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Design of UWB Microstrip Filter Using 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 within 3.13-10.4 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 shows an insertion loss (S21) less than -0.1dB and return loss (S11) better than -16.5 dB. Group delay is also flat in passband.

KEYWORDS: Microwave filter; UWB; microstrip; quarter wavelength; short circuited stubs.

I. 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 spectrum of 7.5GHz from 3.1 GHz to 10.6 GHz in February 14,2002 [1].The UWB used at a very low power level for short range, high bandwidth communication using a large part of radio spectrum. The key passive component in UWB is front end receiver required to meet some stringent specifications compactness, low insertion better return loss . 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.

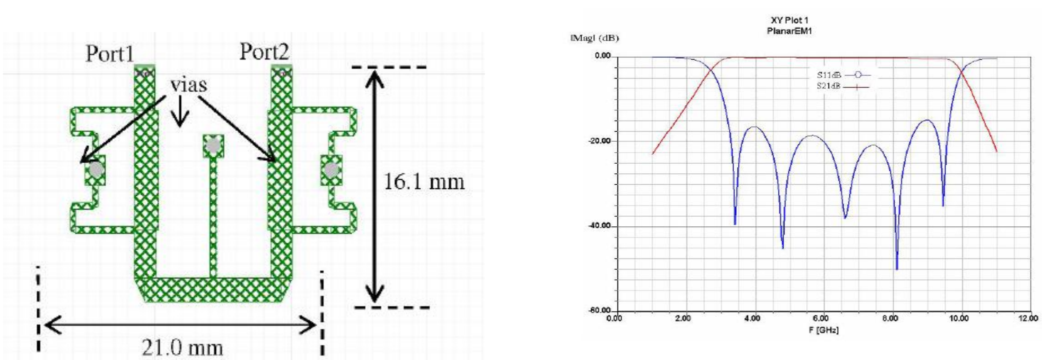
A broadband filter using interdigital bandpass filter microstrip line resonator was presented in [2] with a maximum bandwidth up to66%.In [5] UWB filter is designed using transmission line stubs. Proposed filter achieved insertion loss about-0.1dB, return loss better than -16.5dB and FBW of 106%. The 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 and 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 fractional bandwidth about 117%. In [8] 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 [9] 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 designed parameters (lengths and width) is done in order to achieve improved results. The design procedure is discussed in next section.

II. LITERATURE SURVEY

C. Nguyen [10] A new, compact, very-broadband bandpass filter, consisting of two-parallel-conductor short-circuited spur line resonators, a quarter-wavelength long, is described. This filter Possess a very wide bandwidth, more than 5:l. A microstrip filter having a passband from 1.8 to 9.2GHz has been designed and tested with less than 1dB insertion loss. Filter is very attractive for wideband microwave integrated circuits due to its compactness and very wide bandwidth.

Mohammad ShahrazelRazalli, Alyani Ismail [11] presents a compact 5 poles Ultra-
Wideband (UWB) microwave filter that uses a quarter wave short-circuited stubs. The microwave filter pattern layout as shown in Fig 1.1(a). The overall size of the filter is reduced to 16.1mm x21.0mm as compare to the filter designed using conventional short circuit stub technique 41mm x 12mm.
The UWB bandwidth is obtained from 2.72GHz to9.94GHz. The filter shows an insertion loss of than 0.8 dB, the maximum peak of return loss (S_{ll}) is at -14.88 dB at 9 GHz with the centre frequency of6.33 GHz.



(a) (b)

Fig 1.1: (a) Compact UWB microwave filter (b) insertion loss and return loss of compact UWB microwave filter

Thai Hoa Duong and Ihn S. Kim [12] proposes a modified short-circuited stub bandpass filter suitable for ultra-wideband applications utilizing low temperature co-fired ceramic (LTCC). By modifying the conventional short-circuited stub bandpass filter structure with lower characteristic impedances for stubs and connecting lines ,the number of stubs has been reduced from 5 to 2 stubs on a high dielectric constant substrate ($\varepsilon r = 40$). A wireless local area network (WLAN) stopband in the frequency range of 5.15 to 5.825 GHz has been inserted into the filter characteristic using three short-circuited coupled lines. An insertion loss less than 1.0dB and return loss better than 10 dB in the pass bands have been measured. A FBW of 109.49% has been achieved. The dimension of the filter is 4 × 8 × 0.57 mm3.

