An Overview on Microstrip Spurline Bandstop Filter

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ABSTRACT
This Paper is an attempt to give an overview of Microstrip Spurline Band Stop Filter. The basic concepts and filtering characteristics of Microstrip Spurline Band Stop Filter are introduced and the equivalent circuit models with filter response are also presented. Also, the main applications of Microstrip Spurline Band Stop Filter in microwave technology field are summarized and the evolution trends of Microstrip Spurline Band stop Filter is given.

KEYWORDS: Band Stop Filter, Spurline

1. INTRODUCTION
High Performance, Compact size and low cost often meet the stringent requirements of modern microwave communication systems. There have been some new designing such as Design of Microstrip Spurline Band Stop Filters [1], Compact Microstrip Band Stop Filter Using open stub & Spurline[2], Compact Band Stop Filter using Defected Ground Structure[3], Microstrip Band Stop Filter using Spurline & Defected Ground Structure[4], Novel Compact Microstrip Interdigital Band Stop Filter[5] and so on to enhance the whole quality and response of the system. 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.

2. EXACT DESIGN OF BAND STOP MICROWAVE FILTERS
An exact method for the design of band stop filters which adapts synthesis techniques. This method places no theoretical limit on the width of the stop-band, although, for practical reasons, different (but equivalent) circuit configurations are used for stop bands of different widths. These configurations include a form having open-circuited shunt stubs separated by lengths of line; a second form using resonators which are separate from the main line but parallel to it, so that coupling takes place by the way of fringing fields; and a third form in which the resonators are attached directly to the main line, but are folded parallel to it so that coupling is both by direct connection and by fringing fields. Easy to use formulas are given for the exact design of band stop filters from low pass prototype filters and equations are given for converting one form of filter structure to any of the other equivalent forms.

2.1 USING MICROSTRIP SPURLINE
A first Stripline 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 f₀.

The filter consist of a coupled pair of microstrip lines a quarter wavelength long (referred to the stop-band centre frequency f₀) with an open circuit at the end of one of the coupled lines and with both lines connected together at the other end. Fig. 1 shows an example of such a filter fitting within the width of a microstrip transmission line.

An approximate equivalent circuit is derived which enables the filter to be designed and then analysed and optimized using a computer network analysis program. Graphs are presented which enable the designer to obtain the microstrip geometry from the equivalent circuit element the microstrip geometry from the equivalent circuit element values for the case of alumina substrates with a dielectric constant of 9.6.

Fig. 1 Microstrip spurline Notch filter
Where $\lambda_g$ 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.

A full analysis of spurline filters in inhomogeneous medium (homogeneous medium is a special case) has been presented, allowing filters to be exactly designed a definite advantage compared to single-ridge fin-line bandstop filters. The less radiation characteristic of spurline filters compared to the conventional shunt stubs and parallel-coupled lines bandstop filters makes them more useful than conventional ones. The exact equivalent circuit model allows one to design spurline filters in microwave frequency regions as well as in millimetre-wave regions.

![Fig. 2. Single section Ka-band filter response](image)

**2.2 USING OPEN STUB AND SPURLINE**

This filter combines two traditional BSFs: open-stub filter and spurline filter. Due to the inherently compact characteristics of the spurline, the proposed filter shows a better rejection performance than open-stub BSF without increasing the circuit size. From 3.7 to 5.4 GHz, the proposed BSF has a rejection of better than 20 dB and the maximum rejection level of 61 dB. By cascading more identical open-stub sections of an open-stub filter, a deeper rejection and a wider rejection bandwidth can be achieved at the expense of increasing circuit size and insertion loss. Spurline BSF with its inherently compact characteristics can be embedded between two adjacent shunt open stubs to introduce another attenuation pole which achieves a better rejection performance without any penalty of increasing size. Therefore, a BSF using the combination of open stubs and spurline is proposed.

