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TOWARDS DESIGNING A MICROSTRIP LOW-PASS FILTER AT 2GHz

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Abstract

Low-pass filter has been widely used to suppress harmonics and spurious signals. In this paper, a compact microstrip low-pass filter design methodology is proposed. This is characterized by simple design method with sharp cutoff frequency response with wide band. The prototype filter is synthesized from the equivalent circuit model using available element value from the tables. To optimize the performance of filter, electromagnetic simulation is performed to tune the dimensions of prototype. Further to increase the sharp cutoff response, high impedances are placed at same side of the low impedance equivalent. Response of variation of separation is observed. The simulated result presents a change in attenuation pole with variation in separation between two ports. This method provides a simple attractive method to design high low impedance low-pass filter with improved response.

Keywords and phrases: low-pass filter, cutoff frequency, Sonnet Lite.

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1. Introduction

Low-pass filters (LPF) are usually designed to suppress harmonics and spurious responses for active and passive microwave integrated circuits. A traditional high low impedance filter [4] suffers from the lack of sharp cutoff frequency and narrow stop band [2, 8]. Size miniaturization of the circuit with sharp response has become paramount requirement for modern communication system which requires a number of stubs in the conventional microstrip low-pass filter.

In recent years, it has been found that the capacitive modeling of filter has proved the purpose but it needs a lot of computation [5, 7] to optimize the result. A new compact filter has been proposed by [3]. This filter is based on calculation of parallel coupled microstrip transmission line.

In this paper, we have designed an improved low-pass filter like [3] with the help of traditional high and low impedance filter design techniques which is compatible with the modern filters developed by other methods.

2. Circuit Analysis and Implementation

A third order chebyshev low-pass filter is represented by combination of inductor and capacitor as shown in Figure 1.

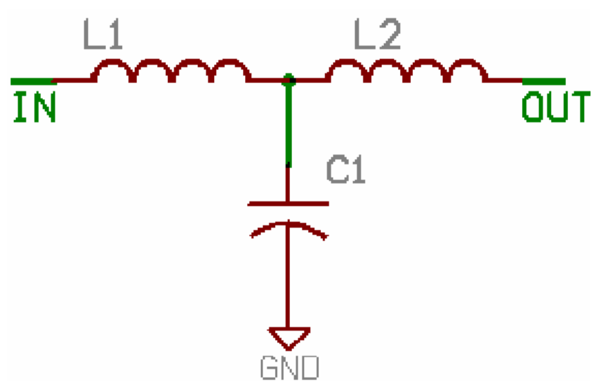

Figure 1. Prototype representation of low-pass filter.

The prototype is converted into high and low impedance microstrip sections using [1] with following formulas:

For high impedance (Z_H)

$$l = \left(\frac{\lambda_H}{2\pi}\right)\sin^{-1}(\omega L/Z_H),$$

$$C_L = \frac{1}{\omega Z_H}\tan\left(\frac{\pi l}{\lambda_H}\right),$$

where C_L is the capacitance associated with inductor and l is the length of microstrip line. Z_H is the high impedance assumed value.

For low impedance (Z_L)

$$l = \frac{\lambda_L}{2\pi}\sin^{-1}(\omega C Z_L),$$

$$L_C = \frac{Z_L}{\omega}\tan\left(\frac{\pi l}{\lambda_L}\right),$$

where L_C inductance, is associated with capacitor and l is the length of the microstrip line. Z_L is the low impedance assumed value.

The equivalent microstrip low-pass filter is shown in Figure 2.

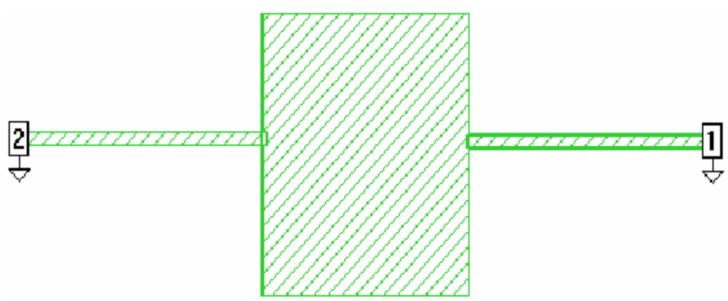

Figure 2. Microstrip low-pass filter.

