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Comparison of Lumped Element UWB printed filter with Discrete Components

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Abstract

The main objective of the paper is to portray the design of microwave bandpass filter with the help of micro strip design. The proposed design of filter is simulated, fabricated, measured and analyzed for lumped and discrete element UWB filters. The range of this filter is about 3.1 GHz to 10.6 GHz. The filter is also expected towards producing low insertion loss. Proposed filter is simulated by HFSS and result show reasonable performances over entire UWB. Averaged insertion loss for UWB of this filter is about 0.2 dB within entire band with constant group delay. The equivalent circuit model of the UWB bandpass structure is presented in this paper. The results of UWB bandpass filter are compared with the general bandpass filter results which show that the UWB filter is fairly good.

Keywords: Bandpass, filter design, DGS, UWB, lumped elements.

Introduction

The bandpass filter in microwave communication systems is the fundamental component which is frequently used in many RF components and in transmitters and receivers. Band pass filter with comparatively wide bandwidth are essentially required in RF front ends, so that's why there quality is very important. Implementing a bandpass filter with larger bandwidth, keeping filter structure to minimum size, less insertion loss and also wideband rejection is very difficult job. Today the ultra wide band technology has become very interesting.

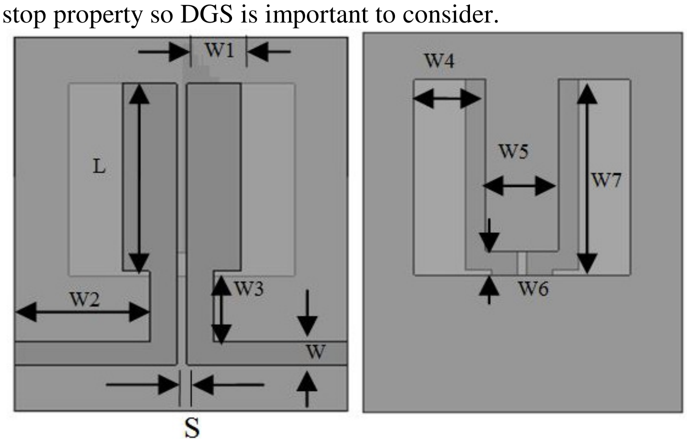
The ultra wide band (UWB) radio approach is acquiring extensive consideration among the educational as well as industrialized aspects. For the reason of its appealing attributes within enormous pace wireless systems; ultra wide band (UWB) transmission has been authorized through the Federal Communication Commission (FCC) in USA published unauthorized limits of frequency starting with 3.1GHz-10.6GHz intended for the domestic and hand held UWB systems in February 2002[1], spacious instant of frequency range of 3.1-10.6GHz with fixed group delay is required to operate in UWB filter. Recent research in microwave filters shows that many efforts have been focused on designing ultra wide band (UWB) band pass filter (BPFs) due to its increasing demand for ultra wide band applications because ultra wide band technology provides high data rates which results low interference, low cost, resistance to jamming and providing high data rates in multipath channel, compared with narrow wide band which provides low channel capacity, providing more interference signal in radio systems. A vital unreceptive element within UWB system states that a front-end filter is essential for meeting few stringent requirements which includes compressed, compact, small insertion thrashing, smooth group gap, in-band frequency refutation scratch, huge selectivity as well as wide band refusal. These all are conditions for UWB filters additionally by considering these, an escalating concern is being awaken amongst the educational and industrialized viewpoint on discovering numerous UWB elements and methods[2]. Researchers have developed many UWB filters using different techniques and designs. In the recent studies there was a technique developed for designing a composite micro-strip band-pass filter that is suitable for ultra-wide band (UWB) wire-less communication with the 3-dB fractional band width of more than 100%. The design is made of a high-pass and a lowpass filter embedding individually into each other. The impedance of low-pass filter attenuate high stop-band as well as quarter wave short circuited stubs are used to realize the lower stop band[3], the main challenge about the bandpass filter is to maintain wide stop-band and sharp passband. An UWB filter was designed for UWB communication system that absorb high frequency signals by using a lossy composite substrate, the insertion loss of this filter was 6dB and at high frequency the impedance matching was poor and also lacking the sharpness at the lower frequency[3]. Lumped element filter design is very difficult to design in microwave frequencies; due to limitations of lumped-element values these designs are generally unpopular. The design of filters on microstrip lines being a popular choice[4]. One of the other methods for the implementation of ultra wide band filter is the highpass filter (HPF) model in which short circuited stubs are cascaded[5]. Another simplest structure of filter constitutes cascaded short circuited stumps which are detached by identical linking lines. At lower cut off frequencies electrical length of these linking lines is two times of length of short circuited stubs[6]. The ultraide band filter was designed by mirroring of many different ring filters[7]. In this technique there are some disadvantages i-e these types of UWB filters encompass incisive band reject filters and the reaction will mortify out of band comeback as well as amount of portions are increased producing huge placing harm and the group delay was very poor. Researchers have developed many structures and methods in order to give rise in the UWB technology. The filter design from lumped-elements is undesirable now days because of the complications of its usage on microwave frequencies besides the restraint of lumped factor values, for that reason the accepted microstrip filters are frequently used[8]. Dielectric resonators are also used to design the ultra wide band band-pass filter. Dielectric resonators (DR) have many benefits in enlarging the accomplishment of radio frequency (RF) and microwave devices such as filters and oscillators and it is also widely used in the wireless applications, because it contains low design profile having wide band width[9]. But the attainment of most the distributed resonators are precise because of the advantage of adequate constant dielectric and there is some disruption in transmission lines. Strip line structures are widely used now days due to the benefits for example easy implementation of both series and shunt stubs and there is no requirement of holes[10].

