ISSN 2320 2599
Volume 2, No.1, January – February 2013
International Journal of Microwaves Applications
Available Online at http://warse.org/pdfs/2013/ijma06212013.pdf

Development of Compact Bandpass Filter using Defected Ground Structure for UWB Systems

Neelamegam D[1], Nakkeeran R[2] and Thirumalaivasan K[3]
[1]Department of Electronics and Communication Engineering
Dr. S.J.S. Paul Memorial College of Engineering and Technology, Puducherry - 605 502, India
[2]Department of Electronics Engineering, School of Engineering and Technology
Pondicherry University, Puducherry - 605 014, India
[3]Department of Electronics and Communication Engineering
Achariya College of Engineering Technology, Puducherry - 605 110, India
{Neelamegam_2020, rnakeeran and thirumalaivasank}@pec.edu

ABSTRACT

This paper presents a compact Bandpass Filter (BPF) using Defected Ground Structure (DGS) for Ultra Wideband (UWB) Systems. The proposed BPF consists of interdigital coupling structure at the top and the rectangular defective ground structure at the bottom of the substrate. This filter provides insertion loss of -0.46 dB and return loss of -25 dB while the -10 dB passband of the developed filter is 9 GHz from 3.4 GHz to 12.4 GHz. The designed filter is simulated using electromagnetic simulator, IE3D and fabricated on FR4 substrate with dielectric constant of 4.4, loss tangent of 0.0004 and thickness of 1.6 mm using dual side Printed Circuit Board (PCB) technology. The total size of the developed filter is 26.2 by 2.7 mm^2. The measured S parameters of the filter are compared with the simulated one, where the results obtained over the desired passband is at acceptable level.

Key words : Ultra wideband, bandpass filter, S parameters, DGS.

1. INTRODUCTION

The allocation of the 3.1-10.6 GHz spectrum for Ultra Wideband (UWB) radio applications by the Federal Communications Commission (FCC) [1] has presented a various exciting opportunities and challenges for designing the filter in the communications arena [2]-[4]. UWB is a wireless short range communication system exchanging data using nano Radio Frequency (RF) pulses and possessing large bandwidth of 7.5 GHz. UWB promises low power implementation with fine time resolution and high throughput at short distances [5]. Device like filter plays a very crucial role in UWB systems like in conventional wireless communication systems [6].

The current state-of-art of the developing UWB devices based on traditional resonators with Defected Ground Structure (DGS) is realized by intentionally designed defect on a ground plane, which creates additional effective inductance and capacitance [7]. This technique can be used to design microstrip lines with desired characteristics such as higher impedance, band rejection and out of band performance while significantly reducing the footprint of the microstrip structure [8]-[10]. The defects in the ground plane of the planar transmission lines disturb the shield current distribution and also change the characteristics of the transmission line viz. capacitance and inductance [11]-[15]. In the proposed work, a microstrip filter with rectangular shaped DGS is developed result in compact and shows optimal performance in terms of functional characteristics of the filter. For easy integration with PCB, filter is fabricated on FR4 substrate.

Rest of the paper is organized as follows: In section 2, design of UWB bandpass filter is briefed. UWB bandpass filter geometry is described in section 3. Results and discussions are presented in Section 4 and Section 5 concludes the paper.

2. DESIGN OF UWB BANDPASS FILTER

The proposed filter design involves two main steps. The first one is selecting an appropriate prototype, here we considered bandpass filter as the prototype and is shown in Figure 1.

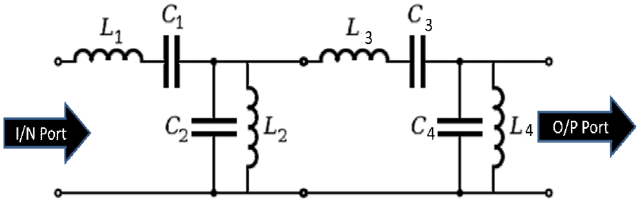


Figure 1: Lumped Equivalent for Bandpass Filter Design

The element values such as $g_0 = g_4 = 1$, $g_1 = g_3 = 1.0316$, $g_2 = 1.1474$ of the bandpass prototype filter, which are usually normalized to make a source impedance of Z_0= 50 and a normalized cutoff of Ω_c=1, from the above made assumption we can calculate the values of lumped inductance and capacitance by using Equations 1 and 2 given below.