However, these lines are accompanied by parasitic elements. From Figure 2, it is evident that capacitor is associated with two adjacent inductors and inductors with a capacitor. In the way of optimization L_C

is subtracted from the inductance value and 2 C_1 from the capacitance value. Finally, based on the formulas stated above, physical lengths are calculated in a substrate media and high and low characteristic impedances width of different sections are obtained. The prototype is simulated and tuned to obtain a response at desired –3dB point. This filter suffers from the low roll off frequency in stopband.

To achieve a good response, two ports are placed at the same side of the capacitive stub and using electromagnetic simulator, it is simulated. With varying the separation(s) between parallel lines placed at the same side a shift in attenuation pole can be achieved. At the same time a marginal shift in –3dB point is also noticed. With a trade off between –3dB and attenuation pole frequency, a filter is designed.

3. Results and Discussion

A 3rd order Chebyshev filter with maximum 0.1dB attenuation in pass band and cutoff frequency of 2GHz is simulated. The prototype values and real values of inductor and capacitor are shown in Table 1.

Table1. Parameters chosen

	Prototype Value	Real Value
L1	1.03	4.10nH
C1	1.14	1.81pF
L2	1.03	4.10nH

In the present design example Dielectric substrate of 3.2 and thickness 0.762mm is selected. Value of $Z_H = 120\Omega$ and $Z_L = 20\Omega$ is assumed. Based on above assumption calculated length of high impedance line is 6.97mm and capacitance associated with it is 0.181pF. In the same way calculated length of low impedance line is 6.72mm and associated inductance is 0.384nH.

To reduce the physical length due to fringing effect, two times capacitance associated with high impedance line is reduced from the value of capacitance calculated. In the same way, one time capacitance value associated with low impedance line is reduced from real value of inductance. Final calculated length of inductive line is 6.24mm and capacitive line is 5.86mm. To tune the dimension for optimum performance, it is adjusted to a value for $6.8 \times 0.3 \text{mm}^2$ in the case of high impedance line and $5.76 \times 6.94 \text{mm}^2$ in the case of low impedance line. When this circuit is simulated using Sonnet Lite simulator on substrate of $30 \times 15 \text{mm}^2$ the result obtained is shown in Figure 3.

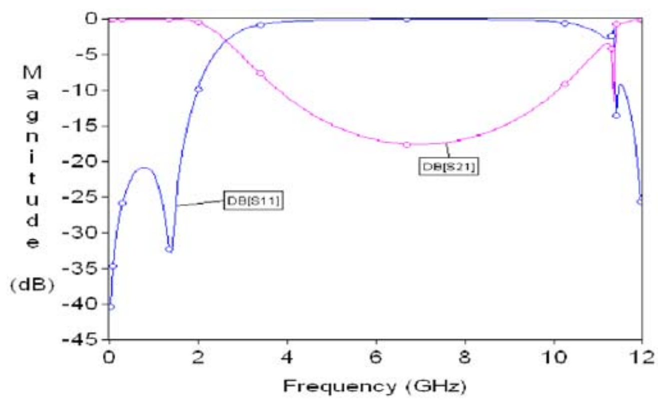

Figure 3. Response of microstrip low-pass filter.

For different value of separation between two lines, when placed at the same side, the variation of attenuation pole is shown in Figure 4.

