International Journal of Engineering & Technology, 7 (4) (2018) 4134-4140

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet. v7i4.19763
Research paper

Miniaturization of Ultra-wideband (UWB) band pass filter micro strip based on folded distributed method frequency 3.1 – 10.6 GHz

Didik Aribowo [1], Herudin [2] *, Fitrah Malik [2], Teguh Firmansyah [2]

[1] *Department of Electrical Engineering Education. Universities Sultan Ageng Tirtayasa*
[2] *Department of Electrical Engineering. Universities Sultan Ageng Tirtayasa*
**Corresponding author E-mail: h3ru3rl1@yahoo.co.id*

Abstract

Filter plays a very important role in many application of RF/microwave/ultra-wideband technology. UWB is a technology which is interested for researcher since being published on February 14, 2002 by U.S Federal Communication Commission (FCC) which has been approved including unlisence frequency at the range of 3.1 – 10.6 GHz and designated for commercial communication. As novelty, this research is proposed of miniaturization of ultra-wideband (UWB) bandpass filter microstrip based on folded distributed method frequency 3.1 – 10.6 GHz. This filter is a depiction of a microstrip substrate Duroid 5880 with relative its dielectric constant as 2.2 and its thickness as 0.787 mm. initial dimension of its filter can be calculated by using simulation software ADS 2011. The result of conventional filter design is fa = 2.80 GHz, fb = 10.48 GHz, BW = 7.68 GHz fc = 6.346 GHz Fbw = 1.210 %. The result of outer folded filter design is fa = 3.475 GHz, fb = 9.650 GHz, bw = 6.175 GHz fc = 6.562 GHz fbw = 0.941 %. The result of inner folded filter design is fa = 3.400 GHz, fb = 9.925 GHz, bw = 6.525 GHz fc = 6.663 GHz fbw = 0.979 %. This result also shows that the usage of UWB outter folded filter has reduction the filter size of 4.25 % and for UWB inner folded filter size reduction of 42.85 % in term of filter size. Overall, these results indicate that filter has good performance with compact size.

Keywords: *Band Pass Filter; Distributed; Folded; UWB.*

1. Introduction

Ultra wideband is a technology which is interested for researcher since being published on February 14, 2002 by U.S Federal Communication Commission (FCC) which has been approved including unlisence frequency at the range of 3.1 - 10.6 GHz and designated for commercial communication [1-7]. This technology has speed of data up to 480 Mbps, with low EIRP level as (-41.3dBm/MHz), low power consumption which is only 100 mW and with bandwidth as bandwidth as 7.5 GHz. UWB can deliver data with the speed of 480 Mbps. UWB system can designed for Bluetooth, which is as personal area network (PAN) technology which operate with low power and distance of about 10 meters. If one video streaming needs 7 Mbps, it means that about 70TV or PC which can access one film at the same time.

To transfer100 Mbit information, information will be divided into 10 or more parts and passed through 10 carrier frequencies. It is what we call as Orthogonal Frequency Division Multiplexed (OFDM) which is network technology of UWB. [4] one of technology which is approximated as the core of supporting access. Therefore, it is understandable if UWB can let through high data with maximum speed. The advantage of UWB is that is has low interference, because the transmission is spread through radio spectrum and the signal spread make it hard to be hindered. This advantage makes military as first party which adopts short distance wireless connectivity technology-based system. Because the signal produced has low power and spread through spectrum, so that the signal can share the space with existing radio communication and it does not disturb the services. This is important consider that nowadays almost all area on radio spectrum has been used as services.

As novelty, this research is proposed miniaturization of ultra-wideband (UWB) bandpass filter microstrip based on folded distributed method frequency 3.1 – 10.6 GHz. Purpose of the research is to design and analyze simulation result of compact ultra wideband filter at the frequency range of 3.1 up to 10.6 GHz.

2. Design of UWB band pass filter base on distributed method

2.1. Ultra wideband (UWB) technology

Ultra Wideband (UWB) is a network technology which can be used in application of wireless network with data utra fast transfer speed classified as short Range Wireless. This technology is another choice of wireless based connection technology such as blue tooth and WIFI. As we known the device/gadget improvement that needs wireless connectivity improve significantly as life style change. The demand of wireless technology development is not only in term of availability in an device/gadget but also have to be supported by the speed and high bandwidth availability of multiple high bandwidth. This advantage is highly needed in various application for example is video streaming, voip and video call which is highly need multiple high bandwidth. Technology which can accommodate this need is ultra wideband technology.

Copyright © 2018 Didik Aribowo et. al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Ultra wideband is a technology which is very highly demanded by researcher since its publication on February 14 2002 by US Federal Communication Commission (FCC) which is approved and including unlicensed frequency at the range of 3.1 – 10.6 GHz which designated for commercial communication. This technology has data speed up to 100mW and with the bandwidth as 7.5 GHz. However UWB working at frequency of 3.1 Ghz-10.6 Ghz. [8-40].

In 2002 UWB regulation is published by FCC US, which is unlisenced frequency with the range of 3.1 GHz, EIRP -41.3 dBn/MHz and minimum bandwidth of 500 MHz. Standard of UWB can be seen at the IEEE 802.15.4a which has been published in 2007. This standard explain frequency band with liw band at the range of 3.1 GHz- 5 Ghz and upper band range of 6 GHz-10.6 GHz. IEEE 802.15.3a, standard which explain physical layer with high data rate with the range of 110 -480 Mbps and range distance less than 10 m.

2.2. UWB band pass filter based on distributed method

Filter plays a very important role in many application of RF/micro wave. B important application such as wireless communication gives challenge for the development of RF filter/ micro wave so that it is better than the previous one, has high performance, smaller size, lighter and cheaper. Newest improvement in material and production technology including High Temperature super conductor (HTS), low temperature cofir ceramic, Micro monolithic integrated wave circuit (MMIC), micro electron mechanic system (MEMS) and micro machine technology has trigger the rapid improvement in microstrip application and other filter for FR/micro wave. In improvement of computer assisted tool design (CAD), such as simulator electromagnetic wave, has given filter design change. Many new microstrip filter with improved filtering characteristic has been found. [13]

Microstrip filter for RF/micro wave application offer unique and comprehensive maintenance based on microstrip structure, provide correlation for application of computer assistant tool design and improvement of material and technology. Many material and filter which is good using design of computer assistant material are discussed, from the basic concept up to practice realization. [14-15].

