic resonator proposed in this work.

Table 1. Substrate Properties of FR-4

Parameters	Values
Dielectric constant	4.7
Magnetic constant	1.0
Loss Tangent	0.012
Resistivity	1.0
Metal Thickness	0.036 mm
Metal Roughness	$1.397e^{-3}$ mm
Height of the substrate	1.499 mm

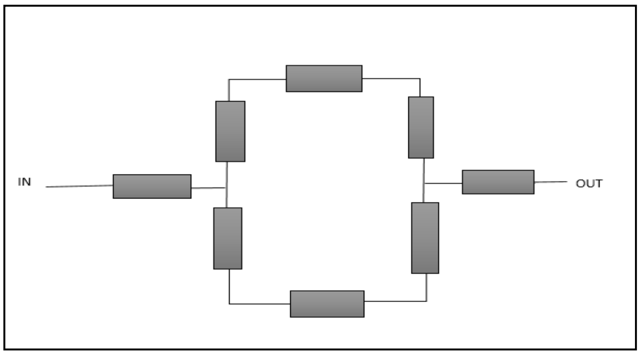

Figure 2. Closed loop resonator topology

This resonator is built for bandpass filter application. The topology is based on the closed loop structure to create a square ring. As can be seen, the closed loop or ring topology is built on six quarter-wavelength transmission lines resulting to one-and-a-half wavelength resonator. The advantage of this configuration is that it's compactness in design. The filter is designed at 10GHz. When simulated, it shows pseudo-elliptic responses of single resonance bandpass with two transmission zeros at the stopbands. As shown in Figure 3, the value of return loss and insertion loss are 6.739 dB and 2.924 dB respectively. These results to poor performance because it does not achieve good filter design specification as required for bandpass filter application. Thus, some modification is introduced to improve the response. This is achieved by introducing two additional quarter wavelength coupled lines for creation of additional resonance and two quarter wavelength transmission lines at the input and output of the ring lines as shown Figure 4. By adding two additional quarter wavelength, the design is now having additional of half wavelength resonator resulting to an additional of resonance. Also, the presence of transmission lines at the input and output has improved the impedance matching of the resonator.

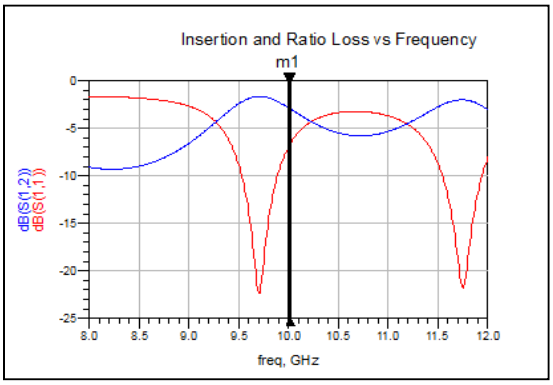

Figure 3. Response of bandpass filter for closed-loop resonator

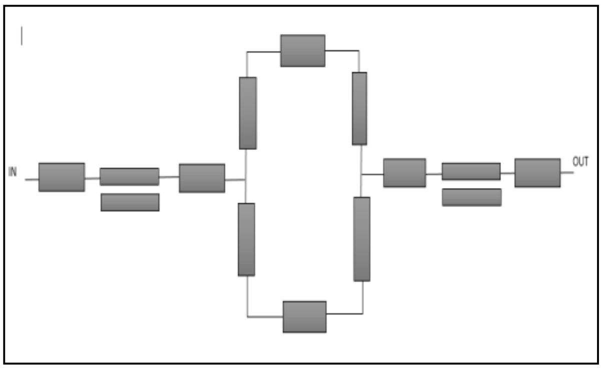

Figure 4. Two coupled-lines with closed-loop resonator

To further explore the possibilities of creating higher order filter, the basic cell is now added with one more quarter wave length coupled line at the output of the ring lines as shown in Figure 5. With the presence of additional coupled-line has created half wavelength resonator. These two newly proposed designs are designed at 10 GHz and simulated to observe the responses.

