Techno-Science 6:2 (2023) 24-30

Techno-Science
Scientific Journal of Mehmet Akif Ersoy University
https://dergipark.org.tr/pub/sjmakeu

Original Research Article

hosted by Turkish JournalPark ACADEMIC

DESING AND IMPLEMENTATION OF A 2.45 GHZ BAND-STOP FILTER USING SINGLE/THREE OPEN STUBS

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ARTICLE INFO

Article History

Received	:	08/09/2023
Revised	:	09/12/2023
Accepted	:	26/12/2023
Available online	:	31/12/2023

Keywords

2.45 Ghz, Advanced design system (ADS), Microstrip filter, Microwave systems

ABSTRACT

The importance of filter structures in RF/microwave applications is quite high. These filters are frequently used in microwave systems, especially in satellite and mobile communication systems. Generally, in devices such as oscillators and mixers; to block unwanted signals, band-stop filters are added to the structures. One of the WLAN applications, IEEE 802.11b has a maximum raw speed of 11Mbit/s and is used to connect the same devices in the original standard. Devices operating in the IEEE 802.11b standard experience interference from other devices (microwave ovens, bluetooth devices, cordless phones) operating at 2.45 GHz. As the main goal of this study; in order to prevent this interference, band-stop filter circuit design with single/three open stubs were carried out at the frequency of 2.45 GHz. Thanks to the realized band-stop filter designs; unwanted signals are filtered and the desired signals are transmitted successfully.

1. INTRODUCTION

Filter circuits are used in a wide variety of applications. They provide the desired attenuation or transmission characteristics in the specified frequency regions. The electromagnetic spectrum is limited and needs to be shared. Filter structures are used to limit RF and microwave signals within specified spectral limits [1-5].Filters have been widely used in several and various wireless systems and circuits due to their ease fabrication, integration and compatibility with others planar devices [6,7].They are used in almost all communication systems such as separation of correct components, noise reduction, signal shaping, while allowing the passage of a certain frequency band, they provide attenuation of frequencies outside the band and are designed for this purpose [8,9].

There are many electronic signals found in the air such as GSM, Radio, Wi-Fi and TV. This diversity of causes signal confusion. An electronic device detects all of these signals. But it only works with one. Other signals may adversely affect or disrupt the system. This is where filters come into play, playing a very important role in electronics. Filters vary for the variety of signals and for separating signals in communication systems. While they are divided into active and passive filters according to their construction elements, they are divided into low-pass filter, high-pass filter, band-pass filter and band-stop filter according to the working principle [10].

Microwave filters are essential elements in communication systems such as channel selection and signal separation. The primary purpose of filters is to distinguish between different frequency bands. Therefore, frequency selectivity is the most common method of classifying filters. These filters include GSM (900 MHz, 1800 MHz), WLAN (2.45 GHz), WIMAX (3.5 GHz), etc. It is used extensively with the developments in wireless and mobile communication systems. Various types of microwave filters such as microstrip structures, wave guides, dielectric resonators are needed due to different requirements such as interference loss, quality factor, selectivity. Among these filter types, microstrip filters are more advantageous than others in terms of cheapness and miniaturization. In terms of miniaturization and being a multi-functional circuit element, multi-band filters are of great importance because they can operate on different frequencies simultaneously [11,12].

Ming-Yu Hsieh and Shih-Ming Wang (2005) produced a new single-section band stop filter that offers compact size, wide bandwidth and low insertion loss. This band stop filter is constructed using a single quarter wavelength resonator with a section anti-couple line with a short circuit at one end. The attenuation pole properties of this type of band stop filters are

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To cite this article: OZTURK B., COSKUN O., (2023). Design and Implementation of a 2.45 GHz Band-Stop Filter Using Single/Three Open Stubs. *Scientific Journal of Mehmet Akif Ersoy University*, vol. 6, no. 2-p.24-30

investigated using the transverse electromagnetic wave transmission line model. They established a good agreement between the simulation results and the experimental results [13].