Defected ground shaped (DGS) is another method for the designing of ultra wide band bandpass filter. Basically DGS is the technique where the ground plane is transform deliberately to improve the accomplishment of the filter. With the help of DGS technique, improvement of the steepness of the roll off, gain is observed with ease of impedance matching. Improvement in the selectivity of the filter by using DGS technique is also observed. DGS is the systematic procedure intended for improving recital of filter in addition it exhibits DGS can boost attenuation encountered in stop band as well as completely removes scrounging pass-band inside stop-band. DGS technique can be understood clearly with the help of engraving faulty sample inside grounded plane. The limitation of gap dimensions might be reduced in support of a particular coupling; consequently space of the complete area of the circuit could be significantly rescued[11]. Another new compact structure for the ultra wide band (UWB) pass filter could be the steeped impedance resonator (SIR) and rectangle slot-defected ground structure DGS which has the advantages of small size and it produces good filtering characteristics[12].The utilization of high dielectric constant substrate, stepped-impedance resonator (SIR) structure and the slow wave effect are highly successful techniques to achieve compact size. A compact coupled micro-strip line filter design with enhanced performance qualifications by making use of symmetrical filter configuration printed on DGS was discussed.[13] An unsophisticated implementation for the coupled microstrip line bandpass filter can be found in Microstrip Filters for RF/microwave Applications by M. J. Lancaster[14]. The design methodology used in Microstrip Filters for RF/microwave Applications by M. J. Lancaster, is further improved to realize the compact symmetrical parallel coupled bandpass configuration by using the impression of lower portion diagonal section of the coupled lines in the upper right section to constitute a symmetrical compact band pass filters structure[15]. Ultimately the characteristics of the compact structure are more improved by realizing the I/O portions of the microstrip feed lines in DGS. Another Z transformation approach is used for combining UWB filter in which the stubs that are open circuited are engaged for producing transmission zeroes inside upper as well as lower stop band for receiving the piercing attenuations[16]. Newly ultra wide band filters consists of coupling through microstrip line towards the coplanar wave guide which can be implemented based on straightforward broad side structure of coupling[17]. Another structure for implementation of wide range band pass filter is suggested through the use of the coupled microstrip line as well as U-shaped ground defected ground (DGS)[18]. These filters can be combined with any UWB antenna to have better performance of overall system[18,19,20]. The main advantage of UWB filter is that it can minimize the signal processing cost when combined with UWB filters in order to mitigate out-band interference.

