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UWB Bandpass Filter With Quarter Wavelength Short- Circuited Stubs

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Abstract—In this paper a high performance Ultra Wide Band microstrip bandpass filter is presented. The filter is designed using λ/4 short circuited stubs to improve the performance of UWB. The designed filter is based on 5th order chebyshev low pass prototype with .1 dB passband ripples. The filter with total size of 45×11 mm operates with in 3.12-10.4 GHz, produces a fractional bandwidth of 106%. The filter is designed on a polystyrene substrate with relative dielectric constant of 2.6 and a thickness of 1.27mm. The simulated result using HFSS 13 shows an insertion loss (S21) less than .14 dB and return loss (S11) better than 16.62 dB . Group delay is also flat in passband.

Index Terms— microwave filter; UWB; microstrip; quarter wavelength; short circuited stubs.

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1.INTRODUCTION

THE demand in high speed communication has led to the design and development of wide band filters to support the applications such as UWB technology that promises communication speed of up to 1000 Mbps. Because of its attractive feature in high speed wireless applications, the ultra wide band communication has been authorized by federal communication commission (FCC) with unlicensed frequency units from 3.1 GHz to 10.6 GHz in February 2001 [1].The key passive component in UWB is front end receiver required to meet some stringent specifications compactness, low insertion better return loss ,flat group delay and sharp wideband rejection. Considering above said requirements researchers have proposed and developed many UWB bandpass filters using different methodologies and structures[2-11]. However minimizing these parameters with optimum size has always been a challenging task.

A broadband filter using quasi lumped interdigital capacitor and quarter wavelength microstrip line resonator was presented in [2] with a maximum bandwidth up to 76%.A Five pole quarter wave short circuited stub is designed with a total size of 41×12mm but not utilizing the proper spectrum of (3.1- 10.6GHz)[3]. A compact four mode resonator filter is proposed which shows close agreement with FCC's indoor limit .but a strong coupling structure is necessary in obtaining broad passband . As a consequence, very narrow coupling gaps are used in the structure which in turn require critical fabrication precision procedure and hence add to cost of filter [4]. In [5] UWB filter is designed using stub loaded multiple mode resonator (MMR). MMR is constructed by loading three open stubs in a uniform impedance resonator. Proposed filter achieved insertion loss about 1 dB, return loss greater than 10 dB and FBW of 117%. The filter proposed in [6] is designed using a slow wave coplanar waveguide MMR. A passband of 3.1 to 10.6 GHz is achieved with .9dB insertion loss an a return loss better than 10 dB. In [7] a quintuple UWB bandpass filter is designed using a multiple stub loaded resonator shows an insertion loss about 1.4 dB and a ffractional bandwidth about 117%. In [8] an UWB bandpass filter is designed on a micromachined silicon substrate showing an insertion loss 1.1 dB, return loss better than 15 dB with a FBW 107%. In [9] a compact notched UWB filter with improved out of band performance is proposed using the technique of quasi electromagnetic bandgap (EBG) structure achieved insertion loss about 1.7 dB and return loss about 10 dB in the passband .A multimode resonator is proposed in [10] which is constructed by cascading interdigital coupled microstrip line sections with short-ended stepped impedance stubs being loaded. The realized filter achieved insertion loss about .7dB with a fractional bandwidth of 106%. .Most of the above discussed technique provide insertion loss about 1 dB and return loss is better than 10 dB. Also the dimensions which are to be implemented are very small which required high resolution lithography machines hence increasing the overall cost of filter. In the present design five short circuited quarter wavelength stubs are utilized to achieve UWB filter characteristics. Optimization and parameterization of

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designed parameters (lengths and width) is done in order to achieve improved results. The design procedure is discussed in next section.

2. UWB FILTER DESIGN

The design is based on a low pass chebychev filter prototype with .1 dB passband ripples. The equivalent structure for short circuited stub filter is shown in figure 1[11]. Here, UWB with centre frequency 6.85GHz and fraction bandwidth 1.06 is designed on a 1.27 mm substrate thick polystyrene substrate with dielectric constant ε_r=2.6 and simulated using HFSS 13.