![Fig. 3. Configuration of BSFs using open stubs and spurline](image)

The optimized dimensions for parameters are $W=0.9$ mm for a 50-$\Omega$ line. LF is chosen as 15 mm for convenience of measurements. Fig. 4 shows the simulated and measured results. The measured 20-dB rejection band of the open-stub, the spurline, and the proposed filters are 3.9-5 GHz, 4.3-4.5 GHz, and 3.7-5.4 GHz, respectively, and the proposed filter has the deepest rejection level of 61 dB among these three filters. Under the circumstance of the same circuit sizes, the proposed filter shows a better rejection than the traditional open-stub filter. Furthermore, the proposed filter has a wider stopband than the spurline filter.

![Fig. 4. Simulated and measured insertion loss of BSFs.](image)

**Application of this BSF to suppress the second harmonic of an open-loop ring band pass filter is also investigated with a 40 dB suppression improvement achieved**

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The proposed BSF shows a much deeper rejection and wider stop band than the conventional open-stub BSF without increasing the circuit size. This filter is also used to suppress the second harmonic of an open-loop ring bandpass filter with a center frequency of 1.95 GHz. From 2.3 to 5.7 GHz, the suppression is better than 30 dB.

### 2.3 USING SPURLINE AND DEFECTED GROUND STRUCTURE (DGS)

This filter consists of two parts: defected ground structures filter (DGS) and Spurline filter. Due to the inherently compact characteristics of the spurline and DGS, the proposed filter shows a better rejection performance than open stub BSF in the same circuit size. The results of simulation and optimization given by HFSSv12. The inherently compact characteristic of spurline and defected ground structures filter, it can get a better rejection band than open-stub band stop filter without increasing the size of circuit [2]. Defected ground structure (DGS) is usually realized by etching a specific pattern on the ground plane of a microstrip line. With an additional inductance due to the magnetic flux flowing through the etched-out apertures and gap capacitance on the ground plane, a certain band of frequencies is prohibited. This DGS has been used for control of an active microstrip antenna, improved efficiency of power amplifiers, performance enhancement of filters, dividers, and branch line couplers. The U-slot DGS provides the band rejection property of -41.7 dB at 5.85 GHz. Relative bandwidth is 8.55%. In comparison with spurline band stop filter, the DGS have a better attenuation in bandwidth, about more 8 dB. But for band stop filter its relative bandwidth is worse about 3%.

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**Fig. 5.** Configurations of filters using two open-loop ring resonators: (a) filter only (b) filter with proposed BSFs

**Fig. 6** Measured insertion loss of band pass filter with and without BSFs

**Fig. 7** Simulation results of DGS
Most conventional microstrip bandstop filters have open-circuited stubs and shunt stubs of a quarter wavelengths. The conventional microstrip band stop filter may be designed using a conventional procedure, as described in [6], [9]. The microstrip band stop filter, using open-circuited stubs, consists of one main transmission line coupled to a half-wavelength resonator; it is generally electrically and magnetically coupled. The resonant frequency depends on the half-wave length resonator. However, the Open circuited stubs are large. The microstrip bandstop filter with the shunt stubs of a quarter wavelengths still must be larger than the quarter-wavelength resonator [6]. Therefore, reducing the size of such filters is essential [9], [11]. In 1970, Alley [11] proposed interdigital capacitors for use in lumped-element microwave integrated circuits. The microstrip interdigital resonator is analogous to the planar interdigital capacitor, whose operating frequency can be changed by control of the capacitances. Hence, an inter-digital resonator is described herein to realize a lumped-element interdigital bandstop filter. Fig. 10 shows the structure of the designed bandstop filter, with one microstrip interdigital resonator and tapped I/O port. The interdigital capacitance then can be referred to a periodic structure of transmission line [11].