This paper presents a band pass filter based on microstrip layout with DGS for UWB system applications. A reasonable circuitry of this filter is also presented which shows a good concurrence between the measured and simulated deign.

The Proposed Filter Configuration

The presented filter configuration is shown in figure-1, where figure-1(a) and figure-1(b) shows front and back views of designed organization. This filter has been designed using duroid6010 and FR4 materials with dielectric constants of 10.8 and 4.4 respectively both having thickness of 0.508mm. The presented implementation of the filter is coupled microstrip lines and a defected ground plane detached through the substrate. The mutual inductance and capacitance can explain the coupling between each microstrip line conductor and the ground plane. In most general structures lines of input and output are attached with the ends of opposite sides of coupled lines but here these lines are attached with endpoints in the same edges. By not using DGS this structure naturally shows a band stop property so DGS is important to consider.



(a) Front view (b) Back view

Figure-1
Geometry of the filter with proposed parameters

Table-1
Parameters of Proposed Filter Design

Variable	W1	W2	W3	W	W4	W6	W5	W7	L	S
Duroid (mm)	1	2.5	1.5	0.5	1.4	0.5	1.4	4.1	4	0.2
FR4 (mm)	1	2.5	1.5	0.5	1.4	0.5	1.4	5.6	6	0.2

Parametric analysis has been carried out to demonstrate the effect of varying lengths (L) of the coupled lines. Results of insertion loss have been shown in figure-1. These results show that by varying the length there is great effect on the operating bandwidth of the filter, by increasing the length, the band become congested and by decreasing length, it expands. At L=4 it almost fulfils the requirement of bandwidth passed by FCC for UWB.

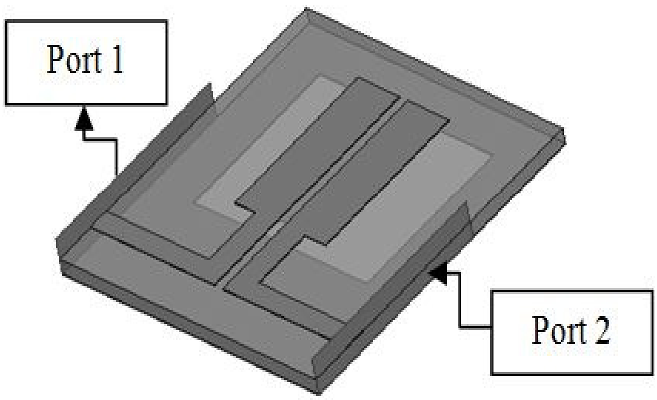


Figure-2
Complete geometry of the filter

RC Equivalent Circuit: The proposed filter design contains two steps the first one is selecting an appropriate prototype and then transforms into the design which is required; here the bandpass filter prototype is considered.

The approximate discrete component model of the bandpass filter from lumped components is shown in figure-3.The capacitor C_3 produces mutual coupling in the design which is the denoted as S in the simulated design and this gap produces the mutual coupling in the simulated model.

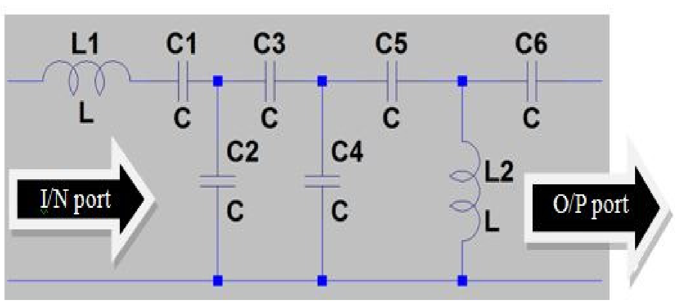


Figure-3
Lumped equivalent for bandpass filter design

This filter is also compared with the general RC bandpass filter. A general RC circuit is made by using LTspice.

