Ultra Wide Band Filter Using Shorted Meandered Coupled Lines and Stepped Line Stubs

D. Packiaraj[1], K. J. Vinoy[2], M. Ramesh[1], Subhalaxmi Rath[1] and A.T. Kalghatgi[1]
[1] Bharat Electronics Limited,
[2] Department of Electrical Communication Engineering, Indian Institute of Science, Bangalore, India
dpackiaraj@bel.co.in

Abstract:

A miniaturized ultra wide band (UWB) filter is proposed and implemented using short circuited meandered coupled lines. In addition, stepped impedance open circuit stubs are incorporated along with the input and output feed lines for achieving wide stop band rejection characteristics. UWB filter over 3.1GHz to 10.6GHz has been analyzed and experimentally validated. The proposed filter has been designed in microstrip medium having thickness of 0.78mm and dielectric constant of 2.17. The insertion loss is found to be less than 1.2dB and group delay variation is less than 0.04ns within the pass band of the UWB filter. Size of the miniaturized experimented filter is 17mm× 17mm×0.78mm

Key Words: coupled line; stub; UWB; stop band.

I INTRODUCTION

Extensive research work has been proposed in the design UWB of devices and systems in the license free unlicensed UWB band (3.1GHz to 10.6GHz) for short range wireless communication applications. Band pass filter is one of the essential passive components in the UWB technology. Different types of topologies/structures have been studied and reported in various literature [1-6]. Attention is also arising to design filter with wide stop band. Modern wireless communication systems such as UWB transceivers require miniaturized low loss, wide pass band filters with extended stop band characteristics. Though several types of designs such as broadside coupled lines, ring resonators, open /short circuit stubs and multi-mode resonators have been reported in literature for the design of such filters [1-6].

Design of a compact wide band pass filters with good in band filtering performance, sharp selectivity and wide stop band still remains as key issues in many system designs. Though conventional high impedance half wavelength parallel-coupled line filter has several salient features, it suffers from constraints of photolithographic and manufacturing processes to realize closely spaced lines required for tight coupling. On the other hand, half wavelength resonator based filters suffer from immediate spurious response at 2fo which limits the performance of the system. Multiple coupled transmission lines with defected ground have been successfully employed by the authors to achieve wide band operation [7].

In this paper, an UWB filter using short circuited coupled line along with meandered line and open circuit stubs is presented along with the following advantages: i) Miniaturization using short circuited coupled lines along with meandered lines, ii) Stop band widening using open circuit stubs, iii) Cross-coupling between the input and output through short circuited coupled lines for improving the selectivity. The filter structure is shown in Fig. 1.

Section II contains the analysis procedure for the design of the proposed filter followed by experimental results and discussions in section III. Section IV concludes this paper.

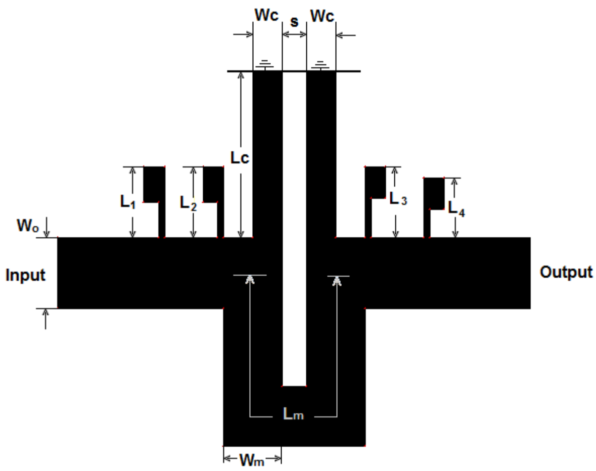

Fig. 1. UWB Filter.

II. DESIGN OF UWB FILTER

This filter is designed with the following specifications

Bandwidth	:3.1GHz to 10.6GHz
Insertion Loss	:<1.5dB
Return loss	:>15dB

Substrate thickness 'h' : 0.78mm
Substrate permittivity 'ε_r' : 2.17.

The basic structure of the proposed filter has input and output feed lines connected to a short circuited quarter wave coupled lines. A meandered transmission line is also connected across input and output. Open circuit stubs 1, 2, 3 and 4 are connected along the feed lines. Combination of all these ensures spurious-free filter response up to 18GHz.

Circuit Analysis: Analysis of the entire filter is based on splitting it into different sections namely open circuit stubs, short circuited coupled lines and meandered coupled lines and analyzing each section. Fig. 2 shows different sections of the filter for the sake of analysis. Even and odd mode propagation parameters are used for the analysis of the coupled line sections and coupled line sections are shown in Fig. 3.