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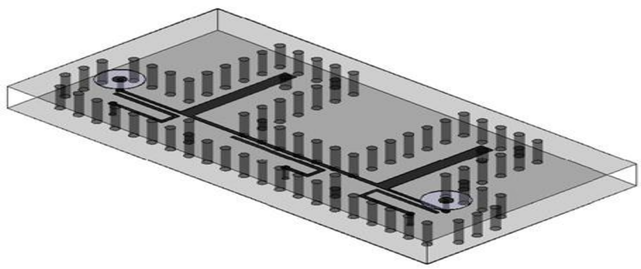

Fig 1.2:- Three dimensional structure of the UWB short circuited stub filter is using LTCC.

III. 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 figure1[13].

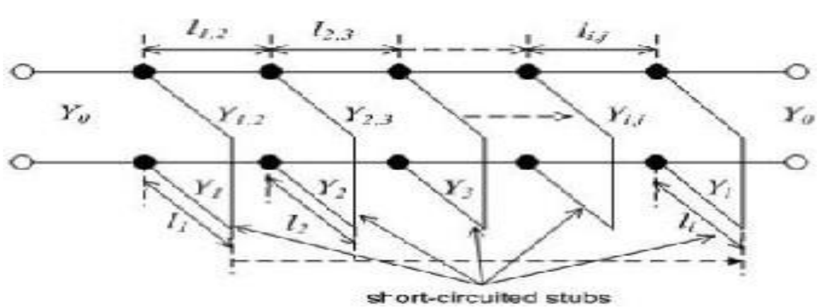

Fig1.3: short circuited stubs filter model

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.

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

$$\frac{J_{1,2}}{Y_o} = g_o\sqrt{\frac{hg_1}{g_2}} \quad (2)$$

h is a dimensionless constant for our example it is taken as 1.

$$\frac{J_{n-1,n}}{Y_o} = g_o\sqrt{\frac{hg_1 g_{n+1}}{g_o g_{n-1}}} \quad (3)$$

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$$\frac{J_{i,i+1}}{Y_o} = \frac{hg_o g_1}{\sqrt{g_i g_{i+1}}} \text{ for } i = 2 \text{ to } n-2 \quad (4)$$

Stub admittance, Y1 and Yn can be found from Eqs. (5) and(6) respectively

$$Y_1 = g_o Y_o \left(1 - \frac{h}{2}\right) g_1 \tan\theta + Y_o \left(N_{1,2} - \frac{J_{1,2}}{Y_o}\right) \quad (5)$$

$$Y_n = Y_o \left(g_n g_{n+1} - g_0 g_1 \frac{h}{2}\right) \tan\theta + Y_o \left(N_{n-1,n} - \frac{J_{n-1.n}}{Y_o}\right) \quad (6)$$

Also, from eq.(7) other values of stub admittances can be calculated

$$Y_i = Y_o \left(N_{i-1,i} + N_{i,i+1} - \frac{J_{i-1,i}}{Y_o} - \frac{J_{i,i+1}}{Y_o}\right) \quad \text{for } i = 2 \text{ to } n-1 \quad (7)$$

The model in figure 1 is derived from J inverters by using conventional filter design and the line admittances, Yi,i+1 given to fulfill the specifications. The separation distance between the stubs are denoted by li,j whereas stub length is given by li. For designing the proposed filter first a 5th order chebychev low pass prototype with .1dB passband ripples is selected [14]. Low pass filter prototype parameters are given as : g0=g6=1,g1=g5=1.1468, g2=g4=1.3712and g3=1.9750.With these prototype values following design equations are solved for calculating admittances values for stubs and connecting lines. Where

$$N_{i,i+1} = \sqrt{\left(\frac{J_{i,i+1}}{Y_o}\right)^2 + \left(\frac{hg_o g_1 \tan\theta}{2}\right)^2} \text{ for } i = 1 \text{ to } n-1 \quad (8)$$