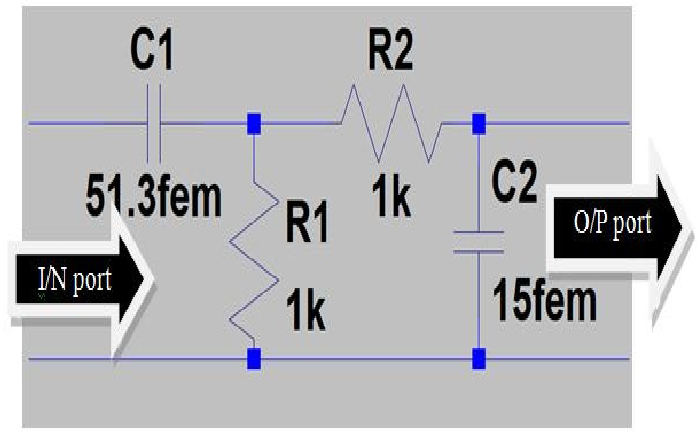


Figure-4
General RC bandpass filter

High pass stage:
F_H =-3dB= 1/2πRC (1)
C= 1/2πFR
C= 51.3femto

Low pass stage:
F_L= -3dB=1/2πRC (2)
C= 1/2πFR
C= 15femto

It is quite obvious that the cutoff of highpass is low and the cutoff of lowpass is high.

Comparison of Simulated and Measured Results: Below graph is the comparison of BPF from lumped components with the BPF from discrete components.

The insertion loss produced by the general bandpass filter is about -4dB which shows that more than half of the power is consumed by the filter itself where as the UWB filter has insertion loss of 0.2dB which shows that its performance is very good.

A good filter's phase response doesn't varry rather it remains constant through out the band. Above graph of phase shows that the pahse of simulated UWB filter shows a good linear property throughout the band, and the pahse of general bandpass filter has some how nonlinear characteristics of it's phase,

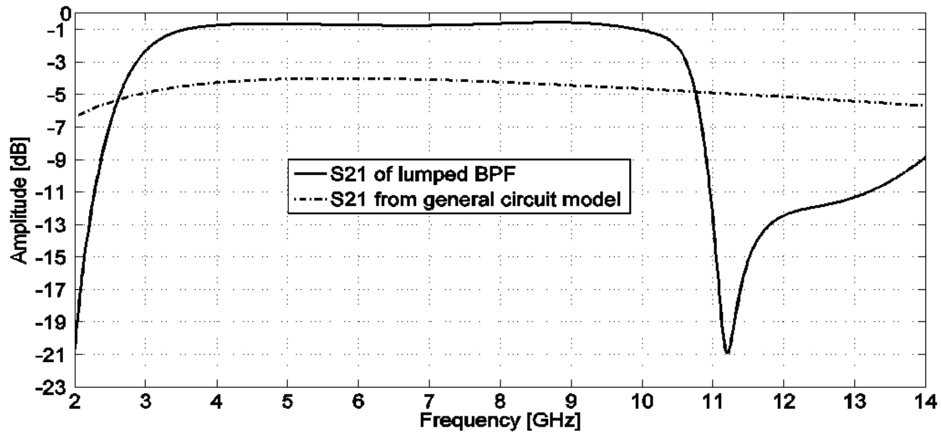


Figure-5
Reflection cofficient of bandpass filter from lumped components in comparison with band pass filter from discrete components