One suspending network which designed especially for frequency respond or Phase known as filter, block diagram of filter can be seen on Figure 1. In its application, filter has to be suitable based on frequency respond which has been determined and another important thing is shorten delay time and respond of phase and the parameter can overcome the change fast. Band Pass Filter is a filter that only passing through signal and its frequency attached in frequency band or certain pass band. Frequency from signal which placed under or above the frequency band, cannot be passed or muted by band pass filter circuit. Figure 1 shows respond of band pass filter.

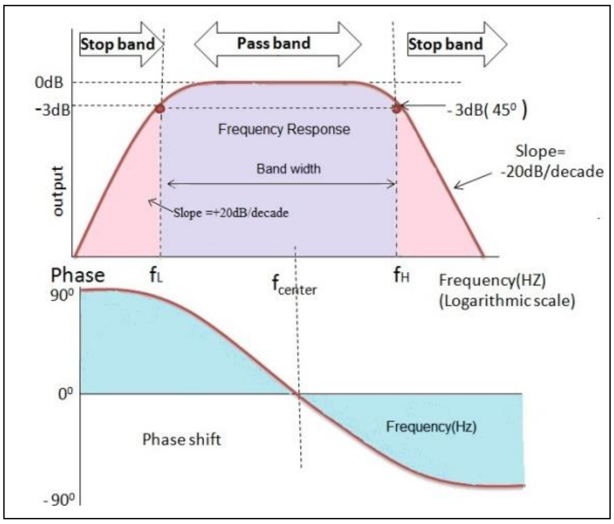


Fig. 1: The Frequency Response of the Band Pass Filter (BPF).

In making a filter there is a calculation to determine the size (length and width) for stubs to make. These stubs represent the electric length θ_c from the predetermined frequency of f_c is separated by connecting line (unit element) from electric length $2\theta_c$.

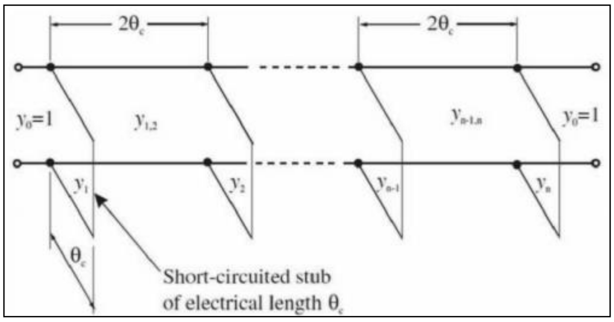


Fig. 2: Optimum Distributed Filter Method.

The characteristic of filter transmission shown in Figure 2, in which f is variable frequency and θ is electric length, which is proportional with f.

$$\theta = \theta c \frac{f}{fc} \quad (1)$$

This filter has pass band frequency from θ_c up to $\pi - \theta_c$ with the cut off at θ_c. Harmonization happen periodically and centralized at $\theta = 3\pi/2,\ 5\pi/2,..$,is separated by atenuasi pole which is located at $\theta = \pi,\ 2\pi$. Transfer function in insertion loss from figure 1 as characteristic of filtering can be explained by:

$$|S_{21}(\theta)|^2 = \frac{1}{1+\varepsilon^2 F_N^2(\theta)} \quad (2)$$

Where ε is constant wave of pass band, θ is dielectric length as explained at (3.10) and F_N is filtering function obtained from:

$$F_N(\theta) = \frac{\left(1+\sqrt{1-x_c^2}\right)T_{2n-1}\left(\frac{x}{x_c}\right)-\left(1-\sqrt{1-x_c^2}\right)T_{2n-3}\left(\frac{x}{x_c}\right)}{2\cos\left(\frac{n}{2}-\theta\right)} \quad (3)$$

Where n is number of stub short circuited,

$$x = \sin\left(\frac{\pi}{2}-\theta\right), x_c = \sin\left(\frac{\pi}{2}-\theta_c\right) \quad (4)$$

And $T_n(x) = \cos(n \cos^{-1} x)$ is function of Chebyshev of first type of n degree.

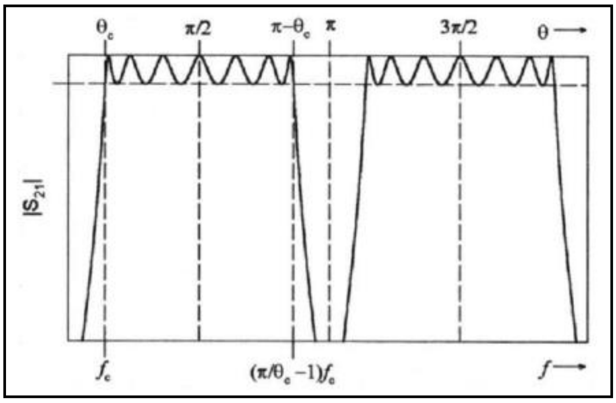


Fig. 3: Characteristic of Optimum Distributed Filter.

This Filter cutoff frequency (f_c) at 3 GHz and 0.1 dB wave pass band up to 12 GHz. From that specification, dielectric length θ_c can be found by:

$$\left(\frac{\pi}{\theta_c} - 1\right) f_c = 12 \tag{5}$$

It explain that $\theta_c = 36^\circ$ from Table 1, using element value for n = 6 and $\theta_c = 35^\circ$, which will give a wider pass band up to 12,4 GHz. Through ekstrapolation from value of element shown id in table 1, element value of $\theta_c = 36^\circ$ is found.