$$L = \frac{Z_0}{g_0} \times \frac{\Omega_c}{2\pi fc} \times g_1 \qquad (1)$$

$$C = \frac{Z_0}{g_0} \times \frac{\Omega_c}{2\pi fc} \times g_2 \qquad (2)$$

Where L and C are the lumped inductance and capacitance respectively [2], by using these values of L and C we can build an equivalent circuit as per our requirement as shown in Figure 1. The next main step is to convert the lumped inductance and capacitance into distributed for by using Equations 3 and 4 shown below.

$$l_L = \frac{\tau_g}{2\pi} sin^{-}\left(\frac{\omega_c L}{Z_{0L}}\right) \qquad (3)$$

$$l_c = \frac{\tau_g}{2\pi} sin^{-}(\omega_c C Z_{0c}) \qquad (4)$$

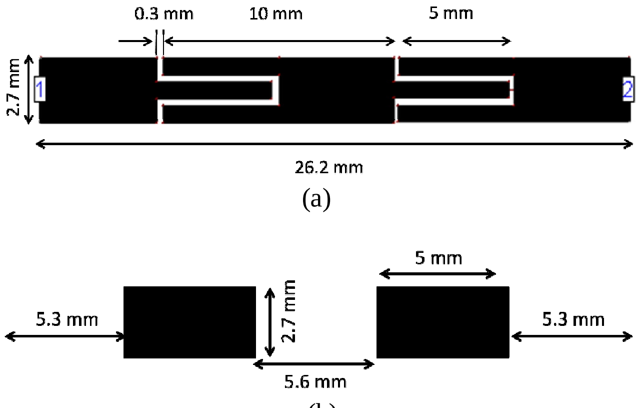
Where Z_{0C} and Z_{0L} denote the characteristic impedances of the low and high impedance lines [2], after calculating the length of the distributed elements, the lumped elements is modeled to a distributed stubs and gaps which is shown in Figure 2.

The proposed geometry of bandpass filter is illustrated in Figures 2(a) and (b), where each open end resonator is approximately a half of the guided wavelength long at the midband frequency f_0 of the bandpass filter. The coupling from one resonator to the other is done through the gap between the two adjacent open ends, and hence is capacitive. In this case, the gap can be represented by the by way of the fields fringing between adjacent resonators separated by spacing of 0.3 mm, respectively.

3. UWB BANDPASS FILTER GEOMETRY

The UWB-BPF consists of interdigital feed lines and coupling gaps on the top of the substrate and a rectangular shaped structure is made defected on the ground plane. This geometry of the filter structure (top and bottom view) is shown in Figures 2(a) and (b), where the interdigital coupled conductor is integrated with microstrip conductor. The size of the stubs is optimized to achieve passband from 3.4 GHz to 12.4 GHz.

The interdigital feed lines used here can enhance the coupling degree between the feed lines. This coupling can be adjusted to control the bandwidth. Thereby, the symmetrical interdigital feed lines can work together to keep the UWB bandpass filter in the desired range.



(a)

(b)

Figure 2: Geometry of Proposed UWB BPF: (a) Top View (b) Bottom View

Several techniques are used for designing filter to cover the desired range of UWB System [16]-[22]. Here microstrip structure has been demonstrated with DGS, where as this achieves wider bandwidth compared to other methods.

4. RESULTS AND DISCUSSION

Simulation is carried out using IE3D, which is a full wave electromagnetic simulator. The simulation S parameters of the proposed bandpass filter are shown in Figure 3. The proposed UWB bandpass filter has one transmission band ranges from 3.4 GHz to 12.4 GHz and has insertion loss of -0.46 dB and return loss of -25 dB.