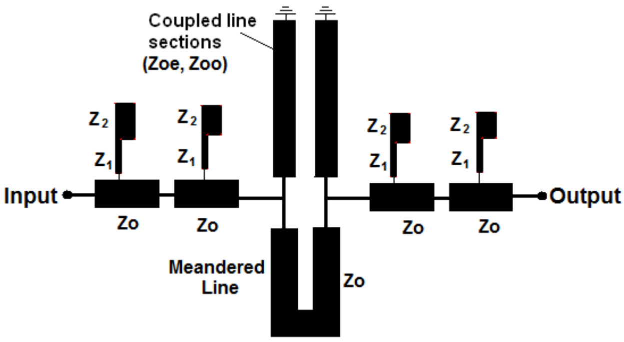

Fig. 2. Sections of UWB filter.

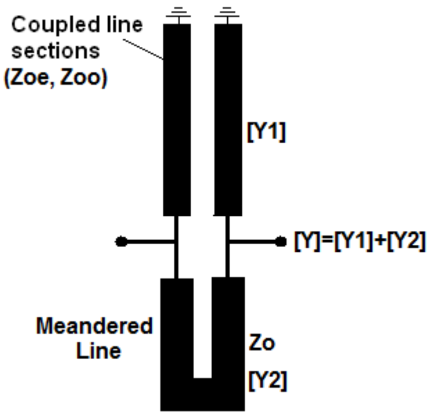

Fig. 3. Analysis procedure for coupled line sections.

Short circuited coupled line sections can be characterized using impedance 'Y' parameters given by [8]

$$Y_{11} = Y_{22} = -j\left(Y_{oe}\cot(\theta_e) + Y_{oo}\cot(\theta_o)\right) \quad (1a)$$
$$Y_{12} = j\left(Y_{oo}\cot(\theta_o) - Y_{oe}\cot(\theta_e)\right) \quad (1b)$$
$$Y_{21} = -j\left(Y_{oo}\cot(\theta_o) - Y_{oe}\cot(\theta_e)\right) \quad (1c)$$

where Y_{oe} and Y_{oo} are even and odd mode admittances respectively. θ_e and θ_e are even and odd mode phase velocities respectively. Stepped impedance open circuit stubs (Fig. 4) are characterized using the following ABCD parameters

$$A_S = D_S = 1 \quad (2)$$
$$B_S = 0 \quad (3)$$
$$C_S = 1/Z_s \quad (4)$$

Where

$$Z_s = Z_H\left[\frac{Z_{LOAD} + jZ_H \tan\theta_H}{Z_H + jZ_{LOAD}\tan\theta_H}\right] \quad (5)$$

$$Z_{LOAD} = -JZ_L \cot\theta_L \quad (6)$$

where Z_L and Z_H are low impedance and high impedances of the stepped impedance stub respectively.

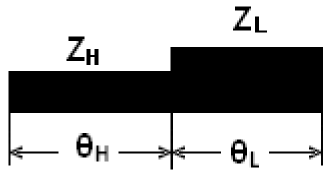

Fig. 4. Stepped impedance stub

Design parameters of the filter are listed in Tables I and II. Circuit model of each section of the filter is combined with other sections to obtain the overall response of the filter. Analysis is based on cascading individual ABCD matrices of three filter sections. Scattering parameters of the filter are extracted from the overall transmission matrix. A comparison is made between the analytical results using the procedure explained above and fullwave simulations using IE3D simulator from Mentor graphics [9] as shown in Fig. 5 and a close agreement between them can be observed.

Table I. Geometrical parameters of filter

Length of coupled lines 'L_c'	7mm
Width of coupled line 'Wc'	1mm
Spacing 's'	0.8 mm
Stub lengths L_1, L_2, L_3 and L_4	2.9mm, 2.7mm, 2.5mm and 2.4mm
Feed line width 'W_o'	2.4 mm
Meandered line width 'W_m'	2.4mm

TABLE II. Electrical Parameters of Filter

Parameters	**Values**
Even and odd mode impedances (Z_{oe}, Z_{oo}) of coupled line and meandered line sections	(63,50)Ω
Stub Impedances (Z_{h}, Z_{L})	160Ω 100Ω
Line impedance (Z_{o})	50Ω
Input and output Impedances	50Ω

Filter has the pass band from 3.1GHz to 10.6GHz. It can be observed from the results that open circuit stubs improve the stop band rejection characteristics of the filter better than 20dB.