Table 1: Element Value from Optimum Distributed Filter with the Wave of zero, 1 Db

n	θ_c	$y_1 y_n$	$y_{1,2}\, y_{n-1,n}$	$y_2\, y_{n-1}$	$y_{2,3}\, y_{n-2,n-1}$	$y_3\, y_{n-2}$	$y_{3,4}$
2	25°	0.15436	1.13482				
	30°	0.22070	1.11597				
	35°	0.30755	1.08967				
3	25°	0.19690	1.12075	0.18176			
	30°	0.28620	1.09220	0.30726			
	35°	0.40104	1.05378	0.48294			
4	25°	0.22441	1.11113	0.23732	1.10361		
	30°	0.32300	1.07842	0.36443	1.06488		
	35°	0.44670	1.03622	0.62527	1.01536		
5	25°	0.24068	1.10540	0.27110	1.09317	0.29659	
	30°	0.34252	1.07119	0.43985	1.05095	0.48284	
	35°	0.46895	1.02790	0.66089	0.99884	0.72424	
6	25°	0.25038	1.10199	0.29073	1.08725	0.33031	1.08302
	30°	0.35346	1.06720	0.46383	1.04395	0.52615	1.03794
	35°	0.48096	1.02354	0.68833	0.99126	0.77546	0.98381

From element value on table 1 it shows element value of y_1 for n = 6 and $\theta_c = 36^\circ$ as:

$$y_1 = 0.48096 + \left(\frac{0.48096 - 0.35346}{5} \times 1\right) = 0.50646$$

By having the same way, the remain of element value can be calculated as:

$$y_{1,2} = 1.014808, y_2 = 0.50873, y_{2,3} = 0.93857, y_3 = 0.825322, y_{3,4} = 0.972984$$

This filter is ended double by $Z_0 = 50\ \Omega$, related to impedance characteristic the line is ended by:

$$Z_i = \frac{Z_o}{y_i} \tag{6}$$

$$Z_{i,i+1} = Z_o / y_{i,i+1} \tag{7}$$

By using equation (6) and (7) impedance characteristic for line element is $Z_1 = 98.72\Omega$, $Z_2 = Z_5 = 98.28\ \Omega$, $Z_3 = Z_4 = 60.58\Omega$, $Z_{1,2} = Z_{5,6} = 49{,}27\Omega$ $Z_{2,3} = Z_{4,5} = 53.37\Omega$, and $Z_{3,4} = 51.39\Omega$. this filter is a depiction of a microstrip substrate Duroid 5880 with relative its dielectric constant as 2.2 and its thickness as 0.787 mm.

Table 2: Data sheet of Rogers Duroid 5880

PROPERTY	TYPICAL VALUES RT/duroid 5870		TYPICAL VALUES RT/duroid 5880		DIRECTION	UNITS[3]	CONDITION	TEST METHOD
[1]Dielectric Constant, ε_r Process	2.33 2.33 ± 0.02 spec.		2.20 2.20 ± 0.02 spec.		Z Z	N/A	C24/23/50 C24/23/50	1 MHz IPC-TM-650 2.5.5.3 10 GHz IPC-TM 2.5.5.5
[4]Dielectric Constant, ε_r Design	2.33		2.20		Z	N/A	8 GHz - 40 GHz	Differential Phase Length Method
Dissipation Factor, tan δ	0.0005 0.0012		0.0004 0.0009		Z Z	N/A	C24/23/50 C24/23/50	1 MHz IPC-TM-650, 2.5.5.3 10 GHz IPC-TM-2.5.5.5
Thermal Coefficient of ε_r	-115		-125		Z	ppm/°C	-50 - 150°C	IPC-TM-650, 2.5.5.5
Volume Resistivity	2 X 10^7		2 X 10^7		Z	Mohm cm	C96/35/90	ASTM D257
Surface Resistivity	2 X 10^7		3 X 10^7		Z	Mohm	C/96/35/90	ASTM D257
Specific Heat	0.96 (0.23)		0.96 (0.23)		N/A	J/g/K (cal/g/C)	N/A	Calculated
Tensile Modulus	Test at 23 °C	Test at 100 °C	Test at 23 °C	Test at 100 °C	N/A	MPa (kpsi)	A	ASTM D638
	1300 (189)	490 (71)	1070 (156)	450 (65)	X			
	1280 (185)	430 (63)	860 (125)	380 (55)	Y			
ultimate stress	50 (7.3)	34 (4.8)	29 (4.2)	20 (2.9)	X			
	42 (6.1)	34 (4.8)	27 (3.9)	18 (2.6)	Y			
ultimate strain	9.8	8.7	6.0	7.2	X	%		
	9.8	8.6	4.9	5.8	Y			
Compressive Modulus	1210 (176)	680 (99)	710 (103)	500 (73)	X	MPa (kpsi)	A	ASTM D695
	1360 (198)	860 (125)	710 (103)	500 (73)	Y			
	803 (120)	520 (76)	940 (136)	670 (97)	Z			
ultimate stress	30 (4.4)	23 (3.4)	27 (3.9)	22 (3.2)	X			
	37 (5.3)	25 (3.7)	29 (5.3)	21 (3.1)	Y			
	54 (7.8)	37 (5.3)	52 (7.5)	43 (6.3)	Z			
ultimate strain	4.0	4.3	8.5	8.4	X	%		
	3.3	3.3	7.7	7.8	Y			
	8.7	8.5	12.5	17.6	Z			
Moisture Absorption	0.02		0.02		N/A	%	.062" (1.6mm) D48/50	ASTM D570
Thermal Conductivity	0.22		0.20		Z	W/m/K	80°C	ASTM C518
Coefficient of Thermal Expansion	22 28 173		31 48 237		X Y Z	ppm/°C	0-100°C	IPC-TM-650, 2.4.41
Td	500		500		N/A	°C TGA	N/A	ASTM D3850
Density	2.2		2.2		N/A	gm/cm³	N/A	ASTM D792
Copper Peel	27.2 (4.8)		31.2 (5.5)		N/A	pli (N/mm)	1 oz (35mm) EDC foil after solder float	IPC-TM-650 2.4.8
Flammability	V-0		V-0		N/A	N/A	N/A	UL94
Lead-Free Process Compatible	Yes		Yes		N/A	N/A	N/A	N/A

Initial dimension of its filter can be calculated by using simulation software ADS 2011.

3. Simulation result and discussion

In this filter simulation making it was used ADS 2011 software, and the initial making was from schematic first, it was not directly at the layout making. This is aim to ease and fasten in term of iteration, because in conducting a filter simulation on schematic is faster because at the time of schematic process is still the rough sketch of which the accuracy is not good yet if it wanted to produce, refer to the filter design on schematic and simulation result on schematic shows ideal result. In this schematic design making filter by using existing component of toolbox arrange to be filter.
Components which will be used in filter making on schematic are MLIN, MTEE, VIAGND, PIN, TERM, GROUND, S PARAM, VAR and MSUB. These components were arranged up to become ultra wide band filter as desired. In this filter making using Rogers Duroid 5880 substrate as can be seen more detail on table 4.1. in this schematic making process it has not finished yet because the next step was on the layout because possibly the result of schematic changed at the time it was being conducted in layout eventhough the change is not significant but it can not be neglected, probably the filter made change into better one the simulation result or vice versa when the filter running lay out.

