Band width improvisation in Bandstop Double Spurline filter and open stub spurline filter

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Abstract—This paper presents a new type of compact bandstop filter. The proposed filter topology consists of double spurlines and double open stubs. Double spurlines are introduced to a conventional open stub filter for filter circuit size miniaturization and bandstop region improvement. It is clearly shown that the rejection region of the proposed filter is wider and deeper compared to the conventional open stub filter without any cascading circuits or periodic structures. The proposed filter is designed with Computed Simulation Technique (CST). To validate the proposed topology, a compact filter prototype with bandstop centered at 3 GHz is fabricated and transmission coefficient measurements are conducted. Measurements show that there is a rejection region from 1.68 to 5.17 GHz with S21 less than -3 dB. The total length of the prototype equals to 49.2 mm.

Index Terms—Spurline filter, Double spurline filter, Open stub Spurline filter

I. INTRODUCTION

Bandstop filters (BSFs) are important components in microwave and millimetre-wave applications to reject higher harmonics and spurious pass bands. The conventional method to design BSFs involves the use of shunt stubs or lumped elements[1]. High Performance, Compact size and low cost often meet the stringent requirements of modern microwave communication systems. The conventional RLC band stop filters suffer from a number of technical limitations, most of which are associated with the use of discrete inductors. These limitations include their large size, difficulty of integration onto a single integrated circuit, large power consumption and susceptibility to parasitic effects in the gigahertz range. These problems affect the electrical length of the resonator and the position of resonator associated with open-circuited stubs of the bandstop filter structure. Therefore, microwave planer filters are important in modern communication systems[3]. Conventional methods to implement bandstop filters involve use of shunt stubs or stepped-impedance microstrip lines with large circuit size.

Among microstrip filter designs, spurline is a simple defected microstrip structure and is the smallest structure compared to other filter designs [9]. It is realized by etching an L-shaped slot on a microstrip line. It can provide moderate rejection bandwidth with its compact size. Its structure is presented in Fig. 1 [10].

![Figure 1: Microstrip spurline filter](image)

A first Strip line Band stop Filter was first reported by Shiffman and Matthaei[6]. However, in microstrip, this filter, hereafter described as a ‘spurline’ filter, has several advantages over other types of microstrip filter. It radiates significantly less than conventional shunt stub and coupled-line filters, and it forms a very compact structure. It is also virtually non dispersive; i.e. the response repeats at almost exact odd multiples of the resonant frequency fo.

Where λg is the wavelength corresponding to the central rejection frequency of the bandstop filter, measured of course in the microstrip line material. This is the most important parameter of the filter that sets the rejection band. The distance between the two coupled lines can be selected appropriately to fine-tune the filter. The smaller the distance, the narrower is the stop-band in terms of rejection.
In this single spurline filter, Simulation results are presented in Figure 3. Here, the center frequency is at 3.6 GHz. For S band frequency is considered 2 to 4 GHz. For this band width is wider and measured by 2.8 to 4.2 GHz.

In this paper, a simple wider rejection bandwidth and deeper rejection microstrip bandstop filter with compact circuit size is proposed. With the use of two spurlines of proper length inserted between double open stubs, it is clearly found that the wider rejection bandwidth and deeper rejection of the proposed filter can be effectively achieved. Details of the proposed design are described. The simulations and experiments are conducted. Then, the simulated and experimental results are presented and discussed[5].

II. NUMERICAL ELECTROMAGNETIC METHOD FOR ANALYSIS

In the numerical electromagnetic method for analysis, the Computer simulation Technique (CST) is conducted to simulate the designs. CST is a software to analyze our designs associated with Maxwell’s equations. To conduct the CST simulations, transmitted electric fields are sampled for the same polarization as the incident fields. The samples that are in time domain then are used to determine the transmission coefficients ($S_{21}$) with Fourier transformation as in the following equation.

$$S_{21} = \frac{FT(E_t)}{FT(E_i)}$$  \hspace{1cm} (1)

where FT stands for the Fourier transformation, $E_i=\text{incident electric fields in time domain}$, and $E_t=\text{transmitted electric fields in time domain}$. The transmission coefficient is a parameter that describes the transmission power response for each frequency obtained from the filters. Consequently, it is very important to extract the parameter for filter performance assessments.

A schematic view of a conventional spurline is presented in Figure 1. The configuration of the spurline is described by slot length (a), and slot width (g). Normally, the slot gap exhibits a capacitive effect while the narrow microstrip line provides an inductive effect [8]. The desired rejected wavelength can be calculated using the follow equation.

$$a = \frac{\lambda g}{4}$$  \hspace{1cm} (2)

where $a$ = the length of the spurline, and $\lambda g$ = the desired rejected wavelength in the substrate.