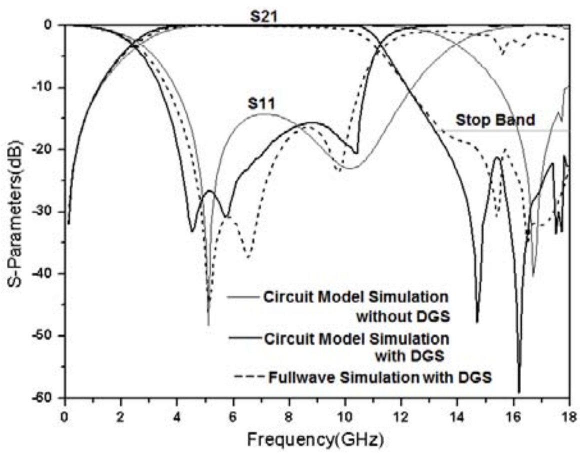

Fig. 5. Simulation results of filter

III. EXPERIMENTAL RESULTS

Fig. 6 shows the experimental prototype UWB filter. The input and output feed lines are designed with line impedance of 50Ω. Dimensions of the filter are 17mm× 17*mm*×0.*78*mm. The filter is tested using vector network analyzer Agilent N5230A. Fig. 7 show that measured results and fullwave simulation using IE3D are in good agreement. Measured frequency band of the filter is 3.1GHz to 10.6GHz. Insertion loss of the filter is less than 1.2dB within the desired pass band. Stop band rejection is better than 20dB upto 18GHz while the second harmonic (13.7GHz) of the filter has been suppressed to a level of 20dB. Measured Group delay over the pass band is constant to within ±0.04*ns* as shown in Fig. 8.

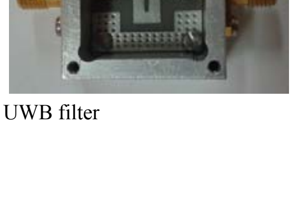

Fig. 6. Assembled UWB filter

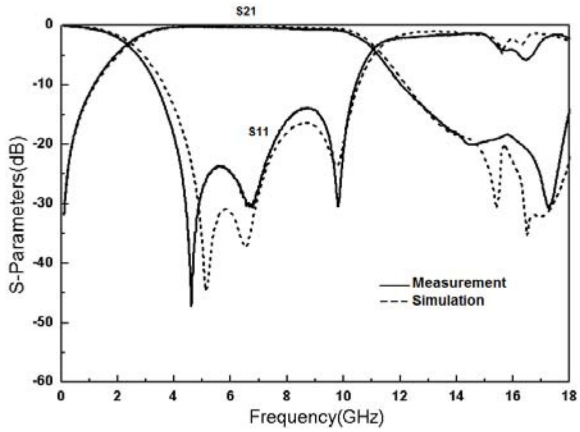

Fig. 7. Measured results of UWB filter

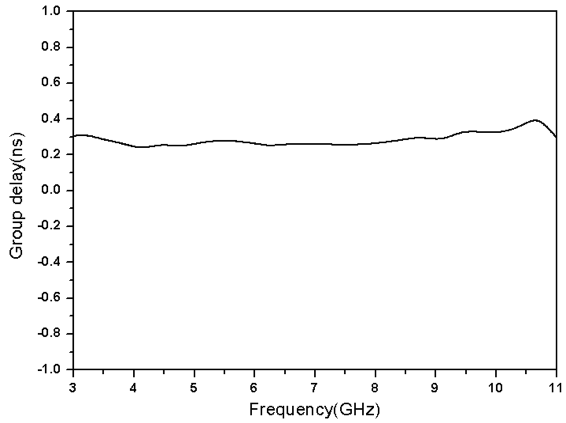

Fig. 8. Measured Group delay

IV. CONCLUSIONS

In this paper, a compact UWB filter is designed and realized using short circuited coupled lines and meandered coupled lines along with open circuit stubs. Open circuit stubs were embedded with input and output feed lines for achieving wide stop band characteristics. The measured insertion loss is 1.2dB and return loss is 13.5dB over the pass band of 3.1-10.6GHz. The UWB filter exhibited stop band rejection of better than 20dB upto 18GHz. Overall dimensions of the filter are $0.5\lambda_g \times 0.5 \lambda_g \times 0.0.024 \lambda_g$

REFERENCES

[1] H. Wang and L. Zhu, "Ultra-wideband bandpass filter using back-toback microstrip-to-CPW transition structure," *Electron. Lett.*, vol. 41, no. 24, pp. 1337–1338, Nov. 2005.

[2] L. Zhu, S. Sun, and W. Menzel, "Ultra-wideband (UWB) bandpass filters using multiple-mode resonator," *IEEE Microw. Wireless Compon. Lett.*, vol. 15, no. 11, pp. 796–798, Nov. 2005.