3.1. Design of ultra-wide band (UWB) conventional stub filter [model-1]

In UWB conventional filter with 10 stubs this is one of the ways to obtain frequency of UWB filter which is at the range of 3.1 up to 10.6 GHz. The table below is the figure if conventional UWB with 10 stubs using ADS 2011 application. This UWB filter is arranged with several components, with different length and width. For length and width of this conventional UWB filter it can be seen on figure 4 with the note of: W1 = 0.67, W2 = 0.68, W3 = 1.75 W12 = 2.431, W23 = 2.16, W34 = 2.28, L1 = 2.431, L2 = 15.63, L3 = 15.69, L4 = 15.66, L12 = 8.11, L22 = 8.11, L23 = 7.9. for length unit and width used in this UWB filter using unit of mm (millimeter).

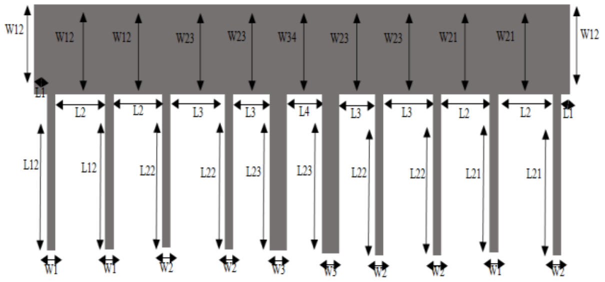


Fig. 4: Scheme of Conventional UWB Filter [Model 1].

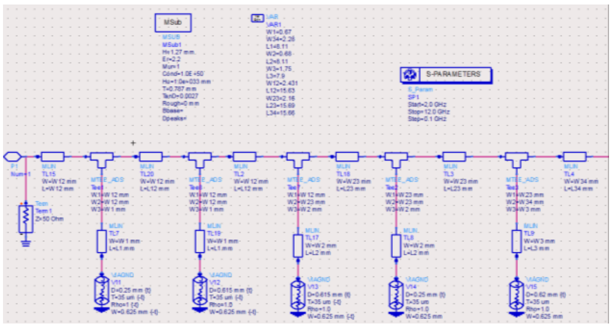
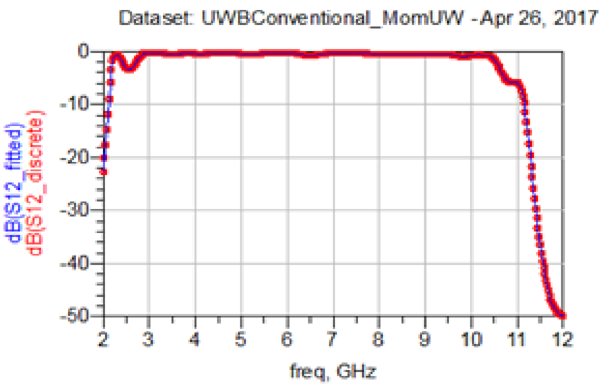


Fig. 5: Schematic of Conventional UWB Filter in Software of ADS [Model 1].

In Conventional UWB filter figure 5 using Rogers Duroid 5880 substract which has dielectric constant as 2.2 and thickness as1.27 mm. The next step after schematic is finished is scheme conversion into layout for cloe to real result. Figure 7 shows the filter design in a form of 10 arrows of stubs. The length of UWB filter is 154.7 mm with the distance between stubs is 15.7 mm, the length of the stub is 8.5 mm with two ports in each tip.

(A)



(B)

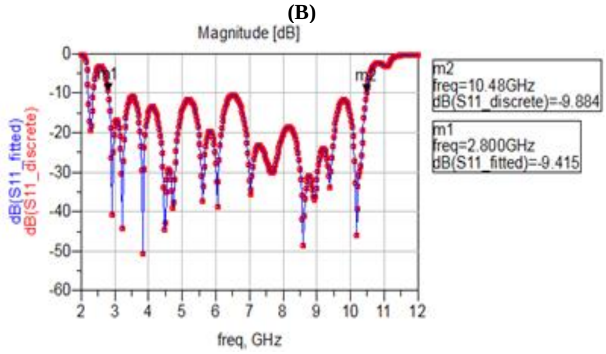


Fig. 6: Result of a) Insertion loss, b) Return Loss of Conventional UWB Filter [Model-1].

In this first iteration the result obtained is the initial frequency located in frequency of 2. Ghz and the final frequency was in the frequency of 10.4 GHz. In term of requirement for UWB filter, it has fulfilled the requirement which is the length of the frequency is at 3.1 up to 10.6 GHz but in the UWB filter design has length of 15.7 mm classified as non efficient because it is too long however it has fulfilled the requirement as UWB filter. The result of conventional filter design : fa = 2.80 GHz, fb = 10,48 GHz, bw = 7.68 GHz fc = 6.346 GHz fbw = 1.210 %.

3.2. Design of ultra-wide band (UWB) based on folded distributed method (outer folded) [model-2]

The design of ultra wide band outer folded filter is the second iteration with the filter design which initially was formed in row it was then changed into u shape with its stubs spread along with the U-shaped filter. This is aim to increase efficiency in term of design which is previously it was too long so that there was an idea to fold the filter which initially straight change into U-shape which has the aim to increase the efficiency in term of design but still fulfilling the requirement of UWB filter. The following figure shows the design of ultra wide band outer folded filter using ADS 2011 software.

U shape design in outer folded UWB filter is arranged with different components and different length and width, to find out the length and the width of outer folded UWB filter, it can be seen on figure 7 the explanation is: W1 = 0.67, W2 = 0.68, W3 = 1.75 W12 = 2.431, W23 = 2.16, W34 = 2.28, L1 = 2.431, L2 = 15.63, L3 = 15.69, L4 = 15.66, L12 = 8.11, L22 = 8.11, L23 = 7.9, L34 = 1.98. for the unit of length and width in UWB filter making is mm (millimeter) and for filter making it was used Rogers Duroid 5880 substrate.

