Design and Development of Wideband Band Pass Filter using Signal Interference Technique for 2.4 Ghz Applications

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ABSTRACT

A wideband band pass filter with a centre frequency of 2.3 GHz and 3-dB bandwidth of approximately 640 MHz, is designed and fabricated. Transmission line section based circuit configuration is used to design the filter. The critical advantage of this scheme is simple structure and easy realization. The designed filter structure is simulated using Agilent ADS tool and the results are in good agreement with the measurement.

Keywords

Microwave filters, band pass filter, transmission line sections, ADS, micro strip line.

1. INTRODUCTION

Recently, high performance band pass filters have received considerable attention due to its application potential in wireless and satellite communication systems. As the limited frequency resources are subdivided into the various bands, the demand of high performance RF band pass filter which has a broadband tenability and constant bandwidth is gradually increasing. The important characteristics of a high performance band pass filter are insertion loss, sharp rejection and bandwidth. In conventional design, higher selectivity is obtained by increasing the filter order. Alternate approaches include cross coupling between the resonators and by using shunt-open stubs on the input and output feed lines.

Micro strip line is more suitable for filter implementation at high frequencies, since lumped elements such as inductors and capacitors are generally available only for limited range of values and are lossy at microwave frequencies. Further, the distances between filter components is not negligible at microwave frequencies. Richards's transformation is used to convert lumped elements to transmission line sections while Kuroda's identities can be used to separate filter elements by using transmission line sections. Micro strip line is one of the most popular planar transmission lines which can be fabricated by photolithographic process. Further it can be easily integrated with other passive and active microwave devices [1]. Unlike strip line, where all fields are contained within a homogeneous dielectric region, micro strip has some of its field lines in the dielectric region between strip conductor and ground plane and some fraction in the air region above the substrate. Signal Interference technique can provide good solution for designing wideband band pass filter [2]. This technique has also been used to design band stop & band pass filters [3- 9]. Also this approach requires a smaller electrical line length for specified skirt selectivity. The filter design procedure adopted in this paper is based on signal interference technique with two transmission line segments.

2. FILTER DESIGN AND CONFIGURATION

The basic and modified open stub filter sections are shown in Fig.1 a&b respectively. As indicated in Fig 1a, Z_1 & Z_2 are the characteristic impedances and θ_1 & θ_2 are the electrical lengths of the transmission line segments. The two lines are joined at both ends at the pass band centre frequency f_o. The input signal is divided into two components at one end and made to interfere at the other end with different phase and magnitudes, which is the concept of signal interference technique [5]. This technique is best suited for designing low insertion loss, sharp rejection and wide band pass filters.

If θ_1 and θ_2 are taken as θ_{10} and θ_{20} at f_o, then at any arbitrary frequency f

$$\theta_i = \frac{f\,\theta_{i0}}{f_o}, \quad i = 1,2 \qquad (1)$$

For the basic filter section, the proposed electrical lengths are $\theta_{10} = 90^o$ and $\theta_{20} = 270^o$ and the corresponding Z_1 & Z_2 values are 25Ω and 50Ω respectively. The advantage of using low impedance values are decreased pass band insertion loss, increased selectivity, increased bandwidth and ease of fabrication. Also, filter 3-dB centre frequency depends on the chosen Z_1 & Z_2 values.

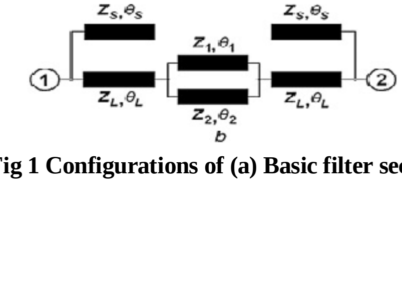

Fig 1 Configurations of (a) Basic filter section

(b) Modified open stub filter section [5]