Equation (2) can be derived into the frequency domain as follows:

$$f_{stop} = \frac{c}{4a\sqrt{\varepsilon_{eff}}}$$  \hspace{1cm} (3)

Where $a$ = the length of the spurline, $\varepsilon_{eff}$ = Effective permittivity of the substrate, $c = 3 \times 10^8$ m/s, and $f_{stop}$ = the desired rejected frequency.

To obtain the wider rejection bandwidth without increasing the overall circuit size, the effects of double spurlines on transmission coefficients are investigated to compare with those of the single spurline[6].

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For both types of spurlines, the Arlon 250 substrate is simulated with the substrate permittivity $\varepsilon_r = 2.60$. The ground plane is at the bottom layer. The length of the microstrip line is 30 mm. The width of the microstrip line is 2.1 mm. The substrate thickness is 0.76 mm. The dimensions of the spurlines are $a = 15$ mm, and $g = 0.4$ mm. The simulated results shown in Fig. 4 demonstrate that the rejected frequency for both types of spurlines is about 3.6 GHz. The rejected frequency obtained from simulated results is verified by a good agreement with the calculation from equation (3). The stopband region at -3 dB level of the double spurline increases to about 3.3 times wider than that of single spurline[1].

Figure 5: Configurations of spurline filter double spurlines

Figure 6: Simulation result of a conventional Double spurline bandstop filter

In figure 6. Simulatio result of Double spurline is mentioned. Here deeper rejection ratio and more wider bandwidth is obtained compare to single spurline filter. Ratio is deeper at -50 dB at 3.8 GHz frequency. Band width is 2.4 to 5 GHz. Single spurline filter and double spurline filter from the simulated results in Figure 7, the rejection bandwidth of double spurlines is very wide compared to that of single spurline. Also the rejection level of double spurlines is very deep compared to that of single spurline. With the compact circuit size of double spurlines, it is very suitable to apply double spurlines as a compact bandstop filter. Both types of spurlines can be modeled as one parallel LCR resonator. The resonant frequencies are modeled by one LC resonator, and the radiation effect and transmission loss are considered as a resistor (R).

Figure 7: Comparison of simulated transmission coefficients ($S_{21}$)

$$R = 2Z_0 \left( \frac{1}{|S_{21}|} \right) - 1 \quad (4)$$

$$C = \sqrt{\frac{0.5(R + 2Z_0)^2 - 4Z_0^2}{2.83\pi Z_0 R_{3dB}}} \quad (5)$$

$$L = \frac{1}{4(\pi f_0)^2 C} \quad (6)$$

Where $Z_0$ is the 50Ωcharacteristic impedance of the microstrip line, $f_0$ is the resonant frequency, $S_{21}$ is the transmission coefficient at $f_0$, and $\Delta f$ is the -3 dB bandwidth of $S_{21}$. From the simulated results in Figure 3, the extracted circuit elements are the following[2].

For the single spurline, $L = 0.977$ nH, $C = 1.9995$ pF, and $R = 17.76$ kΩ. For the double spurlines, $L = 3.095$ nH, $C = 0.601$ pF, and $R = 71.33$ kΩ. The simulated results of the double spurlines in Figure 6 are indicated and compare with open stub band stop filter spurline. The open stub filter is simulated with the dimensions: $L_1 = 14.5$ mm, $L_2 = 15$ mm, and $W = 2.1$ mm on a substrate thickness of 0.76 mm with a relative permittivity of 2.60[3]. The transmission coefficient comparison of both types of filters is presented in Figure 7.

Figure 8: Layout of a conventional open stub bandstop filter
It can be clearly found that the transmission coefficients of the double spurlines are very comparable to those of conventional open stub filter as in Figure 8. In addition, the dimensions of double spurlines can be tuned to obtain the transmission coefficient close to the conventional open stub filter’s.

![Figure 9: Simulated result of a conventional Open stub spurline bandstop filter](image)

**Figure 9:** Simulated result of a conventional Open stub spurline bandstop filter that excellent bandstop characteristics are obtained. The proposed spurline circuit model will be useful in the development of microstrip circuit in CST. The new BSF can be widely used to suppress harmonics in microwave integrated circuit and THz applications.

### III. CONCLUSION

The proposed filter's circuit size is reduced using double spurlines and conventional open stubs. The bandstop characteristics of double spurline filter are studied and its LCR circuit elements are extracted. The spurlines are inserted between two open stubs for the purpose of bandstop region improvement and circuit size miniaturization. The measured results are in good agreement with the CST simulated results. It has been obviously shown that the proposed bandstop filter provides wider bandstop and deeper rejection with compact circuit size compared to the conventional open stub filter. The proposed BSF was measured, and results show excellent bandstop characteristics are obtained. The proposed spurline circuit model will be useful in the development of microstrip circuit in CST. The new BSF can be widely used to suppress harmonics in microwave integrated circuit and THz applications.

### REFERENCES


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