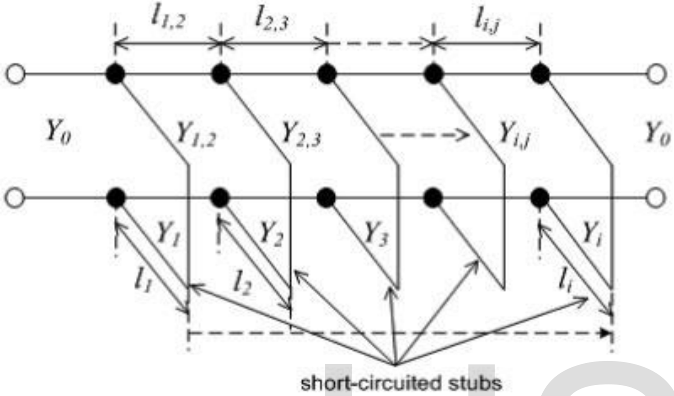


Fig.1. short circuited stubs filter model

The model in figure 1 is derived from J inverters by using conventional filter design and the line admittances, $Y_{i,i+1}$ given to fulfill the specifications. The separation distance between the stubs are denoted by $l_{i,j}$ whereas stub length is given by l_i. For designing the proposed filter first a 5th order chebychev low pass prototype with .1dB passband ripples is selected[11]. Low pass filter prototype parameters are given as : $g_0=g_6=1, g_1=g_5=1.1468$, $g_2=g_4=1.3712$and $g_3=1.9750$.With these prototype values following design equations are solved for calculating admittances values for stubs and connecting lines. The stub length and separation depend on characteristics admittances, Y_i, and transmission line admittances,$Y_{i,i+1}$.

The transmission line admittances, $Y_{i,i+1}$ can be obtained by using Eq.(1)[11].

$$Y_{i,i+1} = Y_0\left(\frac{J_{i,i+1}}{Y_0}\right) \text{ for } i = 1 \text{ to } n-1 \tag{1}$$

Where $J_{i,i+1}$ is the J-inverter given by Eq. (2),

$$\frac{J_{i,i+1}}{Y_0} = \frac{h g_0 g_1}{\sqrt{g_i g_{i+1}}} \text{ for } i = 2 \text{ to } n-2 \tag{2}$$

The constant h is dimensionless to give convenient admittance
taken as unity here.

Stub admittance, Y_1 and Y_n can be found from Eqs. (3) and (4) respectively

$$Y_1 = g_0 Y_0\left(1-\frac{h}{2}\right) g_1 \tan\theta + Y_0\left(N_{1,2}-\frac{J_{1,2}}{Y_0}\right) \tag{3}$$

$$Y_n = Y_0\left(g_n g_{n+1} - g_0 g_1 \frac{h}{2}\right)\tan\theta + Y_0\left(N_{n-1,n}-\frac{J_{n-1,n}}{Y_0}\right) \tag{4}$$

Also,from eq.(5) other values of stub admitances can be calculated

$$Y_i = Y_0\left(N_{i-1,i}+N_{i,i+1}-\frac{J_{i-1,i}}{Y_0}-\frac{J_{i,i+1}}{Y_0}\right) \text{ for } i = 2 \text{ to } n-1 \tag{5}$$

Where

$$N_{i,i+1} = \sqrt{\left(\frac{J_{i,i+1}}{Y_0}\right)^2 + \left(\frac{h g_0 g_1 \tan\theta}{2}\right)^2} \text{ for } i = 1 \text{ to } n-1 \tag{6}$$

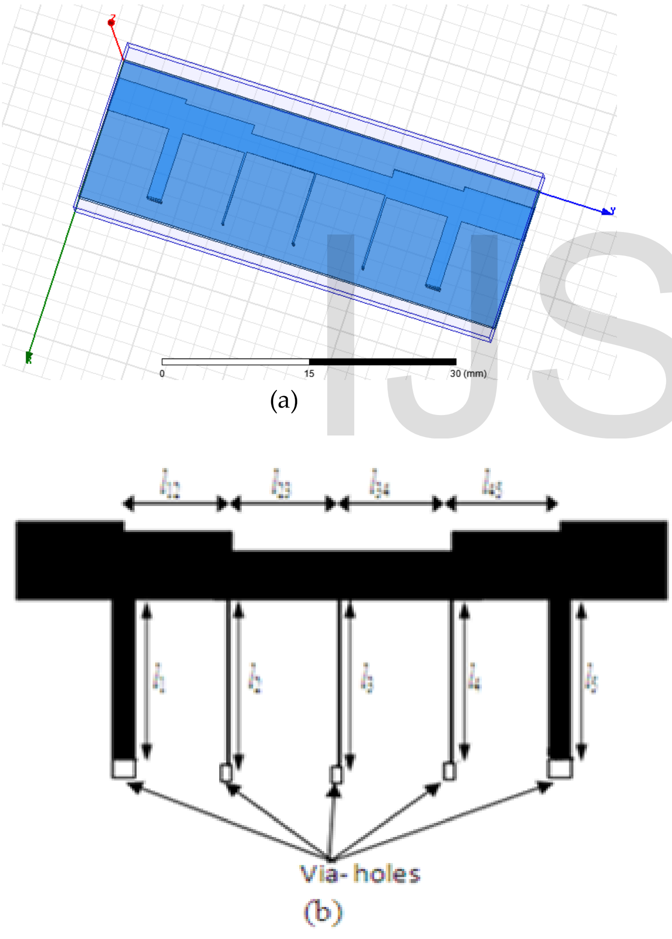
$$\theta = \frac{\pi}{2}\left(1-\frac{FBW}{2}\right) \tag{7}$$

The calculated admittances and impedances for five short-circuited stubs (Y_i and Z_i) and transmission lines ($Y_{i,i+1}$ and $Z_{i,i+1}$) are applied to standard equations for microstrip [11] to obtain the dimension of line given by Table 1.The length corresponding to 50 Ω transmission line at input and output port is taken as 3.52 mm.