Wenquan Che et al., (2010) designed a band stop filter with the help of stepped impedance resonators (SIR- Stepped Impedance Resonators) in their studies. While using this structure, they created a split ground structure just behind the main transmission line. With this design, they have obtained a double band structure. They obtained a structure with center frequencies of 2.4 GHz, 5.2 GHz, and partial bandwidths of 43.8% and 18.7%, respectively [14].

In this study, band-stop filter design was made with single/three open-circuit stubs. Center frequency, bandwidth and S21 parameters obtained from the simulation and measurement results were evaluated.

2. MATERIAL AND METHODS

Fig. 1.a. shows a transmission line of a band stop filter with open-circuit stubs. Here, the open-circuit stubs are quarter wavelength and separated by unit elements that are quarter length at the center frequency.

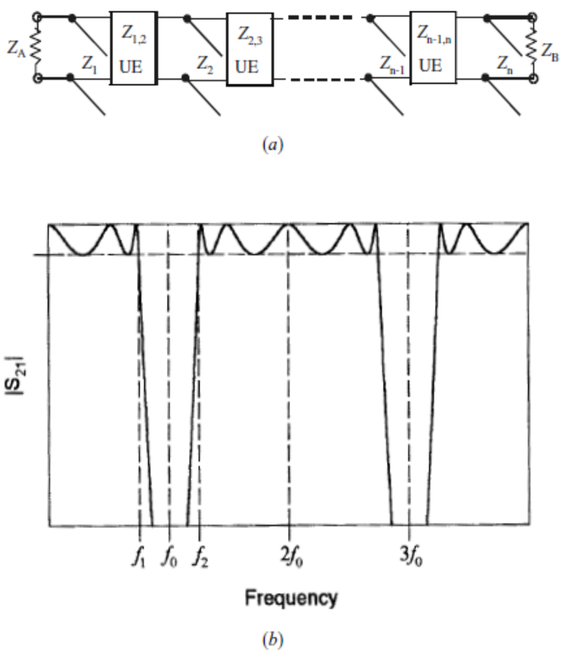

Fig. 1. a) Band stop filter transmission line with open-circuit stubs characteristic **b)** Frequency response on the filter

The filtering properties of the filter depend entirely on the design of the two termination impedance ZA and ZB, as well as the characteristic impedance of the open-circuit stubs Zi and Zi, i+1. Theoretically, this type of filter can be designed to have any stop band width. In practice, however, the impedance of open-circuit stubs becomes reasonably high if the bandwidth is very narrow. Therefore, such band stop filters are more suitable for broadband use.

Such band stop filters can be designed using a design procedure. These design procedures begin with cascading low-pass filter characteristics such as Chebyshey. Then a frequency planning is done.

$$\Omega = \Omega_c \alpha \tan\left(\frac{\pi}{2}\frac{f}{f_0}\right) \quad (1)$$

$$\alpha = \cot\left[\frac{\pi}{2}\left(1 - \frac{KBG}{2}\right)\right] \quad (2)$$

Here Ω and Ωc are the normalized frequency variable. According to the low-pass filter prototype, the cutoff frequency is f and the desired center frequency of the band-stop filter is f_0, where KBG is the partial bandwidth value.

$$KBG = \frac{f_2 - f_1}{f_0} \quad (3)$$

$$f_0 = \frac{f_1 + f_2}{2} \quad (4)$$

As seen in the filter frequency response curve in Fig. 1.b., f_1 and f_2 frequencies are band-stopping filter response frequency points. Band stop filters of this type appear to have periodically centered harmonic stop bands at frequencies that are odd multiples of f_0. These frequencies appear in single multiples of length $\lambda g_0/4$ from open-circuit stubs as shown in Fig. 1.a.

Similar ways are used to design filters in a sequential structure. Below are the design equations for n=1,2,3,4 up to the band stop filter. Here n is the number of stubs on the main transmission line. $\Omega c=1$ and $Z_A=Z_0 g_0$ and α used in the equations are the defined bandwidth parameter shown in Equation (2).

