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Compact UWB Micro Strip Band Pass Filter with Open Circuited Stubs

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Abstract

A filter is a key and critical component for all types of wireless communication receivers, which are used to reject the noises (unwanted frequencies) in accordance with the applications. Band pass filters enable operation of any given module in a particular frequency range. In this paper, a compact microstrip band pass filter is proposed with operating range from 2.7 to 10.7 GHz for Ultra-Wide band (3.1 to 10.6 GHz) applications. The Chebychev elliptic function filtering method is employed. Two open circuited stubs are used to achieve the upper transmission loss and coupled micro strip structure is used to reduce transmission loss. The designed filter has insertion loss greater than -1 dB and return loss lower than -10 dB in pass band. The filter is designed with dimensions of 10mm x 9mm x 1.6mm on FR4 (εr = 4.3) substrate. The sharp cut-off at lower and upper stop bands has been achieved by proper tuning of the widths and lengths of the open circuited stubs. Bandwidth of about 8 GHz and a flat group delay in the pass band have been achieved. In view of its compactness, this filter can be easily integrated with all communication devices. The designed band pass filter has potential and promising application in UWB (Wi-Fi, Wi-Max, WLAN and ITU) applications.

Keywords: Compact BPF, Elliptic Function, Microstrip, Open Circuited Stubs, UWB Filter

1. Introduction

Federal Communication Commission has released that the 3.1 to 10.6 GHz (Ultra Wide Band) as unlicensed spectrum[1]. So researchers show lot of interest in UWB filters which has wide applications in wireless communication receivers. It is better to have a band pass filter with pass band ranges from 3.1 to 10.6 GHz with minimized dimensions. The filters in micro strip structures are recommended due to their small size, low cost and high selectivity. The micro strip filters are of various types like Champlain, inter digital, coupled in parallel and stepped impedance filters[2]. The Champlain, inter digital and coupled in parallel filters have high radiation losses. Stepped impedance filters have significant insertion and return losses in immediate stop band.

Generally band pass filters are designed by cascading high pass-low pass structures[3]. However, the low pass-high pass structures are combined together to reduce the dimensions[4]. A high pass filter consisting of short circuited stubs was presented in [5]. The UWB filter constructed using ring structure has been reported in [6]. Alternate approach to implement wide band filters using parallel coupled lines has been proposed [7,8].

2. Design of UWB Band Pass Filter using Elliptic Function Low Pass Filter

The Chebychev elliptic function low pass filtering is good one to achieve infinite attenuation in immediate stop band[9,10]. In addition to the stepped impedance prototype filtering concept[9], an inductor is connected with the shunt capacitor as shown in Figure 1. As a result of the series resonance in the shunt arm, the frequency nearer to the cut-off point is purely grounded.

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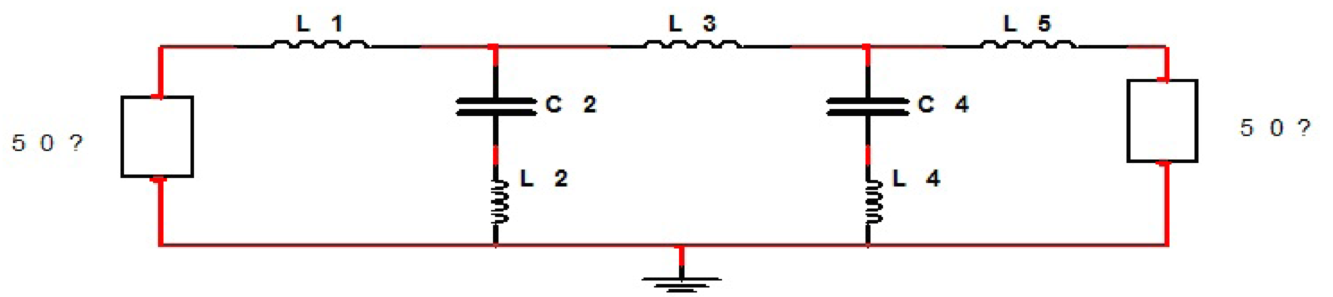

Figure 1. Prototype equivalent of elliptic function filtering.

