

Comblined Bandstop Filter Design and Analysis using Bandstop MEMS Switching

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ABSTRACT

In this paper different band stop filter topologies have been proposed using MEMS to achieve compactness in comparison with the same class of filter topologies available in literatures. A shift in resonance characteristics and bandwidth is reported by using MEMS switch at various positions. All simulations are carried out using Ansoft HFSS and CST MWS.

Keywords

Bandstop filter, MEMS, HFSS, Bandwidth

1. INTRODUCTION

The promising field of MEMS technology has been evolved from the integrated circuit industry. The most intrinsic characteristics are miniaturization, microelectronics integration, and accurate mass production. MEMS technology facilitates it possible to manufacture electromechanical and microelectronics component in a single tiny device ranging from $1\mu\text{m}$ to 1mm . The decrease in dimension of electromechanical systems provides benefits like more reliability, more resonant frequency, and low thermal mass, and hence, there exist significant reduction in power consumption.

In MEMS, while the electronics are manufactured by employing integrated circuit processes, the micromechanical components are constructed using micromachining processes that selectively etch away silicon wafer parts or make more structural layers to form the electromechanical devices. The mechanical sensors and actuators, and electronic controllers and microprocessors have been demonstrated to be fabricated on a single substrate. Lithography guarantees the accurate dimension and position. The batch based fabrication processes have the possibility to get large volume fabrication and therefore, there is reduction in expenditure and considerable enhancement in the yield and reliability.

A band stop filter (BSF) also known as band reject filter can be defined as a network that passes most frequencies unaltered and attenuates those in a specific range to very low levels. A special kind of band stop filter is the notch filter (or wave trap) which is a narrowband band stop filter.

In the recent days researchers all over the world took keen interest to develop different planar band stop filters which are compact in size by employing defective ground, coupled resonators, microstrip line with spiral resonators cut on the line etc. This chapter presents various BSF structures developed using planar technology using MEMS to achieve compact size. Few structures of band stop filter have been presented using the defective ground with mushroom structures in various literature. It uses a multilayer structure to achieve compactness.

2. WIDE BANDSTOP FILTER DESIGN USING MEMS LINES

A band stop filter may be designed by using the shunt quarter-wavelength (at the mid-stop band frequency) long open-circuited stubs separated by a quarter wave length long (at the mid-stop band frequency) transmission line [1] - [3]. The basic structure of the optimum band stop filter [2], [14], [15], is based on the open circuited transmission line stub network as depicted in figure (5.1). Filtering characteristics of this filter entirely depend on the design of characteristic impedances Z_i for the open-circuited stubs, characteristic impedances $Z_{i,i+1}$ for the transmission line elements and two terminating impedances Z_A and Z_B [2].

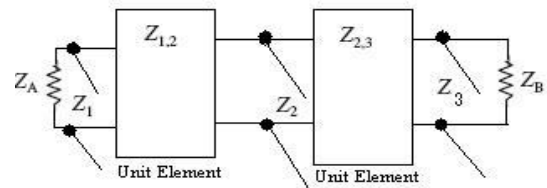


Fig.1. Transmission line network representation of open stub band stop filter.

The design equations are given here for easy reference from [2]. The synthesis of the ladder network shown in figure (1) is based on following transfer function given by equation (1).

$$|S_{21}(f)| = \frac{1}{1 + \varepsilon^2 A_n^2(f)} \quad (1)$$

Where ε is the pass band ripple constant and A_n is the filtering function represented by the following:

$$A_n(f) = B_n\left(\frac{t}{t_c}\right)B_{n-1}\left(\frac{t\sqrt{1-t_c^2}}{t_c\sqrt{1-t^2}}\right) - C_n\left(\frac{t}{t_c}\right)C_{n-1}\left(\frac{t\sqrt{1-t_c^2}}{t_c\sqrt{1-t^2}}\right) \quad (2)$$