For n=1 ;

$$Z_1 = \frac{Z_A}{\alpha g_0 g_1} \quad (5)$$

$$Z_B = \frac{Z_A g_2}{g_0} \quad (6)$$

For n=3 ;

$$Z_1 = Z_A\left(1 + \frac{1}{\alpha g_0 g_1}\right) \quad (7)$$

$$Z_2 = \frac{Z_A g_0}{\alpha g_2} \quad (8)$$

$$Z_3 = \frac{Z_A g_0}{g_4}\left(1 + \frac{1}{\alpha g_3 g_4}\right) \quad (9)$$

$$Z_{1,2} = Z_A(1 + \alpha g_0 g_1) \quad (10)$$

$$Z_{2,3} = \frac{Z_A g_0}{g_4}(1 + \alpha g_3 g_4) \quad (11)$$

$$Z_B = \frac{Z_A g_0}{g_4} \quad (12)$$

3. NUMERICAL RESULTS

The min. return loss in the pass band is shown as LR or the VDDO in the pass band, and the ripple in the pass band is shown as LAR. If defined by the return loss and the min. pass band return loss is LR dB (LR<0), the corresponding pass band ripple is;

$$L_{Ar} = -10\log(1 - 10^{0.1L_R})\ dB \quad (13)$$

In the designed circuits, the pass band ripple was chosen as LAr = 0.1 dB and accordingly the values for Chebyshev low-pass filters are given in Table 1. While calculating the impedance values in the designs, they were calculated according to the values in this table.

Table 1. Values for chebyshev low pass filters (g_0=1.0, Ω_c=1)

n	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}
1	0.3052	1.0								
2	0.8431	0.6220	1.3554							
3	1.0316	1.1474	1.0316	1.0						
4	1.1088	1.3062	1.7704	0.8181	1.3554					
5	1.1468	1.3712	1.9750	1.3712	1.1468	1.0				
6	1.1681	1.4040	2.0562	1.5171	1.9029	0.8618	1.3554			
7	1.1812	1.4228	2.0967	1.5734	2.0967	1.4228	1.1812	1.0		
8	1.1898	1.4346	2.1199	1.6010	2.1700	1.5641	1.9445	0.8778	1.3554	
9	1.1957	1.4426	2.1346	1.6167	2.2054	1.6167	2.1346	1.4426	1.1957	1.0

FR4 material was chosen as the substrate in the designed circuits. The purpose of choosing the FR4 material is that it is easily accessible and the cost is low. The relative permeability coefficient of this material at 1 MHz is 4.5, the loss tangent is 0.022, and the material height is 1.6 mm. In all of these designs, the center frequency was chosen as 2.45 GHz. Transmission lines are λ/4 long. Scattering parameters, center frequencies, and bandwidths were calculated using a computer aided design tool capable of performing microwave circuit analysis.

3.1. Band-Stop Filter Design with Single Open-Circuit Stub

The impedance values of the transmission lines of the circuit designed with a single stub are calculated according to Equation (5) and Equation (6) using the values in Table 1 and are given below. According to these impedance values, the (W) width and (L) length values of the transmission lines were calculated. The schematic of the circuit is shown in Fig. 2, and the scattering parameter values are shown in Fig. 3.