Based on the lossless transmission-line model, the ABCD matrix of the basic configuration of Fig. 1a can be arrived as

$$\begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} = \begin{bmatrix} \dfrac{Z_1 \cot\theta_2 + Z_2 \cot\theta_2}{Z_1 \csc\theta_2 + Z_2 \csc\theta_2} & \dfrac{j Z_1 Z_2}{Z_1 \csc\theta_2 + Z_2 \csc\theta_2} \\ \dfrac{Z_1^2 + Z_2^2 + 2 Z_1 Z_2\, j(\csc\theta_1 \csc\theta_2 - \cot\theta_1 + \cot\theta_2)}{Z_1 Z_2 (Z_1 \csc\theta_2 + Z_2 \csc\theta_2)} & \dfrac{Z_1 \cot\theta_2 + Z_2 \cot\theta_2}{Z_1 \csc\theta_2 + Z_2 \csc\theta_2} \end{bmatrix} \quad (2)$$

The corresponding S parameters are [6]

$$S_{11} = \frac{A_1 + B_1/Zo - C_1 Zo - D_1}{A_1 + B_1/Zo + C_1 Zo + D_1} \quad (3) \text{ and}$$

$$S_{21} = \frac{2}{A_1 + B_1/Zo + C_1 Zo + D_1} \quad (4)$$

Where Zo is the port impedance.

To enhance the filter rejection characteristics, two shunt open stubs having equal characteristic impedance Z_s and electrical length θ_s are connected at both output and input sides. The open stubs are used to improve rejection. Then overall ABCD parameter of the modified section is given by [6].

$$\begin{bmatrix} A_2 & B_2 \\ C_2 & D_2 \end{bmatrix} = \begin{bmatrix} 1 & -jZ_s\cot\theta_s \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta_L & jZ_L\sin\theta_L \\ j\sin\theta_L/Z_L & \cos\theta_L \end{bmatrix}$$
$$\times \begin{bmatrix} A_1 & B_1 \\ C_1 & D_1 \end{bmatrix} \begin{bmatrix} \cos\theta_L & jZ_L\sin\theta_L \\ j\sin\theta_L/Z_L & \cos\theta_L \end{bmatrix}$$
$$\times \begin{bmatrix} 1 & -jZ_s\cot\theta_s \\ 0 & 1 \end{bmatrix} \quad (5)$$

The corresponding S parameters are [10]

$$S_{11} = \frac{A_2 + B_2/Zo - C_2Zo - D_2}{A_2 + B_2/Zo + C_2Zo + D_2} \quad (6)$$

and

$$S_{21} = \frac{2}{A_2 + B_2/Zo + C_2Zo + D_2} \quad (7)$$

3. FILTER SCHEMATIC AND CHARACTERISTICS

The modified open stub filter configuration discussed in the previous section is implemented in ADS tool. The value of Z_1 & θ_1, Z_2 & θ_2 are fixed as 25Ω & 90º, 50Ω & 270º respectively for the design. The operating frequency, the substrate details, impedances and electrical lengths are provided as input to ADS tool, which provide the required length & width of the transmission line segment. The complete filter structure with dimension details & 50Ω transmission lines for both input and output coupling are shown in Fig 2. The corresponding layout generated for the filter is shown in Fig 3.

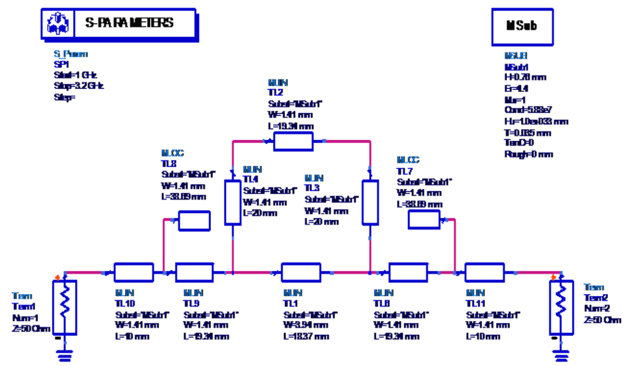

Fig 2. Schematic of modified open stub filter

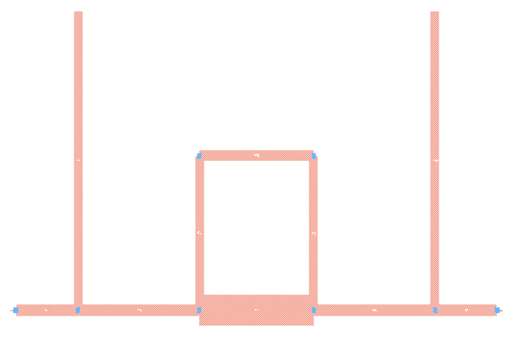

Fig 3. Layout of modified open stub filter

The characteristics of the designed filter are obtained with momentum simulation. The S parameter characteristics are shown in Fig 4.