Where t and t_c are the Richards' transform variables which are given by

$$t = j \tan\left(\frac{\pi f}{2 f_o}\right) \quad (3)$$

$$t_c = j \tan\left(\frac{\pi}{2}(2 - FBW)\right) \quad (4)$$

The fractional band width of the filter is defined as:

$$FBW = \frac{f_2 - f_1}{f_0} \times 100\% \quad (5)$$

$$B_n(x) = \cos(n \cos^{-1} x) \quad (6)$$

$$C_n(x) = \sin(n \cos^{-1} x) \quad (7)$$

where f_0 is the mid-band frequency of the band-stop filter. $B_n(x)$ and $C_n(x)$ used in equation (2) are the Chebyshev functions of the first and second kinds respectively of order n . The impedances Z_A, Z_B, Z_i and Z_{i+1} are defined as:

$$Z_A = Z_B = Z_0$$

$$Z_i = Z_0 / g_i$$

$$Z_{i+1} = Z_0 / J_{i,i+1} \quad (8)$$

Where g_i and $J_{i,i+1}$ are the element values of the lowpass prototype and admittance inverters respectively. An optimum microstrip band-stop filter with three open-circuited stubs and a fractional bandwidth $FBW = 100\%$ at a mid-band frequency $f_0 = 3$ GHz is designed. By considering a pass band return loss of -20 dB, which corresponds to a ripple constant $\epsilon = 0.1005$. For optimized filter the normalized element values are taken from [2] which are $g_1 = g_3 = 0.94806$, $g_2 = 1.67311$, and the impedance inverters $J_{1,2} = J_{2,3} = 0.56648$. The filter is designed to match 50 ohm terminations. Therefore $Z_0 = 50$ ohms, and from equation (5.8) we determine the electrical parameters for the desired filter network. The parameters values so obtained are given below:

$$Z_A = Z_B = 50 \text{ ohms}$$

$$Z_1 = Z_3 = 52.74 \text{ ohms}$$

$$Z_2 = 29.88 \text{ ohms}$$

$$Z_{1,2} = Z_{2,3} = 88.26 \text{ ohms}$$

The lengths and widths of the corresponding microstrip line open stubs are determined by using the equation from (5) to (7). The BSF so obtained is shown in figure (5.2) along with their dimensional values. The width of the microstrip lines connected with two open ended stubs are 0.45mm and width of the 50 ohm microstrip line is 1.82mm.

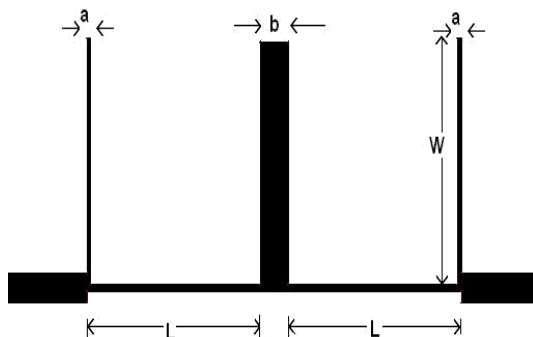


Fig 2. Microstrip BSF with optimum design with $a = 0.3$ mm, $b = 2.3$ mm, $W = 15.15$ mm, $L = 15.5$ mm.

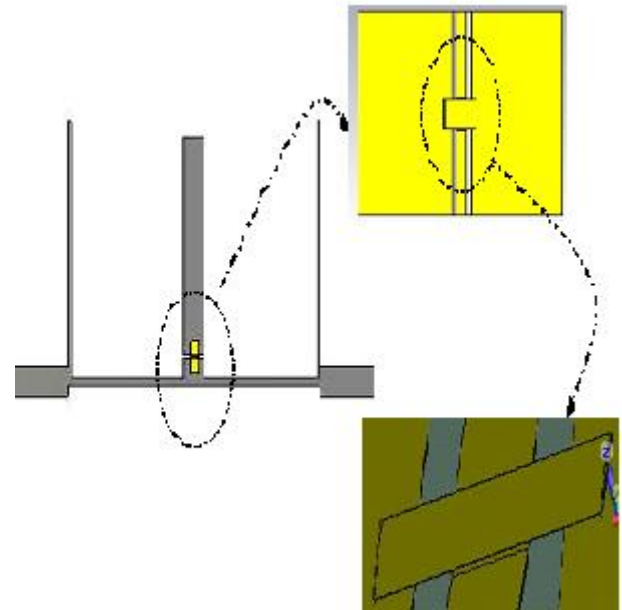


Fig3. Microstrip BSF with optimum design with $a = 0.3$ mm, $b = 2.3$ mm, $W = 15.15$ mm, $L = 15.5$ mm.

3. SIMULATION OF MEMS BANDSTOP FILTER

The above figure shows the structure of BSF. which is simulated using Ansoft HFSS. Fig. 3, 5 and 9 illustrate the simulated design using HFSS.