The series inductors allow and attenuate the low and high frequency signals respectively. Series resonance in shunt arm makes infinite attenuation in stop band. To determine the values of inductors and capacitors, equations (1) and (2) can be used[9].

$$L_i = \frac{Z_O}{2\pi f_c} g_i \qquad (1)$$

$$C_i = \frac{1}{2\pi f_c Z_O} g_i \qquad (2)$$

The value of g_i can selected from elliptic function Chebychev response table[9] with characteristic impedance of 50Ω. By using this analysis, the low pass filter with cut-off at 10.6 GHz has been designed. Then the circuit has been realized using micro strip transmission line structure and is shown in Figure 2. The dielectric substrate used is FR4 with relative permittivity of 4.3 (tanδ=0.025) and height 1.6 mm.

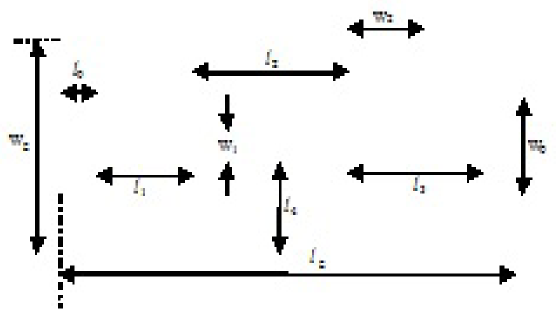

Figure 2. Geometry of elliptic function micro strip low pass structure.

The series inductors are replaced by low-width high impedance lines and series resonance circuits are replaced by open circuited transmission lines having lengths lesser than λ/4[11]. The lengths of micro strip transmission lines are calculated using equation (3)[9]. The line having width wo and length l_o matches the impedance to 50Ω.

$$l_{L_i} = \frac{\lambda_{gl}}{2\pi} \sin^{-1}\left[2\pi f_c \frac{L_i}{Z_{0L}}\right] \qquad (3)$$

In order to avoid the unwanted susceptance effects, the widths and lengths are tuned in trial and error method to get the desired output. The simulated output is shown in Figure 3.

S_{11} is the measure of return loss which indicates the impedance mismatch at port 1. In pass band S_{11} lesser than -10 dB is desirable and in stop band the same should be ideally 0 dB. S_{21} is the measure of insertion loss which indicates the extent of power transfer from port1 to port 2. In pass band S_{21} higher than -1 dB and in stop band lesser than -10 dB are desirable.

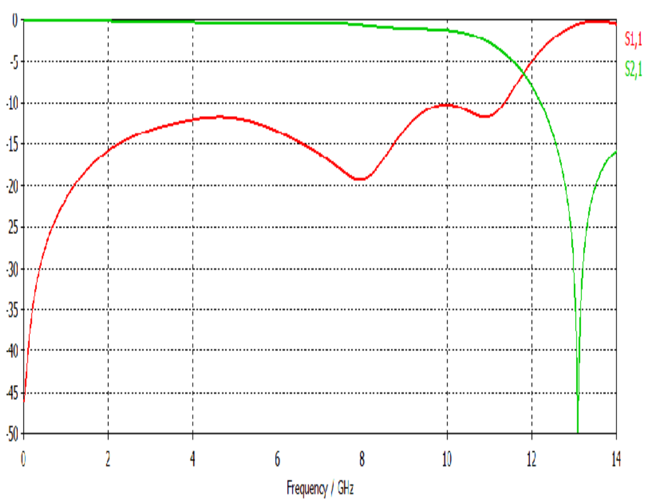

Figure 3. Simulated results of elliptic function low pass filter.