ZA=50 Ω, Z1=163.82 Ω, ZB=50 Ω

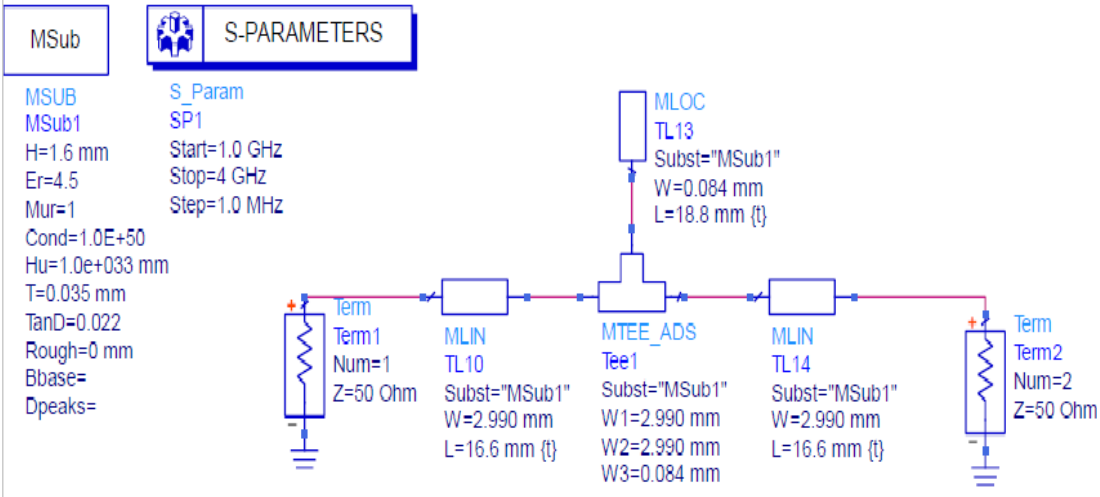

Fig. 2. Band-stop filter design with single open-circuit stub schematic

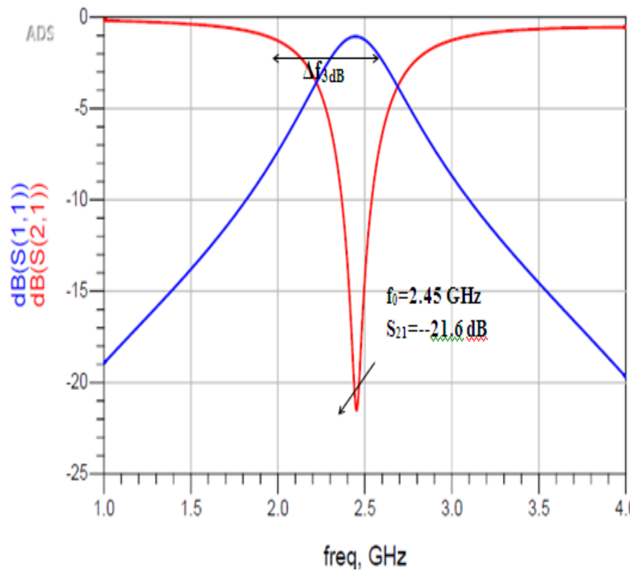

Fig. 3. Tape-stop with single open-circuit stubs filter S-parameter values simulation result

3.2. Band-stop Filter Design with Three Open-Circuit Stubs

The impedance values of the lines of the circuit designed with three stubs were calculated using the values in Table 1. according to Equation (7) - (12) and are given below. Width and length values of transmission lines were calculated according to these impedance values. The schematic of the circuit is shown in Fig. 4 and the scattering parameter value is shown in Fig. 5.

ZA=50 Ω, Z1=98.5 Ω, Z2=43.6 Ω, Z3=98.5 Ω, Z1,2=101.6 Ω, Z1,2=101.6 Ω, ZB=50 Ω

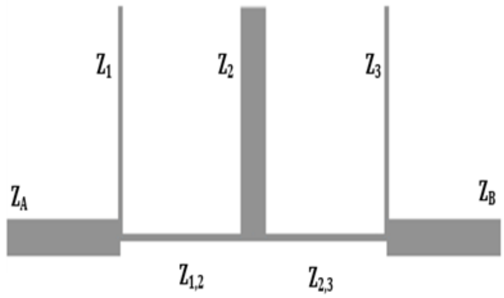

Fig. 4. Band-stop filter design with three open-circuit stubs

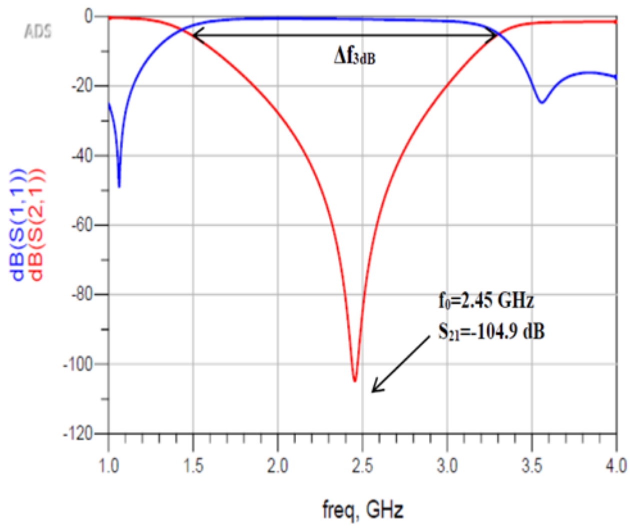

Fig. 5. Tape-stop with three open-circuit stubs filter S-parameter values simulation result