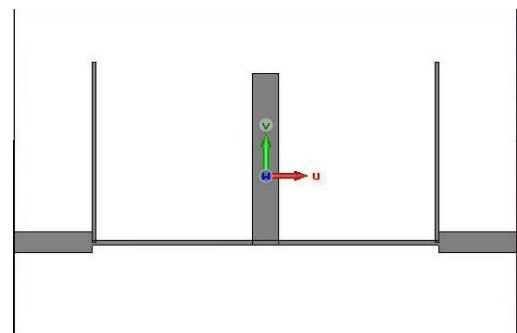


Fig4. Microstrip BSF with optimum design with $a = 0.3$ mm, $b = 2.3$ mm, $W = 15.15$ mm, $L = 15.5$ mm.

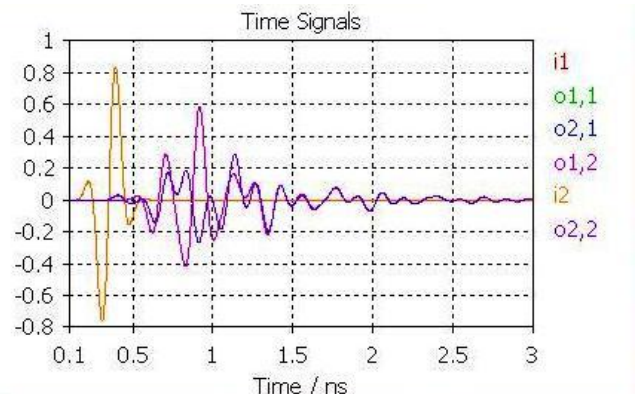


Fig 4. Excitation Signal

Fig.5 shows the excitation signal and the output signal at port number 1 and 2. It clearly shows that there is symmetry between port number 1 and 2.

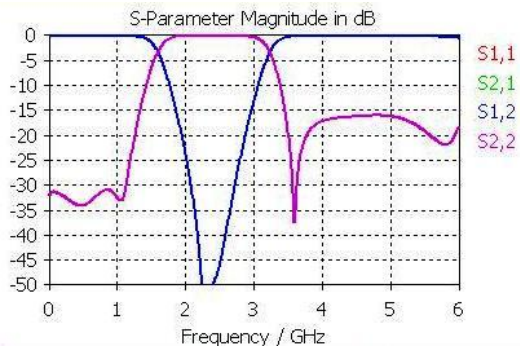


Fig 6. S- Parameter curve for design 1 (without MEMS)

The above design shows the resonance S (1, 2) between the frequencies ranging from 1 to 3 GHz. It shows that when both the switches are opened then the designed filter stop the band having frequency range from 1.8 GHz to 3.4 GHz.

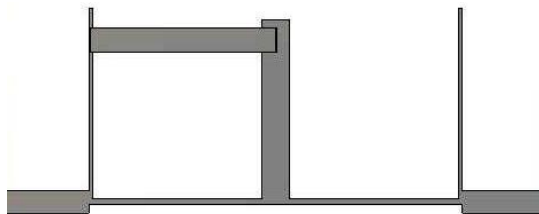


Fig7. Microstrip BPF with optimum design with $a = 0.3\text{mm}$, $b = 2.3\text{mm}$, $W = 15.15\text{mm}$, $L=15.5\text{mm}$.(MEMS Switch between left and centre stub)

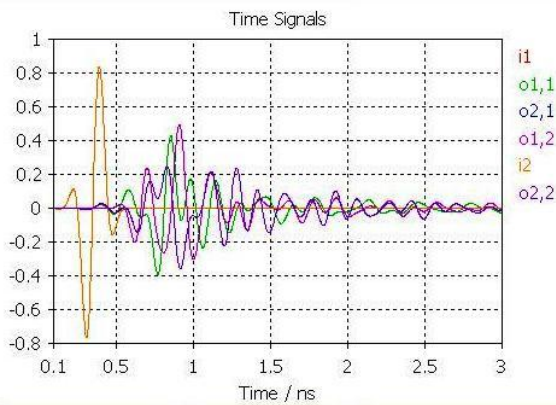


Fig 8. Excitation Signal (MEMS-design1)