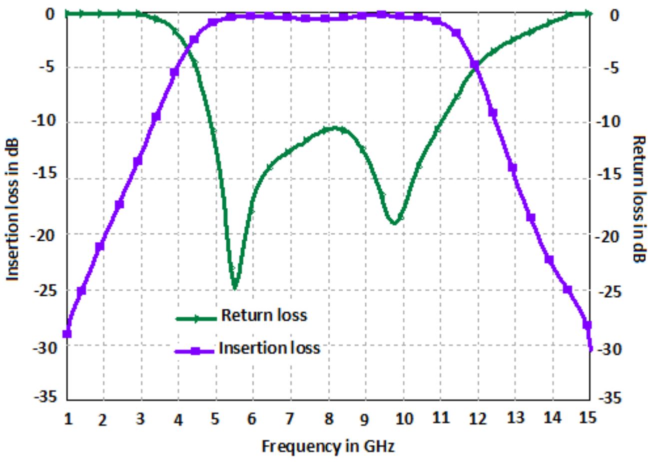


Figure 3: Simulation S Parameters of UWB Bandpass Filter

The developed filter is compact and shows better performance in terms of functional parameters than filters reported in literature. This filter could be integrated with UWB radio systems and efficiently enhance the performance of the system. Figure 4 shows the phase simulation of S_{21} for UWB bandpass filter that is acceptably linear for UWB applications.

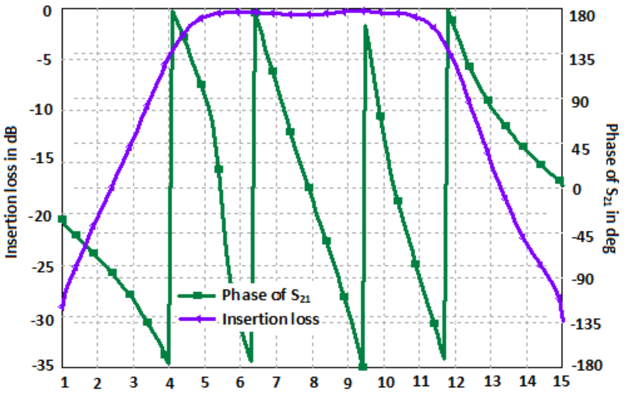
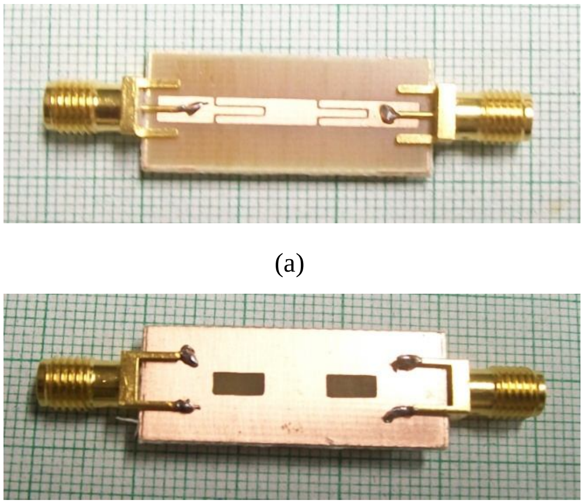


Figure 4: Simulation Phase response of UWB Bandpass Filter

The snapshot of fabricated BPF is shown in Figure 5, where two 50 Ω transmission lines are extended to accommodate the SMA connectors to connect to the Scalar Network Analyzer for measurement. The measured results of insertion loss and return loss for the developed filters are compared with the simulated insertion and return loss characteristics of the filter which is shown in Figures 6 and 7.

The measured insertion loss less than -0.46 dB within the passband is depicted in Figure 7. On comparison with simulation, the measured results are -1.57 dB and -13 dB more in ripples and edges, the small discrepancy between them might be due to fabrication tolerance, loss tangent of the substrate and parasitic effect of the SMA connectors.