Fig.8 Transfer characteristics for BSF with spurline and DGS

With above all structures, conclusion is that the DGS filter has a better band attenuation, but relative bandwidth of it is larger; while the spurline BSF can manage some band attenuation with a narrower bandwidth. The finally, we sacrifice part of the in-band attenuation in exchange for a more narrow bandwidth for designing a filter with a hybrid structure constitutes with spur line and DGS.

2.4 USING INTERDIGITAL RESONATOR

A novel compact microstrip interdigital band-stop filter is designed and implemented. The structure is similar to that of an interdigital capacitor. The input port and output ports are connected to form the bandstop characteristic. This proposed filter with microstrip interdigital geometry not only exhibits good bandstop characteristics and a tunable central frequency, but it also is easy to fabricate and integrate. The features of this microstrip interdigital bandstop filter are smaller than those of the conventional bandstop filter.

A novel microstrip interdigital bandstop filter. The central frequency of the microstrip interdigital bandstop filter with the interdigital capacitor structure can be tuned to a lower frequency, reducing the size of the bandstop filter. The designed bandstop filter is fabricated on one FR4 GD (glass-epoxy double sided) layer with a thickness of 1.6 mm. The experimental results concerning the fabricated filter measured by network analyzer agree closely with the simulation results.

Fig.10 Simulated and measured performance of designed Bandstop filter with one microstrip interdigital resonator \((L1 = 23.3 \text{ mm}, L2 = 17.2 \text{ mm}, L3 = 3 \text{ mm}, W1 = 3 \text{ mm}, W2 = 0.2 \text{ mm}, G1 = 0.2 \text{ mm}, S1 = 0.1 \text{ mm})\).

Fig.9 Structure of novel Band stop filter with one microstrip interdigital resonator and tapped I/O

Fig.11 Structure of the novel band stop filter with two microstrip interdigital resonators \((W3 = 1 \text{ mm})\).
The sharpness of the roll-off response is important in wireless communication systems. More resonators are required to increase the attenuation rate. Fig. 11 presents the proposed novel band stop filter with two microstrip interdigital resonators with the same dimensions. The distance W3 between the two microstrip interdigital resonators is 1 mm. Fig. 12 plots the simulated and measured performance of the designed novel band stop filter with two microstrip interdigital resonators and tapped I/O. The simulated results demonstrate a central frequency fo of 1.19 GHz, an FBW of 32%, and an insertion loss of ~42 dB. The designed novel band stop filter has a measured central frequency fo = 1.2 GHz, an FBW of 30% and an insertion loss of ~41 dB, as determined using an Agilent 8753E network analyzer. The slight difference between the simulations and measurements may be caused by defects in the material and technical errors in the fabrication process.

![Fig.12 Simulated and measured performance of designed Band stop filter with two microstrip interdigital resonators.](image)

Novel bandstop filters with microstrip interdigital resonators and tapped I/O were designed and fabricated. The procedure for designing novel bandstop filters is presented. The novel band stop filters show good microwave characteristic; their central frequencies can be tuned by changing the capacitance. Moreover, the novel band stop filters are smaller size than the conventional band stop filters.

2.5 PROPOSED FILTER

Proposed structure consist of combination of spurline bandstop filter with interdigital Capacitance as defected ground structure (DGS) bandstop (notch) filter at designed frequency and its effect with and without diagonal coupling between interdigital structures. Lossless conditions are taken into account and the substrate used is RT duroid3003 with dielectric constant 3 with the thickness of 30mil (0.762mm), and did structure calculations and got simulated results with very good attenuation. The results of simulation and optimization given by HFSSv12 prove the correctness of the design.

3. CONCLUSION

Here, the comparison of three different configurations is done. The spurline band stop filter is included in previously done work. Analysis of interdigital capacitance as a defected ground structure shows that it not only exhibits good band stop characteristics, but it has tunable central frequency that can be achieved by changing the capacitance. Moreover, the features of this microstrip interdigital band stop filter are smaller than those of the conventional band stop filter. Both the above explained configurations are compared with proposed structure.

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