TABLE 1
Stubs and Transmission Line Dimension

I	stubs		Transmission lines	
	L(mm)	W(mm)	L(mm)	W(mm)
1	7.5	1.49	7.5	3.05
2	7.76	.23	7.6	1.983
3	7.5	.21	7.6	1.983
4	7.76	.23	7.5	3.05
5	7.5	1.49	---	---

The designed structure and its layout is shown in figure 2.



(a)

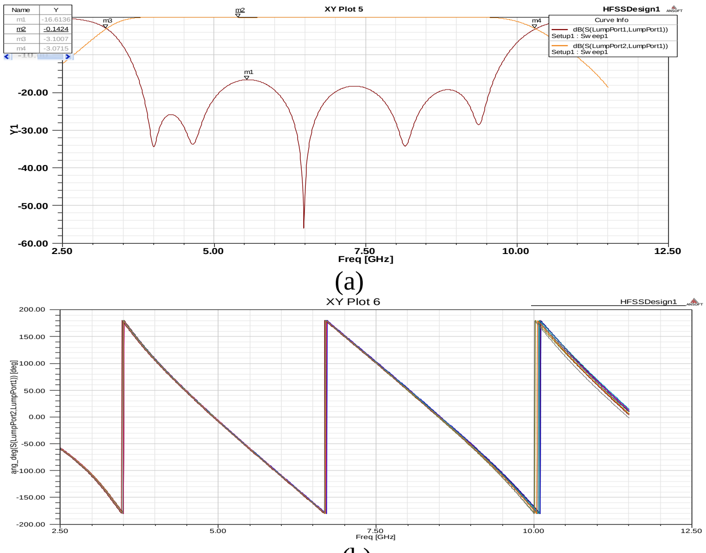
(b)

Fig. 2.(a) Designed UWB filter in HFSS 13 (b) layout with parameters(l_1=l_2=l_4=l_5=7.5mm;l_3=7.76mm;l_{12}=l_{45}=7.5mm;l_{23}=l_{34}=7.6mm @6.85GHz)

Each stub in figure 2(a) is short circuited to ground through a via at each end.The structure in figure 2 (a) is simulated using HFSS 13.with stub dimension shown in table 1. To get better results dimensions are adjusted slightly to get better results.

3. RESULTS AND DISCUSSION

Filter is designed using a low cost 1.27 mm thick polystyrene substrate of relative dielectric constant ε_r=2.6.The minimum dimension of filter i.e 0.21mm which can be realized using simple optical lithography or micromachining technique. The simulated results of scattering parameters using HFSS 13 is shown below in figure 3. The size of as designed UWB filter size ($1.36\lambda_g \times 0.33\lambda_g$).The measured results show an in-band insertion loss of 0.14dB in the entire passband of 7.23 GHz thus providing lowest insertion loss when compared with minimum insertion loss(<0.7dB) as shown in Table 2. The filter shows return loss better than 16.6dB thus good impedance matching is achieved at the I/O ports. The designed filter gives a 3-dB fractional bandwidth of 106% from 3.12 GHz to 10.4 GHz; hence almost entire band allocated by FCC is utilized. The phase response is ripple free in entire pass band of 7.28GHz.The calculated value of group delay is about .26 ns remains almost flat over entire bandwidth because phase response is ripple free in the passband .Thus the simulated scattering parameters and group delay manifest that designed filter has a stable and excellent performance over entire UWB spectrum



(a)

(b)

Fig. 3.simulated result (a) S_{11} (dB) and S_{21} (dB) (b) phase response

TABLE 2
Comparison with other filters

Ref.	Insertion Loss (dB)	Return Loss (dB)	3dB FBW	Group Delay [nsec]	Size $\lambda_o \times \lambda_o$
[6]	≤0.9	≥10	109%	-----	0.32 × 0.12
[7]	≤ 1.4	≥11	117%	0.85	0.51×0.37
[8]	≤ 1.1	≥15	107%	0.3	0.109×0.7
[9]	≤ 1.7	≥12	106%	0.3	0.87× .54
[10]	≤ 0.7	≥17	106%	0..9	0.48×0.12
Present Work	≤ 0.14	≥16.6	106%	0.26	1.027 × 0.25

4. CONCLUSION

An UWB microwave filter utilizing quarter wavelength short-circuited stubs has been designed. Detailed parametric analysis is done successfully to achieve a low loss and good performance UWB filter with flat group delay. The simulated scattering parameters and phase response over the others discussed in Table 2 proved that filter has excellent characteristics i.e flat group delay, low insertion loss and better return loss over entire UWB spectrum and can widely be used in wireless personal area network (WPAN) applications, wireless monitors ,sensor networks, imaging system which include Ground Penetrating Radar (GPR) system etc.

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