4. DISCUSSION

R. Habibi et al., (2012) designed a broadband band stop filter for use in the X band in their study. They created their designs by making five pairs of L-shaped stubs on the microstrip line. The operating frequency of the created filter was controlled by changing the dimensions of the L-shaped stubs. Simulation results and experimental results showed excellent agreement [15].

Gang Liu et al., (2017) designed a narrowband stop filter based on L-shaped microstrip resonators connected to the transmission line. Three loosely coupled microstrip resonators are connected in a cascade to form a band-stop filter circuit. They used an open radial patch to effectively reduce the size of the circuit. The designed circuit was produced on Rogers RO4350B substrate material. As a result, a narrowband absorber band-stop filter with a three-stage resonator is designed for the 2.23 GHz center frequency. At the center frequency and the 20 MHz band, the return loss was measured to be better than 30 dB [16].

Devika Mohan et al., (2018) designed a microstrip bandstop filter with open loop resonators in their work. While creating their designs, they used 50 Ω input impedance and connected it to the main circuit with an impedance converter. By using a substrate material with a dielectric constant of 4.4, a stop band was obtained at a center frequency of 3.3 GHz [17].

Yusuke Kusama and Ryota Isozaki (2019) designed a compact and broadband bandstop filter in their work. While designing the filter, they added quarter wavelength open circuit stubs on the main transmission line. The proposed structure was to obtain the T bias with an open-circuit stub in order to prevent the reverse flow of the radio frequency signal to the DC source. They used FR4 material in their designs and analyzed them using the HFSS program. As a result, bandstop filter design operating in wide band at 2.5 GHz center frequency has been designed [18].

With the rapid development of wireless systems, demands for RF devices with advantages such as low cost, low energy consumption, high performance and easy integration have increased. Bandstop filters, one of the critical components in many wireless systems, are critical in suppressing spurious rejection and parasitic passband [19,20].

In this study, the band-stop filter structure designed with single/three open-circuit stubs has been investigated. First of all, the design was made using the Chebyshev low-pass filter characteristics on the computer environment. Then, the designed circuit was implemented and the measurement was made in the laboratory environment. Parameters such as center frequency, bandwidth, S21 value and size of the circuit are clearly negotiated. The values of the designs with these two different open circuit stubs are given in Table 2.

Tab. 2 Results of band-stop filter designs with single/three open circuit stubs

CIRCUITS	**Single open circuit stub**	**Three open circuit stubs**
f_0 (GHz)	2.45	2.45
S_{21} (dB)	-21.6	-104.9
% BG	22.45	81.6
Length (mm)	34.9	76.2

It has been observed that as the number of stubs increases in the designs, the designed circuits move towards duality as the bandwidth (BG) increases. Bandwidth increased between 22.45 % and 81.6 % between the single open circuit stub and the three open circuit stub design.

5. CONCLUSIONS

According to these results, it was seen that the deviation between the center frequencies was 1% as a result of the measurements made on the computer environment and in the real environment. This frequency deviation; while the relative permittivity coefficient of the dielectric material used is dependent on the frequency; considering the connector, cable and solder losses. It is an acceptable value. Considering the losses that may occur while making real measurements, unlike the simulation environment the study resulted in success. While bandwidth is generally preferred according to the place of use, the importance of compact structures in microwave circuits should not be overlooked. It can be designed according to the desired size, center frequency and bandwidth according to the place to be used.

While bandwidth is generally preferred depending on the place of use, on the other hand, as the number of stubs increases, the size of the circuit also expands. Since compact structures are generally preferred in microwave circuits, design parameters can be determined according to the desired structure. Although the selection is made according to the desired size and bandwidth, it is observed that the design moves towards duality as the number of stubs increases.