[3] R. Li and L. Zhu, "Compact UWB bandpass filter using stub-loaded multiple-mode resonator," *IEEE Microw. Wireless Compon. Lett.*, vol. 17, no. 1, pp. 40–42, Jan. 2007.

[4] C.-L. Hsu, F.-C. Hsu, and J.-T. Kuo, "Microstrip bandpass filters for ultra-wideband (UWB) wireless communications," in *IEEE MTT-S Int.Dig*, Jun. 2005, pp. 679–682.

[5] J.-S. Hong and H. Shaman, "An optimum ultra-wideband microstrip filter," *Microw. Opt. Technol. Lett.*, vol. 47, no. 3, pp. 230–233, Nov. 2005.

[6] C. Y. Hsu, C. Y. Chen and C. H. Huang, "A UWB filter using a dual-mode ring resonator with spurious pass band suppression," *Microwave Journal*, pp. 130-136, Nov 2005.

[7] D. Packiaraj, K. J. Vinoy, M. Ramesh, A. T. Kalghatgi, Varsha Chaware and G. J. Phatak "LTCC Ultra Wide Band Filter ", *Microwave and optical Technology Letters.*, vol.53, No.11, pp.2580-2583, Nov 2011.

[8] G. Matthaei, L. Young and E. M. T. Jones, *Microwave* Filters, Impedance Matching Networks and Coupling structures. Reprint Edition, MA, Norwood: Artech House Inc,1985.

[9] Mentor Graphics Inc., "IE3D 15.1", 2011.

BIO DATA OF AUTHORS

D. PACKIARAJ is currently a Research Staff at Central Research Laboratory of Bharat Electronics Limited, Banglaore. He received M. E degree in communication systems from National Institute of Technology, Trichirappali in 2002. His area of interest includes microwave filters, antennas and Phase shifters. He is a research student under Prof. K. J. Vinoy in IISc, Bangalore.

K. J. VINOY is an Associate Professor in the Department of ECE at the IISc, Bangalore. He received M. Tech degree from CUSAT, Cochin, and Ph.D. degree from the Pennsylvania State University, USA in 1993, and 2002 respectively. From 1994 to 1998 he worked at National AICX Aerospace Laboratories, Bangalore, India. He was a research assistant at the Center for the Engineering of Electronic and Acoustic Materials and Devices (CEEAMD) at the Pennsylvania State University, from 1999 to 2002. He continued there from 2002 to August 2003 for Post Doctoral research. His research interests include several aspects of microwave engineering such as antennas, circuits, RF-MEMS and Computational Electromagnetics. He has published over 120 papers in technical journals and conferences. His other publications include three books: Radar Absorbing Materials: From Theory to Design and Characterization, RF MEMS and their Applications and Smart Material Systems and MEMS: Design and Development Methodologies.

M. RAMESH was born in India in 1969. He received his B. E Degree from Andhra University Visakhapatnam in 1990 and M.Tech degree from the Indian Institute of Technology Kharagpur in 1993. His areas of interest include Microwave circuits and antennas. He has published 30 research papers in various international journals.

SUBHALAXMI RATH received the B.Tech degree from KIIT University, Bhubaneswar in Electrnics & Communication Engineering in 2008 and M.Tech degree from IIT Kharagpur in RF & Microwave Engineering in 2011. Currently she is working as Member Research Staff in CRL BEL, Bangalore since Aug 2011. Her interests include RF Passive Circuits.

Dr. A. T. KALGHATGI is currently Director (Research and Development) of Bharat Electronics Ltd., India. He has more than 30 Years of Experience in the field of RF & Microwave Engineering. After Graduating from Mysore University with BE in Electronics & Communications, he completed his M Tech in Microwave & Radar Engineering from IIT, Kharagpur and Ph.D., from Leeds University UK. He worked in Avionics Design Bureau of HAL Hyderabad as Design Engineer responsible for Microwave front-ends & IFF transreceiver. From 1988 to 1993 he was in the University of Leeds, UK for his Ph.D as a Commonwealth Research Scholar and later as a Post Doctoral Fellow. From 1994 he has been with Central Research Lab of Bharat Electronics Ltd. His research interests are in RF and Microwave system, Smart Antennas, RF MEMs & Secure Communication Technologies. He has more than 60 research papers and a patent to his credit. He is recipient of R&D Award from BEL for significant contribution to its R&D programme, and the Society of Defence Technologists (SODET) Gold Award for Technology Development & Innovation for the year 2005-06. He is also recipient of Raksha Mantri Award of Excellence in Innovation for the year 2007-08 as well as for the year 2008-09. He is a member of review committees of Government of India, Member of the Editorial Board of IET's Microwave & Antennas research publications, Member of IEEE and IET-UK..