Simulation result of the design, at the initial frequency of UWB filter is different at the frequency of 3.475 Ghz and the final frequency was 9.650 GHz. The design on figure 8 has total length of filter was 62.4 mm which is previously was 154.7 mm, and filter width as 38.3 mm which was previously was 10.9 mm.

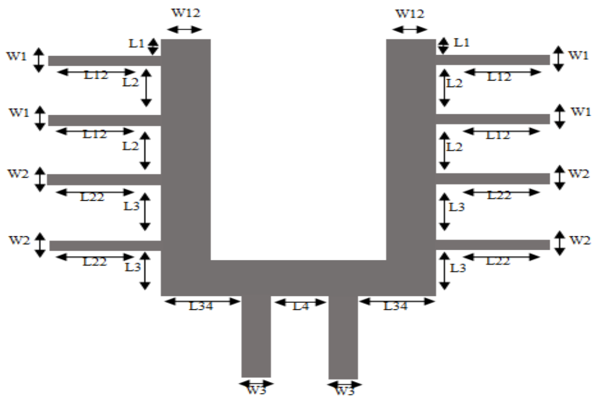


Fig. 7: Scheme of UWB Filter Based on Folded Distributed Method (Outer Folded) [Model-2].

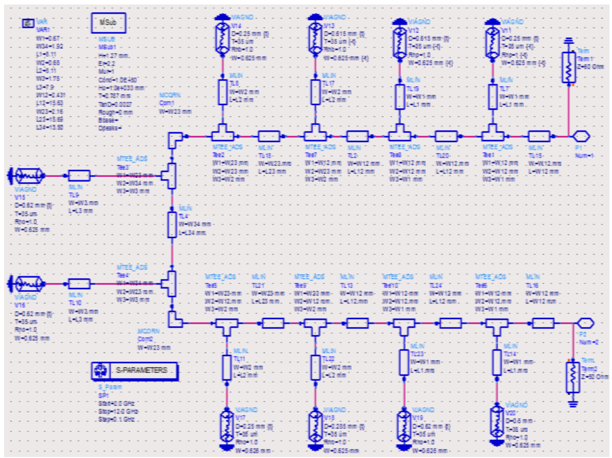


Fig. 8: Schematic of UWB Filter Based on Folded Distributed Method (Outer Folded) in Software of ADS [Model-2].

From figure 8 can be seen the design which initially has to be change into U-Shape with the stub placed at outer part of the bend.

It aims in order that UWB filter is more efficient in term of square therefore the design is changed.

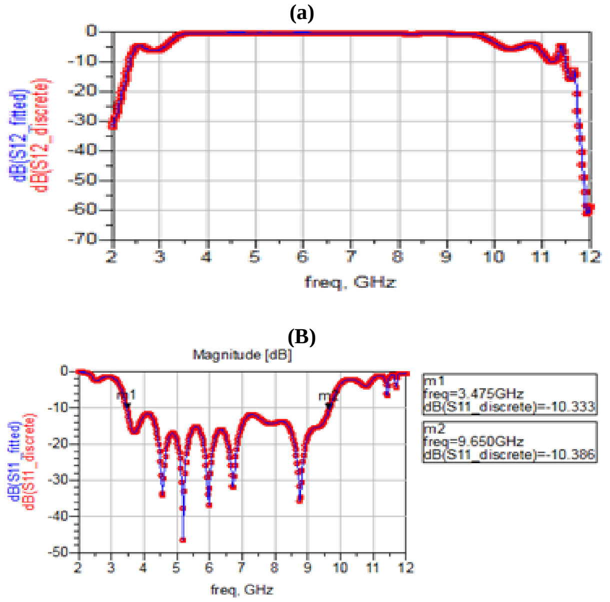


Fig. 9: Result of (a) Insertion loss, (b) Return Loss of UWB Filter Based on Folded Distributed Method (Outer Folded) [Model-2].

In term of simulation UWB filter has decrease which was previously at conventional UWB filter it had initial frequency of 2.8 Ghz and had final frequency of 10.4 GHz. However in term of filter length, outer folded UWB filter has advantage which previously has length of 154.7mm change into 62.4 mm and has effect at filter width which increase from 10.9 mm into 38.3 mm.

3.3. Design of ultra-wide band (UWB) based on folded distributed method (inner folded) [model-3]

Design of Ultra Wide Band Inner Folded Filter is third iteration from Ultra Wide Band Inner Folded Filter. The distinctive difference in stub spread at the bend, which previously at the iteration both stubs spread around the filter but at the third iteration. It can be seen that distinctive difference in second iteration, on figure 10 the stubs which are initially at the second iteration of ultra wide band inner folded filter located at the outer side encircle filter

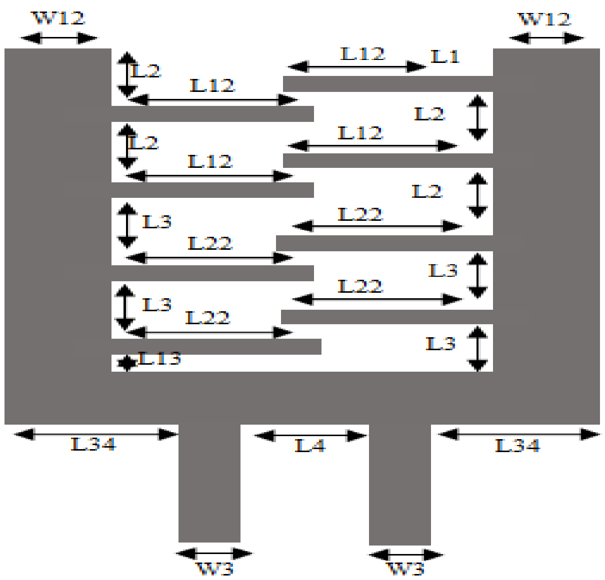


Fig. 10: Scheme of UWB Filter Based on Folded Distributed Method (Inner Folded) [Model 3].