REFERENCES

[1] Borja, A. L., González, A. B., Boria, V. E. (2020) Design procedure of continuous profile stopband filters implemented with empty substrate integrated coaxial lines. IEEE Transactions Microwave Theory Techiques 68(4): 1520- 1528.

[2] Nasiri, B., Errkik, A., Zbitou, J., Tajmouati, A., E Abdellaoui, L., Latrach, M. (2017) A new compact microstrip band-stop filter by using square split ring resonator. International Journal of Microwave and Optical Technology 12(5): 360-366.

[3] Yechou, L., Tribak, A., Mohamed, K., Zbitou, J., Bouyahyaoui, A., Sanchez, A. M. (2017) Planar wideband bandstop filter with T-inverted shaped open stubs for wideband applications. International Journal of Microwave and Wireless Technologies 9(2): 773-780.

[4] Kong, M., Wu, Y., Zhuang, Z., Liu, Y. (2018) Wideband bandstop filter with extreme sharp skirt selectivity. IEEE Microwave Wireless Components Letters 28(12):1104-1106.

[5] Gupta, A., Chauhan, M., Rajput, A., Mukherjee, B. (2020) Wideband bandstop filter using L-shaped and quad mode resonator for C and X band application. Electromagnetics 11: 1- 9.

[6] Gupta, A., Rajput, A., Chauhan, M., Mukherjee, B. (2021) Wideband band-stop filter for C-band and S-band applications using finite integration in time-domain technique. Advances in Computational Intelligence and Communication Technology Springer 359- 366.

[7] Feng, W., Hong, M., Che, W., & Xue, Q. (2017) Dual-band microstrip bandstop filter with multiple transmission poles using coupled lines. IEEE Microwave and Wireless Components Letters 27(3), 236–238.

[8] Bowick, C. (1982) RF circuit design. Butterworth-Heinemann, USA.

[9] Carr, C.C. [2001] Secrets of RF circuit design. McGraw-Hill, USA.

[10] Kınayman, N., Aksun, M.I. (2005) Modern microwave circuits. Norwood, MA, USA, Artech House.

[11] Pozar, M. (1998) Microwave engineering. Newtork, John Wiley and Sons.
[12] Hunter, I. C., Billonet. L., Jarry, B., Guillon, P. (2002) Microwave filters applications and technology. IEEE Trans. on Microwave Theory and Tech. Vol.50 No:3 pp.794-805.
[13] Hsieh, M. Y., Wang, S. M. (2005) Compact and wideband microstrip band stop filter. IEEE Microwave and Wireless Components Letters, 15(7), 472-474.
[14] Che, W., Feng, W., Deng, K. (2010) Microstrip dual-band band stop filter of defected ground structure and stepped impedance resonators. International Journal of Electronics 97(11), 1351–1359.
[15] Habibi, R., Ghobadi, C. H., Nourinia, J., Ojaroudi, M., Ojaroudi, N. (2012) Very compact broad band stop filter using periodic L-shaped stubs based on self-complementary structure for X-band application Electronics Letters, 48 (23), 1481-1482.
[16] Mohan, D., Jwala, A., Sreekumar, M., Krishnan, T. B., Menon, S. K. (2018) Realization of band stop filter using perturbed microstrip line. Second International Conference on Inventive Communication and Computational Technologies (ICICCT), 20-21 April, Coimbatore.
[17] Liu, G., Xu, J., Liu, Z. (2017) A narrowband absorptive band-stop filter based on a resistor-loaded compact resonator. Progress in Electromagnetics Research Symposium - Spring (PIERS), 22-25 May, St. Petersburg, Russia.
[18] Kusama, Y., Isozaki, R. (2019) Compact and broadband microstrip band-stop filters with single rectangular stubs Applied Sciences MDPI Journals, 9(2), 248.
[19] Xin, Li et al. (2023) Band-stop filter based on glide-symmetric substrate-ıntegrated coaxial lines for band-gap control and bandwidth customization. Phys. Rev. Applied 19, 024018.
[20] Xie, Y., Chen, F.C. (2021) Dual-band and wide stopband coaxial filters using open-circuited-stub-loaded resonators. IEEE Trans. Circuits Syst. II Express Briefs 68, 1872.

Techno-Science *Paper ID: 1357307*