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DESIGN AND ANALYSIS OF COMPACT UWB BAND PASS FILTER

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ABSTRACT

This paper presents design, implementation and analysis of an ultra-wideband (UWB) band-pass-filter using parallel-coupled microstrip line with defective ground plane and a uniform multi-mode resonator. The structure of the filter is designed on microwave substrate GML 1000 of dielectric constant 3.2 and height is 0.762 mm. Simulation is carried out by CST MSW software and optimized structure is fabricated. The frequency response is measured on vector analyzer and measured results show close approximation with simulation results. In this article modeling of the proposed filter is also reported. The electric model of the filter is analyzed by circuit theory and MATLAB. This model is validated by comparing the results with the CST simulation and VNA measured results. This filter is compact in size of dimension 30×1.87 mm2 may be useful for modern wireless application of communication.

KEYWORDS

Multi-mode resonator (MMR), Fractional bandwidth (FBW), Ultra-wide band (UWB), Band pass filter (BPF), Parallel-coupled microstrip line (PCML).

1. INTRODUCTION

In 2002, Federal Communication Commission (FCC) released Ultra-wide band (UWB) system from 3.1 GHz to 10.6 GHz for the use of indoor and hand-held systems. Ultra- wideband (UWB) band pass filters play a key role in the development of UWB systems [1]. After the release of UWB, there were lot of challenges to design such a band pass filter, with a pass band of the frequency range (3.1 GHz - 10.6 GHz), and a fractional bandwidth of 110% by conventional method of filter design. Initially broad band filters were designed, and covered only 30 to 40 % of UWB not the whole UWB [2].In [3-7] many researchers reported various techniques, like aperture compensation, microstrip-coplanar waveguide structure design, ground plane aperture technique and multiple-mode resonator were used to design UWB filters. Many new techniques [8-13], like U-shaped slot coupling [8], asymmetric parallel-coupled lines [9], right/left-handed transmission line [10], differential- mode wide band BPF using two stage branch-line structures with open circuited stubs [11], tunable harmonic stepped-impedance resonators [12] and parallel coupled line microstrip structure [13] were used to design the UWB filters.

In this paper a design and analysis of a compact UWB filter is presented. In section 2, design and development of the UWB filter using double PCML, MMR and DGS is demonstrated. Small size stubs at input and output end are used for impedance matching to improve the performance of the filter. The electrical analysis of the filter is mentioned in section 3. Finally paper is concluded in section 4.

2. DESIGN OF UWB FILTER

The layout of the proposed structure is shown in Fig.1 which consists two parallel coupled microstrip line (PCML) of quarter wave length with a rectangular shaped DGS and a uniform multi-mode resonator (MMR). The designed structure of filter is simulated and optimized by using CST Microwave Studio software by using microwave laminate GML 1000 of dielectric constant 3.2, height h = 0.762 mm and loss tangent 0.001. The design parameters of the proposed filter are mentioned in Table I.

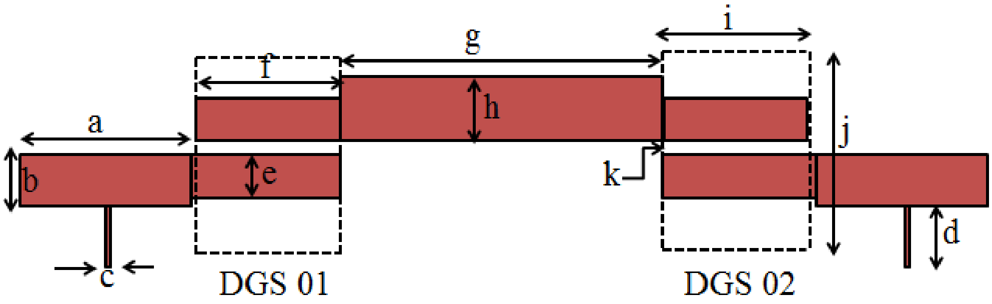
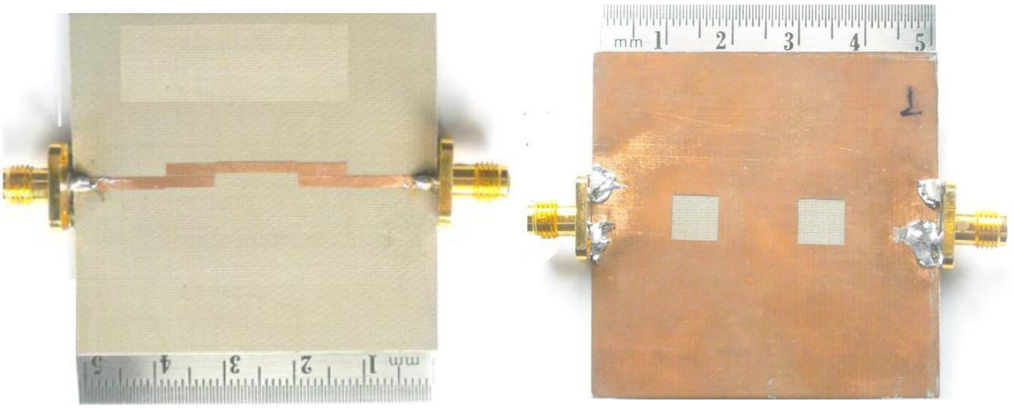