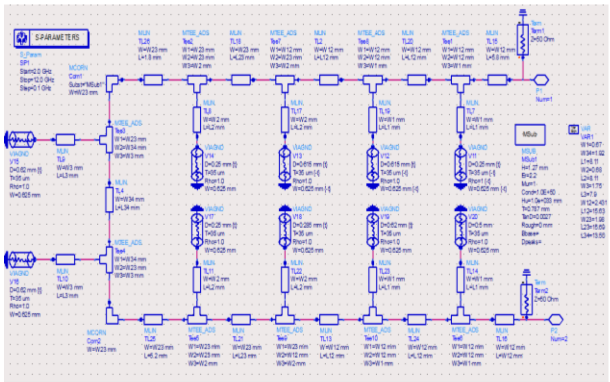


Fig. 11: Schematic of UWB Filter Based on Folded Distributed Method (Inner Folded) in Software of ADS [Model 3].

Meanwhile at the third iteration ultra-wide band inner folded filter, the stubs were on the inside of the filter. In term of length efficiency, ultra wide band inner folded filter has filter length as 67.6 mm which was previously was 62.4 mm, at third iteration filter length was longer because of the adjustment in order that the result still fulfill the requirement of ultra wide band filter. So that the length of the filter is a bit longer from second iteration. And for the width of ultra wide band inner folded filter reduce which was previously was 38.3 mm change to 21.0 mm. There was distinctive change at filter width at second iteration from 38.3 mm to 21.0 mm, it makes ultra wide band filter is more efficient than before in term of width and length which change at the second iteration.

The U design of outer folded UWB filter was arranged from different components as well as length and width of different component, to discover the length and the width of outer folded UWB filter it can be seen on figure 10 as explained , W1 = 0.67, W2 = 0.68, W3 = 1.75 W12 = 2.431, W23 = 2.16, W34 = 2.28, L1 = 2.431, L2 = 15.63, L3 = 15.69, L4 = 15.66, L12 = 8.11, L22 = 8.11, L13 = 1.8, L23 = 7.9. The length and width unit is mm (millimeter). And for filter making the substrate used was Rogers Duroid 5880 substrate.

In schematic of UWB filter figure 12 using Rogers Duroid 5880 substrate which has 2.2 dielectric constant and 1.27 mm thickness. The next step after schematic is finished the scheme conversion into layout for close-to-real result.

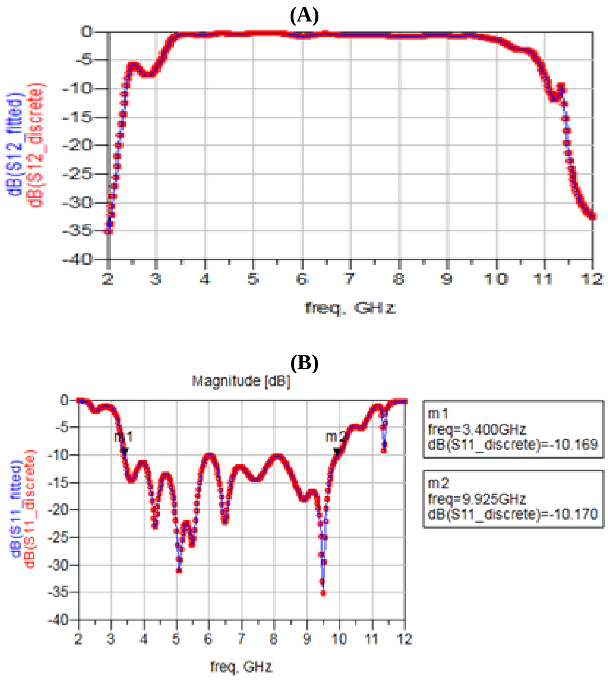


Fig. 12: Result of a) Insertion loss, b) Return Loss of UWB Filter Based on Folded Distributed Method (Inner Folded) [Model-3].

The result obtained from simulation using ADS 2011 software from ultra-wide band inner folded filter, initial frequency of the filter was 3.40 GHz and the final frequency was 9.925 GHz, it had fulfilled the requirement of ultra wide band filter which is at the range of 3.1 to 10.6 GHz. At the third iteration at ultra wide band filter the width of frequency was smaller than previous ones, this was due to drastic change in filter design which was initially straight with rows of stubs has good result at the frequency of 2.8 GHz – 10.4 GHz which fulfill the requirement as ultra wide band filter with the range of 3.1 to 10.6 GHz. In term of iteration result it can categorized into ultra wide band filter because of the ribbon width which was at the frequency of 3.4 GHz-9.925 GHz, although it did not reach the initial and end limit of the frequency determined for ultra wide band filter. However if it is compared to the third iteration the inner folded is more efficient in term of design because this design simplify initial shape which initially very long into simpler U-shape.

Table 3: Comparison of UWB BPF Performance

Performance	Conventional Filter [Model -1]	Outer Folded Filter [Model -2]	Inner Folded Filter [Model -3]
Lower band f_a (GHz)	2.80	3.475	3.40
Upper band f_b (GHz)	10.48	9.650	9.925
Center frequency f_c (GHz)	6.346	6.562	6.663
Bandwidth BW (GHz)	7.68	6.175	6.525
Fractional Bandwidth FBW (%)	1.21	0.941	0.979
Size (cm^2)	24.96	23.899	14.264
Size reduction	-	4.25 %	42.85 %

4. Conclusion

This research is proposed of miniaturization of ultra-wideband (UWB) bandpass filter microstrip based on folded distributed method frequency 3.1 – 10.6 GHz. This filter is a depiction of a microstrip substrate Duroid 5880 with relative its dielectric constant as 2.2 and its thickness as 0.787 mm. initial dimension of its filter can be calculated by using simulation software ADS 2011. The result of conventional filter design is fa = 2.80 GHz, fb = 10,48 GHz, BW = 7.68 GHz fc = 6.346 GHz Fbw = 1.210 %. The result of outer folded filter design is fa = 3.475 GHz, fb = 9.650 GHz, bw = 6.175 GHz fc = 6.562 GHz fbw = 0.941 %. The result of inner folded filter design is fa = 3.400 GHz, fb = 9.925 GHz, bw = 6.525 GHz fc = 6.663 GHz fbw = 0.979 %. This result also shows that the usage of UWB outter folded filter has reduction the filter size of 4.25 % and for UWB inner folded filter size reduction of 42.85 % in term of filter size. Overall, these results indicate that filter has good performance with compact size.