The stub length and separation depend on characteristics admittances, Yi, and transmission line admittances,Yi,i+1. The transmission line admittances, Yi,i+1 can be obtained by using Eq.(9)[13].

$$Y_{i,i+1} = Y_o \left(\frac{J_{i,i+1}}{Y_o}\right) \text{ for } i = 1 \text{ to } n-1 \quad (9)$$

The calculated admittances and impedances for five short- circuited stubs (Yi and Zi) and transmission lines (Yi,i+1 and Zi,i+1) are applied to standard equations for microstrip [13] to obtain the dimension of line given by Table 1.The characteristic admittance of input and output lines are taken as 50 Ω for better impedance matching.

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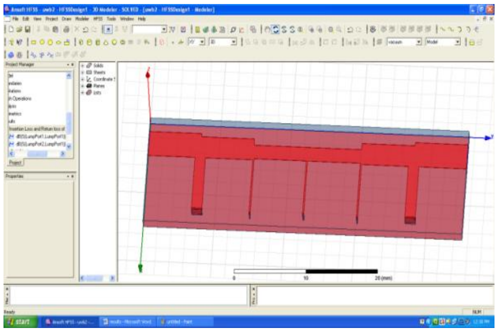
TABLE1

Dimensions specification	Length (mm)	Width (mm)
Dimension of stub1= stub5 ($l_1 = l_5$)	7.5	1.5
Dimension of stub2= stub4($l_2 = l_4$)	7.76	0.2
Dimension of stub3 (l_3)	7.747	0.194
Dimension of connecting lines12= lines45 ($l_{12}=l_{45}$)	7.51	3.05
Dimension of connecting lines23= lines34 ($l_{23}=l_{34}$)	7.614	1.985
Dimension of connecting lines at Source and load end	7.475	3.5



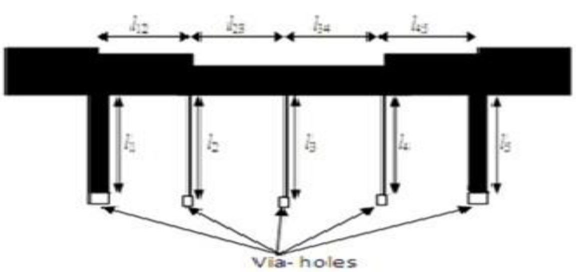


Fig1.4(a) Designed Ultra Wide Bandpass filter using quarter wave short circuited stubs (b) layout of ultrawide bandpass filter

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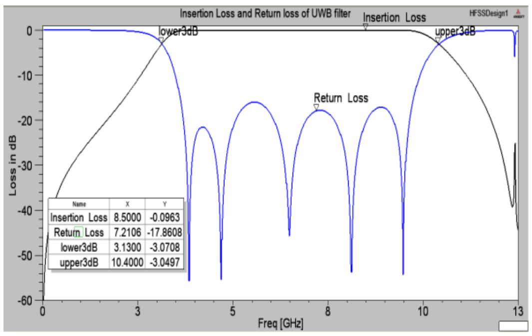
Each stub in figure1.4 is short circuited to ground through a via at each end. The structure in figure 1.4 is simulated using HFSSwith stub dimension shown in table 1. To get better results dimensions are adjusted slightly to get better results.

IV. 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 is shown below in figure 3. The size of as designed UWB filter size (45mmx11mm).The measured results show an in-band insertion loss of -0.1dB in the entire passband of 7.27 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 16.5dB 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 to10.4 GHz



I. Fig1.5:simulated result (a) S11 (dB) and S21 (dB) (b) phase response

Comparison with other filters

Ref.	Insertion Loss(dB)	Return Loss(dB)	3dB FBW
[6]	≤0.9	≥10	109%
[7]	≤ 1.4	≥11	117%
[8]	≤ 1.1	≥15	107%
[9]	≤ 1.7	≥12	106%
[10]	≤ 0.7	≥17	106%
Present Work	≤ -0.1	≥-16.5	106%

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Hence almost entire band allocated by FCC is utilized. The phase response is ripple free in entire pass band of 7.27GHz.Thus the simulated scattering parameters that designed filter has a stable and excellent performance over entire UWB spectrum

V. 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 . 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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