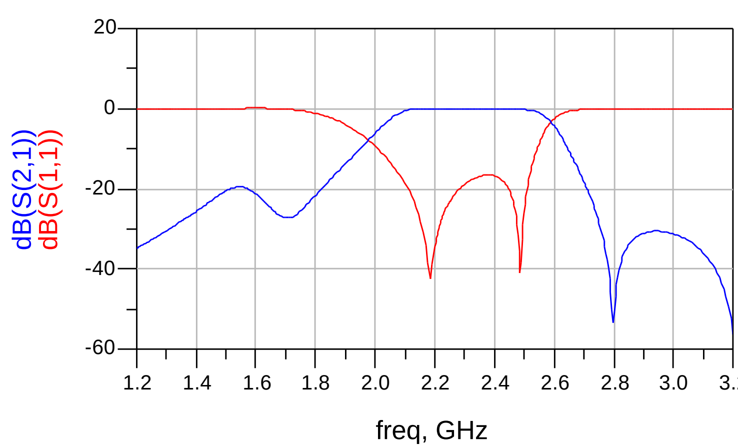

Fig 4. S parameter characteristics

Fine tuning of segment parameters is required to obtain the exact characteristics which are then converted into Gerber file for fabrication.

From the S parameter plot, it is observed that the filter design gives a rejection level of approximately -20 dB from 1.4 to 1.7 GHz and a rejection level of -30 dB from at 2.8 to 3.2GHz. Measured pass band insertion loss is below 1 dB from 2.1 to 2.55 GHz.

4. FABRICATION AND MEASUREMENT

Following the above guidelines, a band pass filter is fabricated on FR4 substrate with a dielectric constant (ε_r) of 4.4, dielectric thickness of about 0.76mm with copper thickness of 35 microns. The photograph of the fabricated filter is shown in Fig 5.

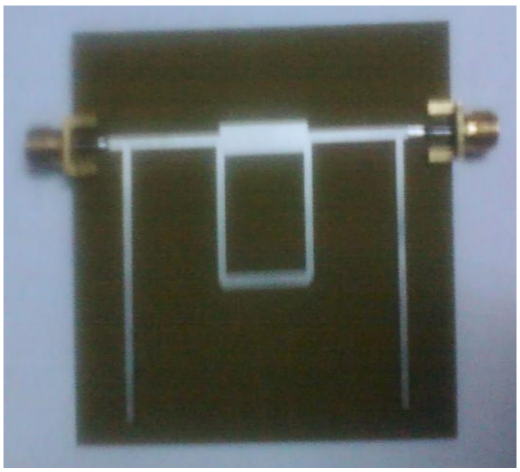

Fig 5. Photograph of fabricated filter

The filter characteristics are measured with Agilent E5071B ENA series Network Analyzer with the operating range of 300KHz to 8.5GHz.

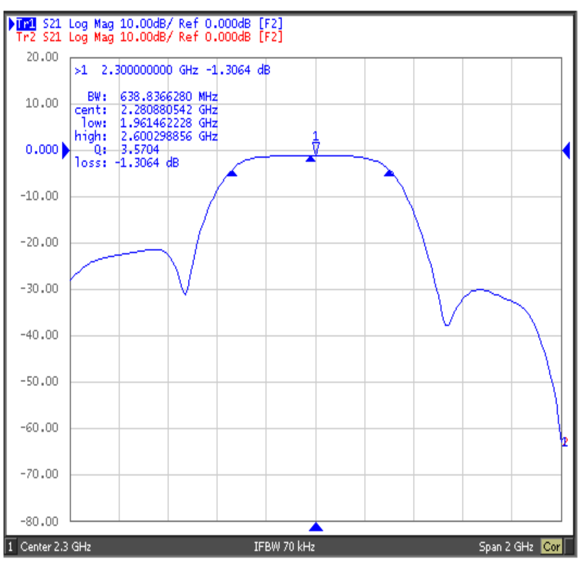

Fig 6. 3-dB Bandwidth Measurement

The S_{21} characteristic for 3-dB measurement is shown in Fig 6. The measurement shows a 3-dB bandwidth of 640MHz with a centre frequency of 2.3GHz. Fig 7 shows the 20-dB bandwidth of the filter as 938 MHz.