Acknowledgement

The authors thank the LPPM Universitas Sultan Ageng Tirtayasa (UNTIRTA) and Ministry of Research, Technology and Higher Education, Indonesian Government, KEMENRISTEK DIKTI for the financial support.

References

[1] C. Chen, Y. Takakura, H. Nihie, Z. Ma and T. Anada, "Design of compact notched UWB filter using coupled external stepped-impedance resonator," *2009 Asia Pacific Microwave Conference*, Singapore, 2009, pp. 945-948. https://doi.org/10.1109/APMC.2009.5384326.

[2] Z. Jicong, Z. Xiangjun and L. Hai, "UWB bandpass filter using complementary split-ring resonator-based highpass filter and defected ground structure," *2011 International Conference on Electronics, Communications and Control (ICECC)*, Ningbo, 2011, pp. 1194-1196. https://doi.org/10.1109/ICECC.2011.6066616.

[3] P. Ranjan, N. Kishore, V. K. Dwivedi, G. Upadhyay and V. S. Tripathi, "UWB filter with controllable notch band and higher stop band transmission zero using open stub in inverted T-shaped resonator," *2017 IEEE Asia Pacific Microwave Conference (APMC)*, Kuala Lumpar, 2017, pp. 817-820. https://doi.org/10.1109/APMC.2017.8251574.

[4] Y. Saini and M. Kumar, "Design analysis of UWB bandpass filter using suspended microstrip technology," *2014 International Conference on Signal Propagation and Computer Technology (ICSPCT 2014)*, Ajmer, 2014, pp. 1-4. https://doi.org/10.1109/ICSPCT.2014.6884896.

[5] M. Shen *et al*., "A compact UWB band-pass filter using embedded circular slot structures for improved upper stop-band performance," *2016 IEEE International Conference on Ubiquitous Wireless Broadband (ICUWB)*, Nanjing, 2016, pp. 1-3. https://doi.org/10.1109/ICUWB.2016.7790551.

[6] N. Zhao, X. He, W. Tian and W. Yang, "Acs-fed UWB bandpass filter with new structure," *2016 IEEE 13th International Conference on Signal Processing (ICSP)*, Chengdu, 2016, pp. 1729-1732. doi: 10.1109/ICSP.2016.787812

[7] S. Kumar, R. D. Gupta and M. S. Parihar, "Multiple Band Notched Filter Using C-Shaped and E-Shaped Resonator for UWB Applications," in *IEEE Microwave and Wireless Components Letters*, vol. 26, no. 5, pp. 340-342, May 2016. https://doi.org/10.1109/LMWC.2016.2549700.

[8] A. Joshi and D. Bhatia, "Analysis and design of compact UWB bandpass filter with single notch-band," *2014 International Conference on Advances in Engineering & Technology Research (ICAETR - 2014)*, Unnao, 2014, pp. 1-3. https://doi.org/10.1109/ICAETR.2014.7012801.

[9] S. Parvez, N. Sakib and M. N. Mollah, "A novel quasi-lumped UWB high pass filter with multiple transmission zeros," *2017 International Conference on Electrical, Computer and Communication Engineering (ECCE)*, Cox's Bazar, 2017, pp. 895-898. https://doi.org/10.1109/ECACE.2017.7913030.

[10] M. Żukociński, "A 5.8–10.6 GHz UWB filter using novel SIR structure," *2018 22nd International Microwave and Radar Conference (MIKON)*, Poznan, 2018, pp. 477-480. https://doi.org/10.23919/MIKON.2018.8405261.

[11] A. Kamma, R. Das, D. Bhatt and J. Mukherjee, "Multi Mode Resonators Based Triple Band Notch UWB Filter," in *IEEE Microwave and Wireless Components Letters*, vol. 27, no. 2, pp. 120-122, Feb. 2017. https://doi.org/10.1109/LMWC.2017.2649383.

[12] A. S. Tantawy, M. F. Habash and A. B. Abdel-Rahman, "B7. UWB band pass filter with two band notches using T-shape resonators," *2015 32nd National Radio Science Conference (NRSC)*, 6th of October City, 2015, pp. 51-56. https://doi.org/10.1109/NRSC.2015.7117814.

[13] Qing Shan, Chunhong Chen and Wen Wu, "Design of an UWB bandpass filter with a notched band using asymmetric loading stubs," *2016 IEEE International Conference on Microwave and Millimeter Wave Technology (ICMMT)*, Beijing, 2016, pp. 410-412. https://doi.org/10.1109/ICMMT.2016.7761791.

[14] Firmansyah, T., Praptodinoyo, S., Wiryadinata, R., (...), Alaydrus, M., Wibisono, G. Dual-wideband band pass filter using folded cross-stub stepped impedance resonator. *Microwave and Optical Technology Letters*. 59(11), pp. 2929-2934. 2017. https://doi.org/10.1002/mop.30848.

[15] Firmansyah, T., Praptodiyono, S., Pramudyo, A.S., Chairunissa, C., Alaydrus, M. Hepta-band bandpass filter based on folded cross-loaded stepped impedance resonator. *Electronics Letters*. 53(16), pp. 1119-1121. 2017. https://doi.org/10.1049/el.2017.1121.

[16] Jung, M., Min, B.-W."A highly selective UWB bandpass filter using stepped impedance stubs. International Journal of Microwave and Wireless Technologies, vol. 10(3), pp. 301-307. (2018). https://doi.org/10.1017/S175907871800020X.

[17] Sahu, B., Singh, S., Meshram, M.K., Singh, S.P." Super-compact ultra-wideband microstrip band-pass filter with improved performance using defected ground structure-based low-pass filtel". Journal of Electromagnetic Waves and Applications, 32 (5), pp. 635-650. (2018). https://doi.org/10.1080/09205071.2017.1402712.

[18] Kavosi, M., Nourinia, J., Ghobadi, Ch., Bazdar, A., Mohammadi, B." A compact UWB ring resonator BPF with double notched bands" IEEE 4th International Conference on Knowledge-Based Engineering and Innovation, KBEI 2017, 2018-January, pp. 0069-0071. 2017

[19] Setty, R., Kaplan, B., Morgan, M., Boyd, T."Combining MMIC reflectionless filters to create UWB bandpass filters" Microwave Journal, 61 (3), pp. 60-72. (2018).