By the concept of prototype filter, series capacitor will produce high attenuation for low frequency signals. As equivalent, an air gap of g_1 = 0.0021 mm has been provided between matching line and high impedance line in the structure shown in Figure 4. It attenuates low frequency signals up to 2.7 GHz. The purpose of gap g_2 is to improve the return loss in pass band[12]. The optimized structure and its simulation results are given in Figure 4 and Figure 5. Figure 6 shows the flat group delay in pass band.

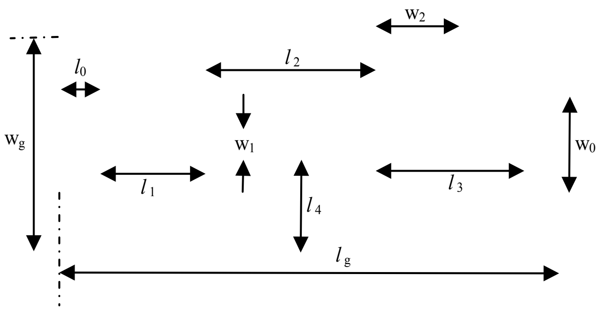

Figure 4. Geometry of UWB micro strip band pass filter, Simulated structure.

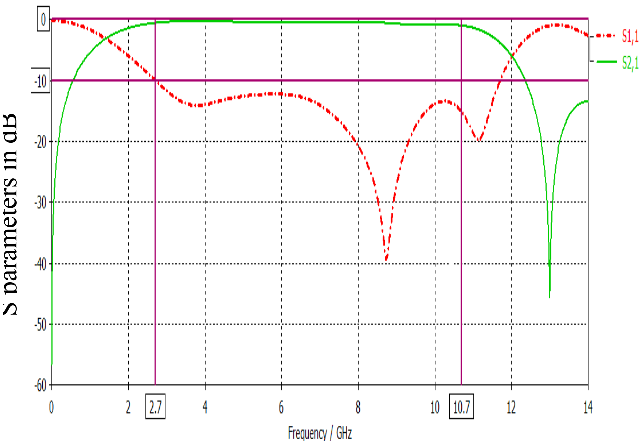

Figure 5. Simulated results of UWB micro strip band pass filter.

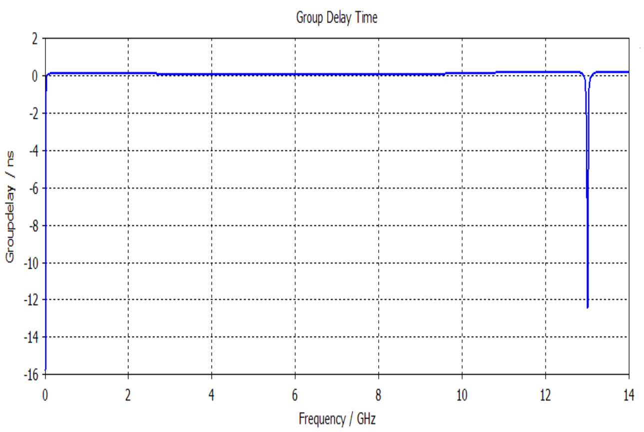

Figure 6. Simulated group delay of UWB micro strip band pass filter.

From Figure 5, it can be observed that, the pass band ranges from 2.7 to 10.7 GHz with the insertion loss higher than -1 dB and return loss lesser than -10 dB (maximum return loss of -39 dB), with flat group delay.

The values of parameters given in Figure 4 are as in Table 1.

Table 1.

Parameters	mm	Parameters	mm
w_o	3.13	l_o	2
w_1	1	l_1	1.24
w_2	1	l_2	2
l_3	1.76	g_2	0.07
w_g	10	l_g	9.0021

3. Conclusion

In this paper, a very compact UWB microstrip band pass filter has been designed based on Chebychev elliptic function. By varying the air gap g1, the lower cut off can be varied. By varying the lengths of open circuited stubs, the upper cut off can be varied. By including open or short circuited stubs with proper lengths and widths, notches can also be created in pass band. The designed filter has a frequency band from 2.7-10.7 GHz which covers the UWB applications.

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