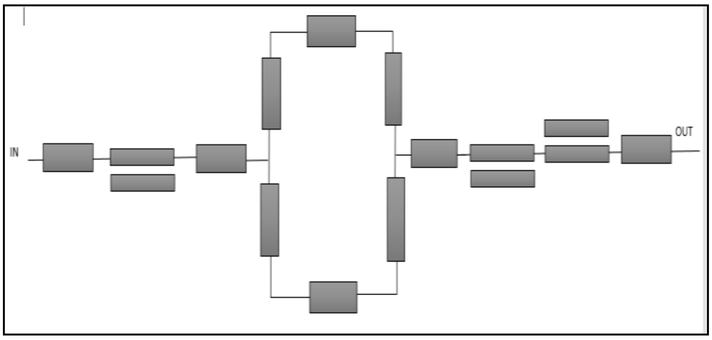

Figure 5. Three coupled-lines with closed loop resonator

3. RESULTS AND ANALYSIS

In this section, the simulated results of the two newly proposed resonators are presented. In Figure 6, two resonances are found at frequency 9.680 GHz and 10.95 GHz. The return loss is attenuated at 21.593 dB while insertion loss is found at 3.719 dB. There are two transmissions zeros, found at the lower and upped side band of the response to give high selectivity bandpass filter response.

In Figure 7, the response of the filter shows three resonances with four transmission zeros. At 10 GHz, the return loss, S11 attenuated at 18.095 dB while insertion loss, S12 is 2.706 dB. The four transmissions zeros are found at 8.12 GHz, 9.360 GHz, 11.46 GHz and 11.88 GHz. From both simulations it can be seen that by adding coupled lines create more resonance and at the same time the additional of transmissions lines improve the impedance matching. The formation of transmission zeros at the lower and upper stopbands improve the selectivity of the bandpass responses.

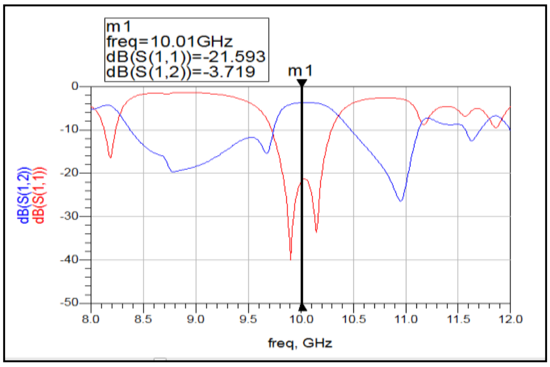

Figure 6. Response of the S-parameters for two coupled-lines with closed loop resonator

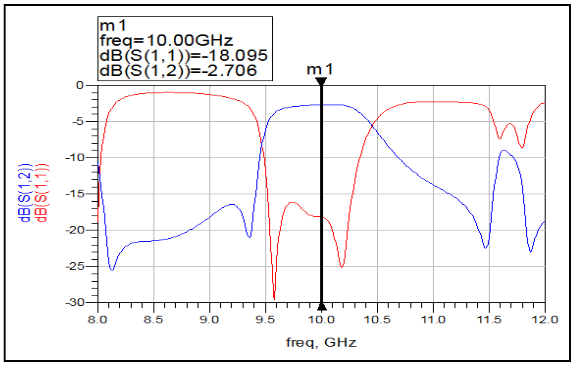

Figure 7. Response of the S-parameters for three coupled-lines with closed loop resonator

4. CONCLUSION

A single closed loop resonator topology was presented. Based on this concept, quarter wavelength coupled lines is introduced to create higher order filter. Quarter wavelength transmission lines are introduced in the ring structure to create for impedance matching and improve in band response. The designs were designed at 10 GHz, simulated using full wave electromagnetic simulator and the results were observed. The results showed good performance of resonators for in terms of insertion losses and return losses. Finally, these resonators can be further explored for higher frequency spectrum. To conclude the work, these proposed resonators are suitable for bandpass filter applications that require high selectivity

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Education Malaysia, under Niche Research Grant Scheme (NRGS) [600-RMI/NRGS 5/3 (3/2013)] and the Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia

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Norfishah Ab Wahab was born in Malaysia, in 1963. She received the degree in Electronics Engineering from Universiti Teknologi MARA (UiTM), Malaysia, MSc in Telecommunication and Information Engineering and PhD in microwaves, electromagnetism in the same university. Currently, she is a senior lecturer in Faculty of Electrical Engineering, UiTM Shah Alam, Malaysia. She has been working in UiTM since April 2008. From 1992 to 2004, she was employed by Telekom Malaysia. She worked in various divisions such as microwave, fiber cable and network system departments. Her major research areas are in microwave and electromagnetic modeling, low-powered electronic design, energy harvesting and efficiency.

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