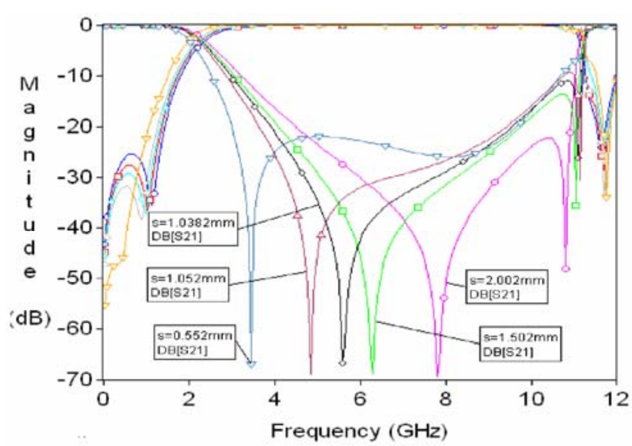

Figure 4. Response of proposed low-pass filter with different separation.

The result shows that when two lines are tightly coupled, value of attenuation pole frequency is close to cutoff frequency which is desired. The final circuit layout obtained is shown in Figure 5. The response of the circuit is shown in Figure 6. The final dimension of the substrate is $15 \times 15\text{mm}^2$. However, this value can be varied. At 2GHz frequency S_{21} is –3.02dB and at 3.45GHz it becomes –66.86dB which shows a sharp cutoff response. –20dB stop band is available up to 9.75GHz.

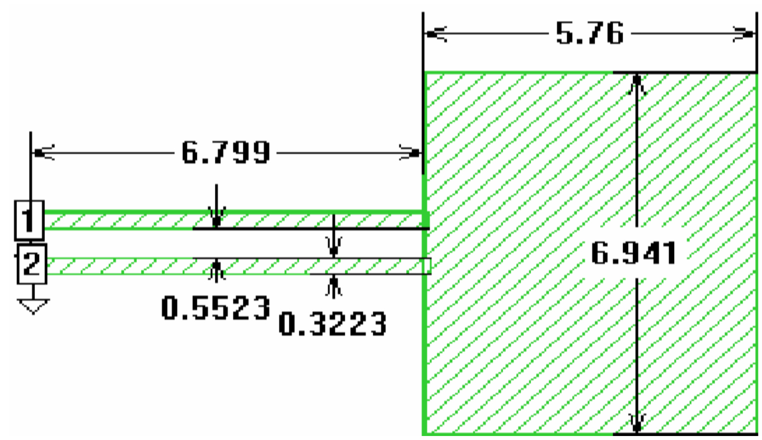

Figure 5. Layout of proposed low-pass filter.

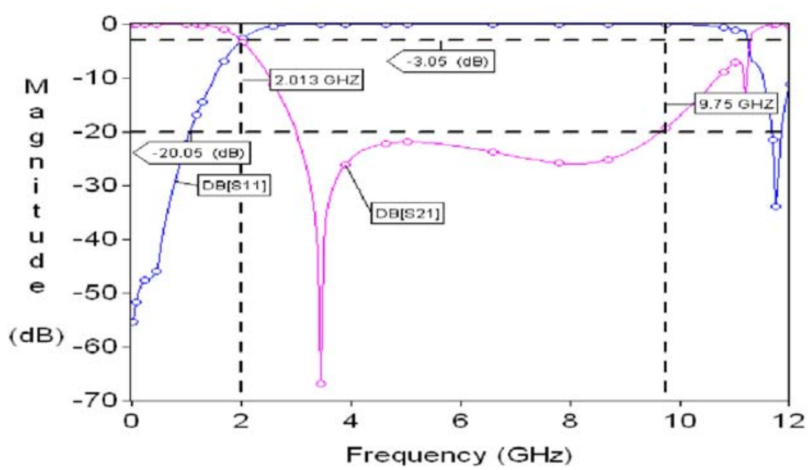

Figure 6. Response of proposed low-pass filter.

4. Conclusions

The method described in the present paper is simple and utilizes the simulation software to calculate the separation. The design methodology is based on traditional filter design technique but response achieved is comparable with other available methods. This method may be extended to design higher order filter and irregular pattern low-pass filter design.

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