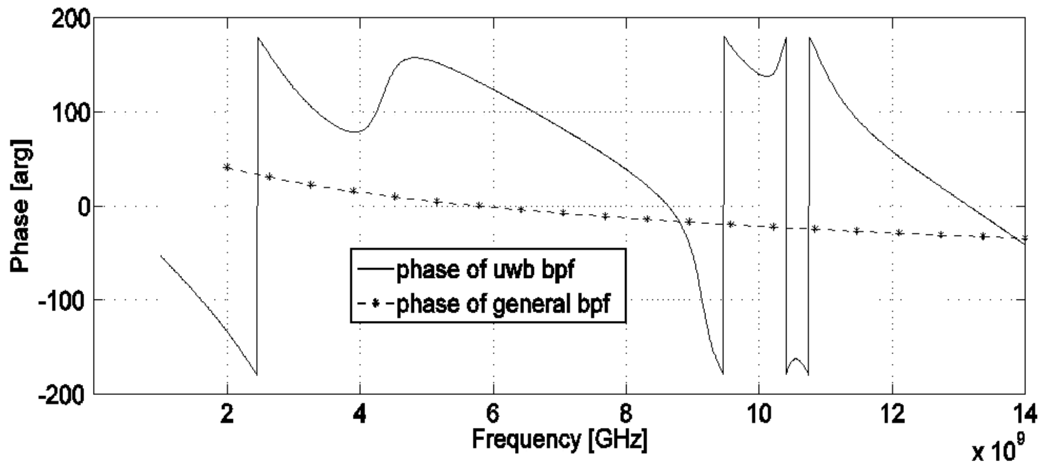


Figure-6
phase of general bandpass filter results compared with the simulated lumped element UWB filter.

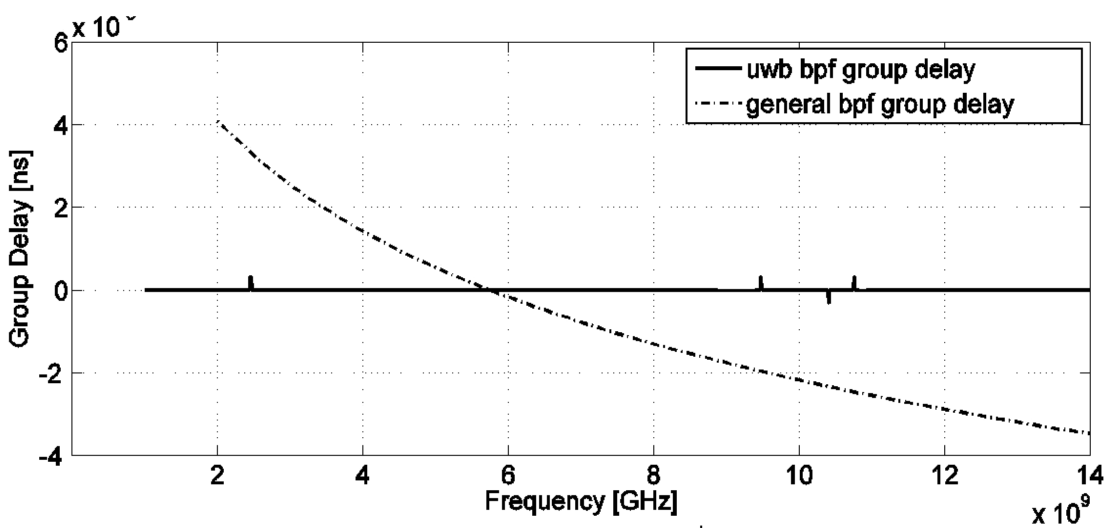


Figure-7
Group delay of general bandpass filter results compared with the simulated lumped element UWB filter.

Above figure signifies that the group delay of simulated UWB filter is almost constant where as the general band pass filter's group delay is not constant it is varying.

Results and Discussion

A filter with reasonable averaged insertion loss and UWB characteristics is designed and compared the results with the general band pass filter from discrete components. It is evident from the comparison that UWB filter from lumped components out performs the general model of the filter. The transmission loss of the designed filter is 0.2dB in comparison with single section band pass filter with insertion loss of 4dB. Moreover, sharp cutoff is observed with the low roll-off factor at both ends of the band. Out band is suppressed by more than 20dB at high frequency cut-off for the designed filter. Proposed filter is good candidate for UWB applications because of its size and performance.

Conclusion

UWB filter design with sharp roll off factor is challenging task. The designed filter is suitable for all type of UWB applications. The designed filter with lumped components have roll off factor that makes sharp transition at the rising and falling edge of in band frequency. More over the designed filter has negligible insertion loss as compared to the filter designed from discrete components. Out band gain suppression is within the required range to use the component as a filter for UWB applications. Approximate model of lumped components in the form of discrete components are also presented. Comparison of first order band pass filter using discrete components with the lumped components is presented for analysis. Phase and magnitudes of the filters are compared to show the performance enhancement of lumped component filter design over discrete component filter design.

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