Fig.1 Schematic of UWB filter

Table I: Design parameters of the UWB filter

Notation	Parameters of the filter	Dimensions in(mm)
b	Width of the feed line	1.83
a	Length of the feed line	10.5
c	Width of the stub	0.32
d	Length of the stub	1.87
e	Width of the PCML	1.71
f	Length of PCML	6.94
g	Length of MMR	11.32
h	Width of MMR	1.71
i	Length of DGS	6.74
j	Height of DGS	6.5
k	Spacing between PCML	0.11

The optimized filter is fabricated by conventional photo lithographic process and the photograph of the fabricated filter is shown in Fig.2. The frequency response of the fabricated filter is measured on Agilent Tech. E5071C ENA Vector Network Analyzer. The measured frequency response is compared with the simulated frequency response which is shown in Fig.3.The comparison results shown in Fig.3 are in close approximation to each other. The measured results show insertion loss S21 of value better than -2.0 dB and return loss better than -10.0 dB in the frequency range from 3.1 GHz to 10.6 GHz. A slight mismatch between measurement and simulation result is due to the imperfection in measurement, fabrication process and the quality of the substrate used.



(a) (b)

Fig.2 Photo graph of fabricated filter (a) Top view (b) bottom view

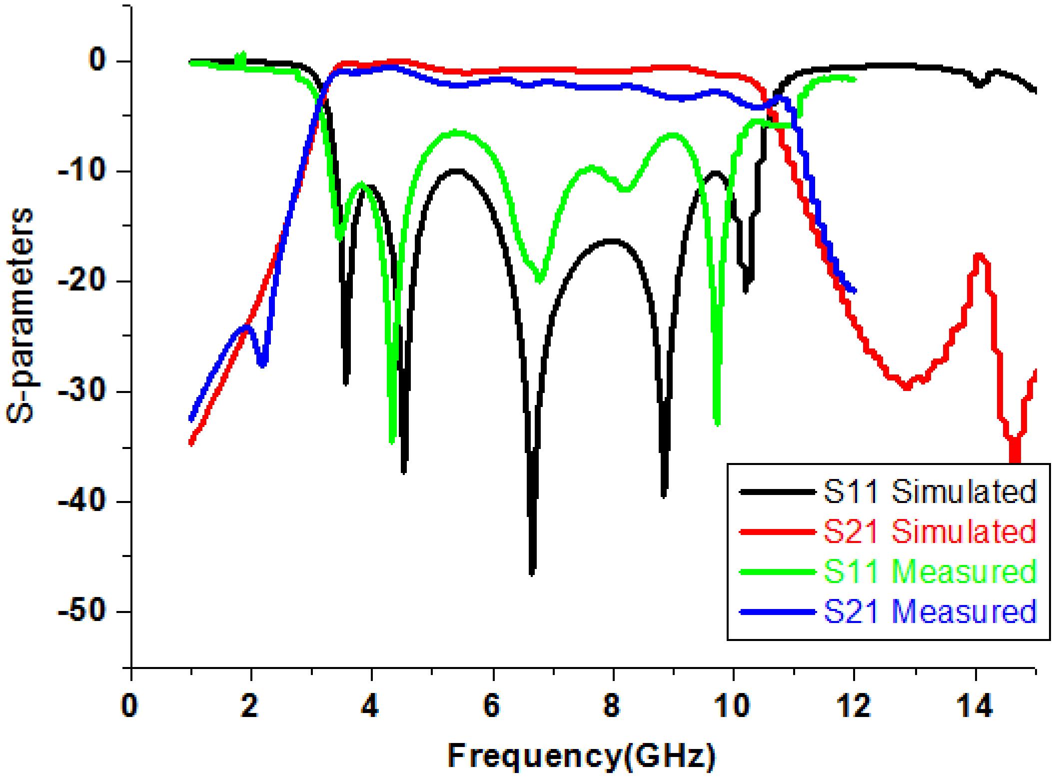