[20] Karimi, G., Javidan, F., Salehi, A.H.”A compact UWB band-pass filter with a notch band using multi-mode stub-loaded resonators (MM-SLR)” International Journal of Microwave and Wireless Technologies, 10 (2), pp. 227-233. (2018) https://doi.org/10.1017/S1759078718000041.

[21] Thiasiriphet, T., Teich, W.G., Lindner, J.” A novel comb filter based rake-like receiver for code-reference UWB transmission”/ Conference on Signal Processing and Communication Systems, ICSPCS 2017 - Proceedings, 2018-January, pp. 1-9. 2017,

[22] Ionescu, V., Hnatiuc, M.” FEM modelling of split ring resonator based metamaterials for UWB notch filter applications” IEEE 23rd International Symposium for Design and Technology in Electronic Packaging, SIITME 2017 - Proceedings, 2018-January, pp. 29-32. 2017

[23] Xiao, R.-Q., Yang, G., Wang, Y., Wu, W.” Compact and high performance UWB band-pass filter based on parallel coupled line”. IEEE International Symposium on Microwave, Antenna, Propagation, and EMC Technologies, MAPE 2017, 2018-January, pp. 300-302.

[24] Sahoo, A.K., Gupta, R.D., Parihar, M.S.” Highly selective integrated filter antenna for UWB application”. Microwave and Optical Technology Letters, 59 (5), pp. 1032-1037. (2017). https://doi.org/10.1002/mop.30449.

[25] Xia, X., Liu, Y., Lin, H., Yang, T., Jin, H.”Novel UWB BPF with a controllable notched band using hybrid structure”. IEICE Electronics Express, 14 (6), six p. (2017).

[26] Li, X., Xia, Q., Zeng, J.” A compact quadruple-mode ultra-wideband bandpass filter with a broad upper stopband based on transversal-signal interaction concepts” Progress in Electromagnetics Research Letters, 69, pp. 119-125. (2017). https://doi.org/10.2528/PIERL17010204.

[27] Tsai, L.-C., Chen, W.-J.”A UWB antenna with band-notched filters using slot-type split ring resonators”. Microwave and Optical Technology Letters, 58 (11), pp. 2595-2598.2016 https://doi.org/10.1002/mop.30101.

[28] Kim, H.-J., Leaird, D.E., Weiner, A.M.” Rapidly Tunable Dual-Comb RF Photonic Filter for Ultrabroadband RF Spread Spectrum Applications”. IEEE Transactions on Microwave Theory and Techniques, 64 (10), pp. 3351-3362. (2016) https://doi.org/10.1109/TMTT.2016.2599162.

[29] Alqaisy, M.A., Chakrabraty, C., Ali, J., Alhawari, A.R.H., Saeidi, T. “Reconfigurable Bandwidth and Tunable Dual-Band Bandpass Filter Design for Ultra-Wideband (UWB) Applications” Electromagnetics, 36 (6), pp. 366-378. (2016) https://doi.org/10.1080/02726343.2016.1207766.

[30] Tseng, T.-H., Fang, W.-T., Lin, Y.-S.” Super compact and ultra-wideband bandpass filter using bridged-T coils” IEEE MTT-S International Microwave Symposium Digest, 2016-August, art. No. 7540338, . (2016)

[31] Shaman, H.N., Almughamis, A.M., Alamro, A.M., Alharthi, Y.S.” Compact ultra-wideband (UWB) bandpass filter with wideband harmonic suppression” International Conference on Microwave, Radar and Wireless Communications, MIKON 2016, art. No. 7492045.

[32] Yun, Y.-C., Oh, S.-H., Lee, J.-H., Choi, K., Chung, T.-K., Kim, H.-S.”Filter for UWB Applications Using an Improved Particle Swarm Optimization”. IEEE Transactions on Magnetics, 52 (3), art. No. 8001004, . 2016. https://doi.org/10.1109/TMAG.2015.2486141.

[33] Nilotpal, Upadhyay, D.K.” A compact UWB bandpass filter based on CRLH via-less CPW-fed” Microwave and Optical Technology Letters, 58 (2), pp. 276-279. (2016). https://doi.org/10.1002/mop.29548.

[34] Ghazali, A.N., Sazid, M., Pal, S.”A miniaturized microstrip-to-CPW transition based UWB-BPF with sharp roll-off and minimum insertion loss”. Microwave and Optical Technology Letters, 58 (2), pp. 289-293. (2016) https://doi.org/10.1002/mop.29551.

[35] Khan, S.M., Iftikhar, A., Asif, S.M., Capobianco, A.-D., Braaten, B.D.” A compact four elements UWB MIMO antenna with on-demand WLAN rejection”Microwave and Optical Technology Letters, 58 (2), pp. 270-276. (2016) https://doi.org/10.1002/mop.29546.

[36] Sharbati, V., Rezaei, P., Shahzadi, A., Fakharian, M.M.”A planar UWB antenna based on MB-OFDM applications with switchable dual band-notched for cognitive radio systems”.International Journal of Microwave and Wireless Technologies, 8 (1), pp. 95-102. (2016). https://doi.org/10.1017/S1759078714001317.

[37] Yang, L., Zhu, L., Choi, W.-W., Tam, K.-W.”Vertical microstrip-to-microstrip transition through the highpass-filter topology for ultra-wideband (UWB) applications”. HKIE Transactions Hong Kong Institution of Engineers, 23 (1), pp. 19-25. (2016)

[38] Naghar, A., Aghzout, O., Alejos, A.V., Sanchez, M.G., Essaaidi, M.” Design of compact wideband multi-band and ultrawideband band pass filters based on coupled half wave resonators with reduced coupling gap IET Microwaves, Antennas and Propagation, 9 (15), pp. 1786-1792. (2015) https://doi.org/10.1049/iet-map.2015.0188.

[39] Ramya, S., Rao, I.S.”Design of compact ultra-wideband microstrip bandstop filter using split ring resonator”. International Conference on Communication and Signal Processing, ICCSP 2015, art. No. 7322658, pp. 105-108. 2015

[40] Li, C., Tong, C., Qi, L., Zou, X., Ji, M.”Multimode resonator based on composite right-/Left-handed transmission line for UWB bandpass filter application”. International Journal of RF and Microwave Computer-Aided Engineering, 25 (9), pp. 815-824. (2015). https://doi.org/10.1002/mmce.20920.