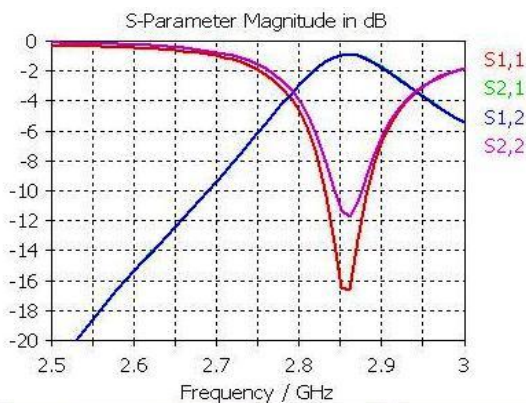


Fig 9. S- Parameter curve for design (MEMS Switch between left and centre stub)

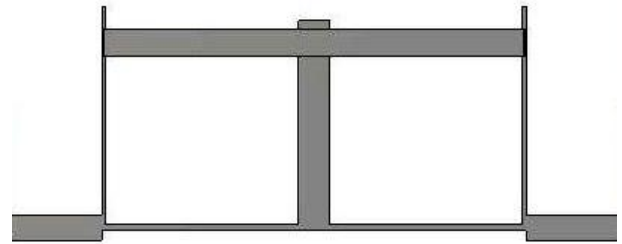


Fig 10. Microstrip BPF with optimum design with $a = 0.3\text{mm}$, $b = 2.3\text{mm}$, $W = 15.15\text{mm}$, $L=15.5\text{mm}$. (MEMS Switch between left and right stub)

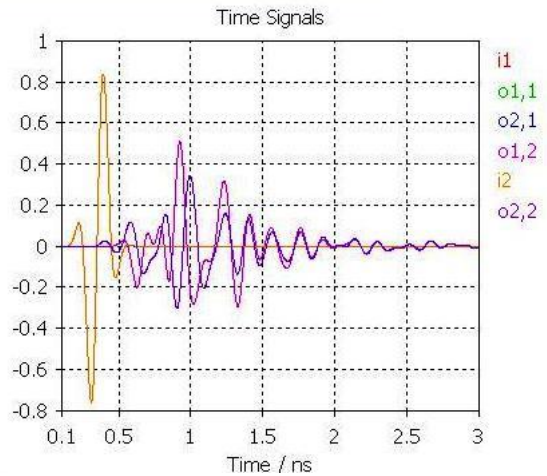


Fig 11. Excitation Signal (MEMS-design2)

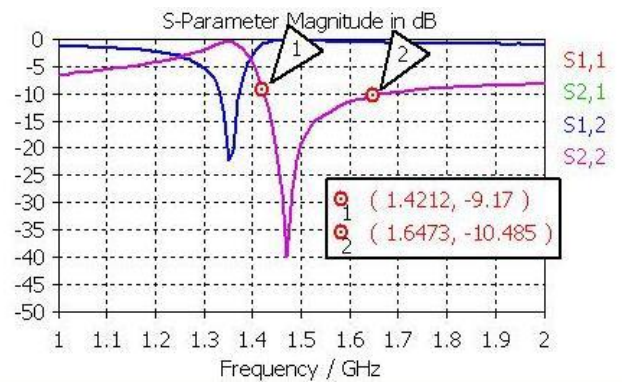


Fig 12. S- Parameter curve for design (MEMS Switch between left and centre stub)

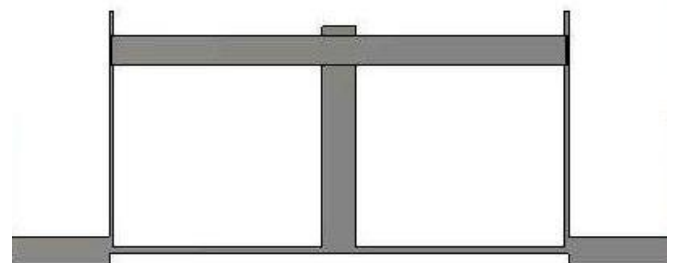


Fig 13. S- Parameter curve for design (MEMS Switch between left and centre stub)

4. CONCLUSION

The proposed design shows the resonance S (1, 2) between the frequencies ranging from 1.2 to 1.50 GHz. It shows that when the MEMS switch between both the left and right with center stub is closed then the designed filter stop the band having frequency range from 1.33-1.38GHz. The designs also shows the resonance S (1, 2) is between the frequencies ranging from 2.5 to 3.0 GHz having return loss upto -17dB. It also shows that when the MEMS switch between left and center stub is closed and right one is opened then the designed filter stop the band having frequency range from 2.8GHz to 2.9 GHz.

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