(a)

(b)

Figure 5: A Snapshot of Fabricated BPF : (a) Top View (b) Bottom View

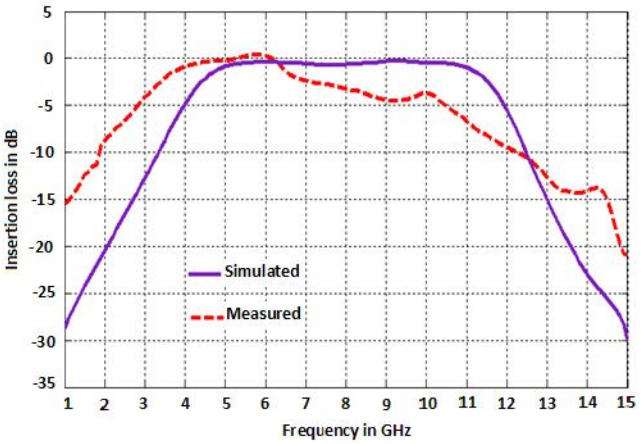


Figure 6: Simulated and Measured Insertion Loss of UWB Bandpass Filter

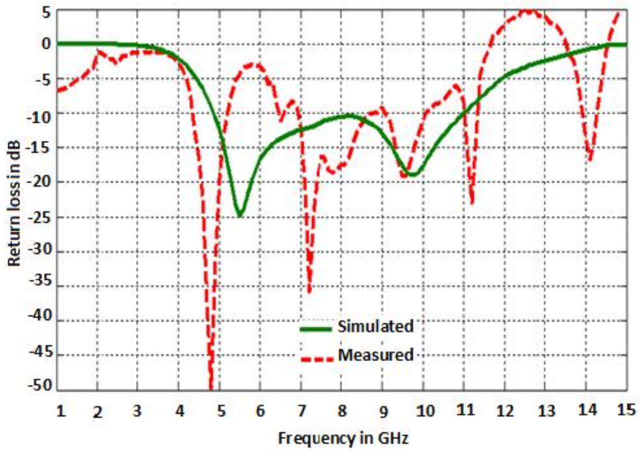


Figure 7: Simulated and Measured Return Loss of UWB Bandpass Filter

Simulation results of proposed BPF is compared with the developed one in terms of prime parameters of the filter namely, insertion loss and return loss, which is tabulated in Table 1.

Table 1: Comparison of Filter Parameters

S parameters	Simulated	Measured
IL (dB)	-0.46	-2.03
RL (dB)	-25	-50

Table 2: Comparison of Proposed Bandpass Filter with Existing Filters

References	IL (dB)	RL (dB)	FBW (%)	Passband (GHz)
[8]	<-1	-22	-	6.4
[13]	<-1.7	<-18	91	5
[17]	-0.98	-20	72	3.8
[20]	-	-37	84	4.6
This Work	**-0.46**	**-25**	**113**	**9**

The above mentioned Table 2 Compares the results of proposed filter with the existing filters available in the literature where the proposed filter performs better in terms of insertion loss, return loss, fractional bandwidth and compact in size.

5. CONCLUSION

A compact UWB BPF using defected ground structure is proposed, developed and presented in this paper. The functional parameters, particularly, insertion loss and return loss of the filter obtained by simulation are experimentally verified. The developed filter demonstrates a fractional bandwidth of 113%. The measured results are in good agreement with simulated one.