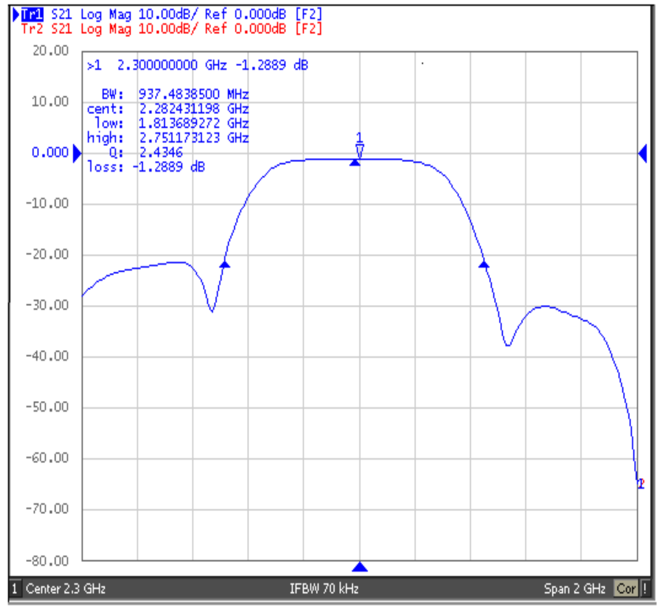

Fig 7. 20-dB Bandwidth Measurement

For broad band filters, group delay variations are very important. The measurement is shown in Fig 8, where a delay less than 2 ns is observed in the pass band region. This is in accordance with the values for broad band filters as reported by Mandal etal [5].

Fig 8. Group Delay Measurement

S_{11}, S_{21} and S_{22} characteristics are plotted for the same frequency range and the centre frequency of 2.3 GHz. The return loss in the pass band is greater than -20 dB. Further the insertion loss of the designed filter is found to be below 1 dB (Fig 9). This is in close agreement with the simulation results shown in Fig.4.

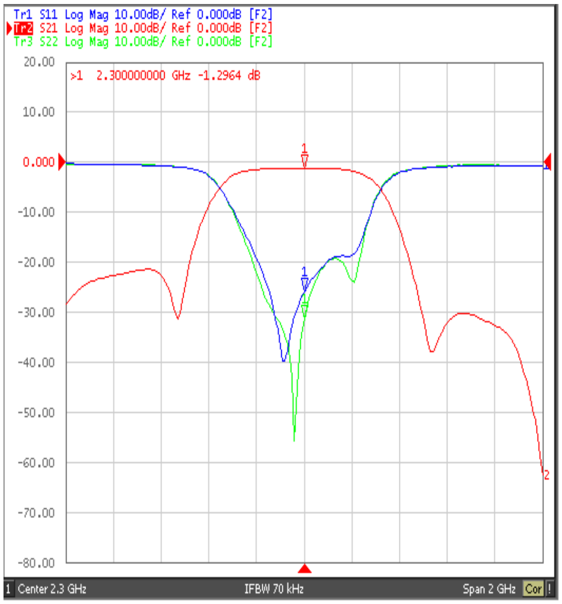

Fig 9. S Parameter Measurement

The rejection level with reference to the 2.3 GHz is approximately 21dB from 1.3 to 1.7GHz on the left side of pass band and it is approximately 30dB from 2.7 to 3.3GHz on the right side of pass band. The average power handling capacity of micro strip lines are generally in the range of 100 – 200W and it depends upon the transmission line losses, thermal conductivity and surface area [11]. Since the designed filter is meant for low power applications, power handling considerations may not be significant. Further, the average power level calculation of micro strip line filter is based on a temperature rise to 100^0C [12], which is beyond the scope of the present work.

5. CONCLUSION

A more practical configuration using two transmission-line sections and shunt open stubs is presented for designing high-performance wideband band pass filter. The main advantage is low insertion loss, simple structure and easy realization. The designed filter structure is simulated using Agilent ADS tool and the results are in good agreement with the measurement.

6. REFERENCES

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