REFERENCES

1. FCC Report and Order, ET Docket 98-153. **Revision of Part 15 of the commission's rules regarding ultra-wideband transmission Systems**, Feb. 14, 2002.
2. J. S. Lim, Y. T. Lee, J. H. Han, J. S. Park, D. Ahn, S. Nam. **Application of defected ground structure in reducing the size of amplifiers**, *IEEE Microwave and Wireless Component Letters*. Vol. 12, No.7, July 2002.
3. J. S. Hong and M. J. Lancaster. ***Microstrip Filters for RF/Microwave Application***, Wiley, New York, 2001.
4. D.M. Pozar, Microwave ***Engineering***, *Wiley*, New York, 1998.
5. G. Mattaei, L. Young, and E. M. T. Jones. ***Microwave Filters, Impedance-Matching Networks, and Coupling Structures***, Artech House, Norwood, MA, 1980.
6. N. Engheta and R. W. Ziolkowski. ***Metamaterials: Physics and Engineering Explorations.*** Hoboken, NJ: John Wiley & Sons, 2006.
7. C. Caloz and T. Itoh. ***Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications. Hoboken***, NJ: John Wiley & Sons, 2006.
8. M. Gil and F. Martín. **Composite right/left-handed metamaterial transmission lines based on complementary split-rings resonators and their applications to very wideband and compact filter design**, *IEEE Trans. on Microwave Theory and Tech.*, vol. 55, no. 6, pp. 1296-1304, Jun 2007.
9. R. Marques, F. Martin, and M. Sorolla. **Metamaterials with negative parameters: Theory, Design and Microwave Applications**. Hoboken, NJ: John Wiley & Sons, 2007.
10. Lai, T. Itoh. **Composite right/left-handed transmission line metamaterials**, *IEEE Microwave Magazine,* Vol. 5, no. 3, pp. 34-50, Sept. 2004.
11. A. Sanada, C. Caloz, and T. Itoh. **Planar distributed structures with negative refractive properties**, *IEEE Trans. Microwave Theory Tech.*, Vol. 52, No. 4, pp. 1252-1263, Apr. 2004.
12. J. Bonache, I. Gil, J. García, and F. Martín. **Novel microstrip bandpass filters based on complementary split rings resonators**, *IEEE Trans. on Microwave Theory and Tech.*, Vol. 54, No. 1, pp. 265-271, Jan. 2006.
13. K. Y. Liu, C. Li, and F. Li. **A new type of microstrip filter with complementary split-ring resonator**," PIERS Online, Vol. 3, No. 5, pp. 603–606, Jan. 2007.
14. A. Ali and Z. Hu. **Metamaterial resonator based wave propagation notch for ultra wideband filter applications**, *IEEE Antennas and Wireless Propagation Letters,* Vol. 7, No. 4, pp. 210-212, Aug. 2008.
15. C. J. Lee, Kevin, and T. Itoh. **Metamaterial transmission line based bandstop and bandpass filter designs using broadband phase cancellation**, *IEEE Trans. on Microwave Theory and Tech.*, Vol. 31, No. 2, pp. 935-938, Nov. 2006.
16. C. H. Tseng and T. Itoh**. Dual-band bandpass and bandstop filters using composite right/left-handed metamaterial transmission lines**, *IEEE Trans. on Microwave Theory and Tech.*, Vol. 11, No. 4, pp. 931-934, Nov. 2006.
17. J. Bonache, F. Martin, F. Falcone, I. Gil, J. Garcıa-Garcıa, R. Marques, and M. Sorolla. **Microstrip bandpass filters with wideband widthand compact dimensions**, ***Microwave and Optical Technology Letters***, Vol. 46, No. 4, Aug. 2005.
18. L. Qi, L. Chang-Hong, Z. Wei, and X. Wei Feng. **Novel compact UWB bandpass filter with notched band**, *Microwave Optical Techniques Letters,* Vol. 52, No. 6, pp. 280-283, Feb. 2010.
19. S. Kahng, G. Jan, J.Anguera. **Metamaterial dual band bandpass filters using CRLH zero order resonators and improving its intermediate stopband**, *IEEE Trans. on Microwave Theory and Tech.*, Vol. 19, No. 6, pp. 1-4, Apr. 2009.
20. H. L. Hu, X.D. Huang and C.H. Cheng. **Ultra wideband bandpass filter using CPW to microstrip coupling structure**, *Electronics Letters* , Vol. 42, No. 10, pp. 51-52. May 2006.
21. X. Q. Lin, H. F. Ma and T. J. Cui. **Design and analysis of super-wide bandpass filters using a novel compact meta-structure**, "*IEEE Trans. on Microwave Theory And Tech.*, Vol. 55, No. 4, pp. 747-753, Apr. 2007.
22. M. A. Abdalla, M. A. Fouad, H. A. Elregeily, and A. A. Mitkees. **Wideband negative permittivity metamaterial for size reduction of stopband filter in antenna applications**, *Progress in Electromagnetics Research C,* Vol.25, pp. 55-66, 2012.