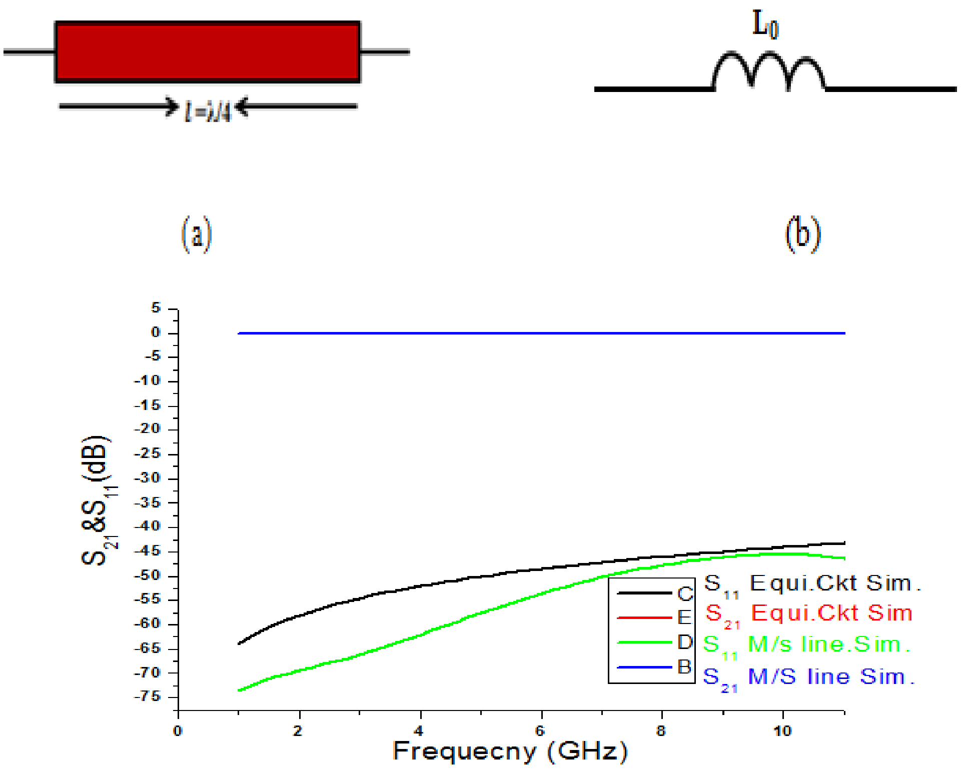
Fig.3 Comparison of frequency responses

3. ELECTRICAL ANALYSIS OF THE UWB FILTER

The electrical analysis of the proposed filter is carried out by making electrical equivalent of the filter. The S-parameters of the electrical equivalent circuit is obtained by circuit theory. The frequency response of this electrical equivalent is obtained by MATLAB and, it is compared with the simulation results to justify the topology used to make the equivalent circuit of the filter. The parallel coupled microstrip line with DGS, MMR and feed lines are the basic components of the filter circuit. The overall electrical equivalent of this UWB filter can be obtained by combing the equivalent circuit of individual components of the filter circuit.

3.1 Equivalnt Circuit of Feed Line

Microstrip line 50 ohm transmission line can be represented by distributed R, L, C and G elements. At very high frequency in GHz range, resistive and conductive components can be neglected and line is represented by reactive elements. A small section of feed line of 50 ohm impedance can be represented by an inductance. Simulation results of physical line are compared with its equivalent circuit simulation results is shown in Fig.4.



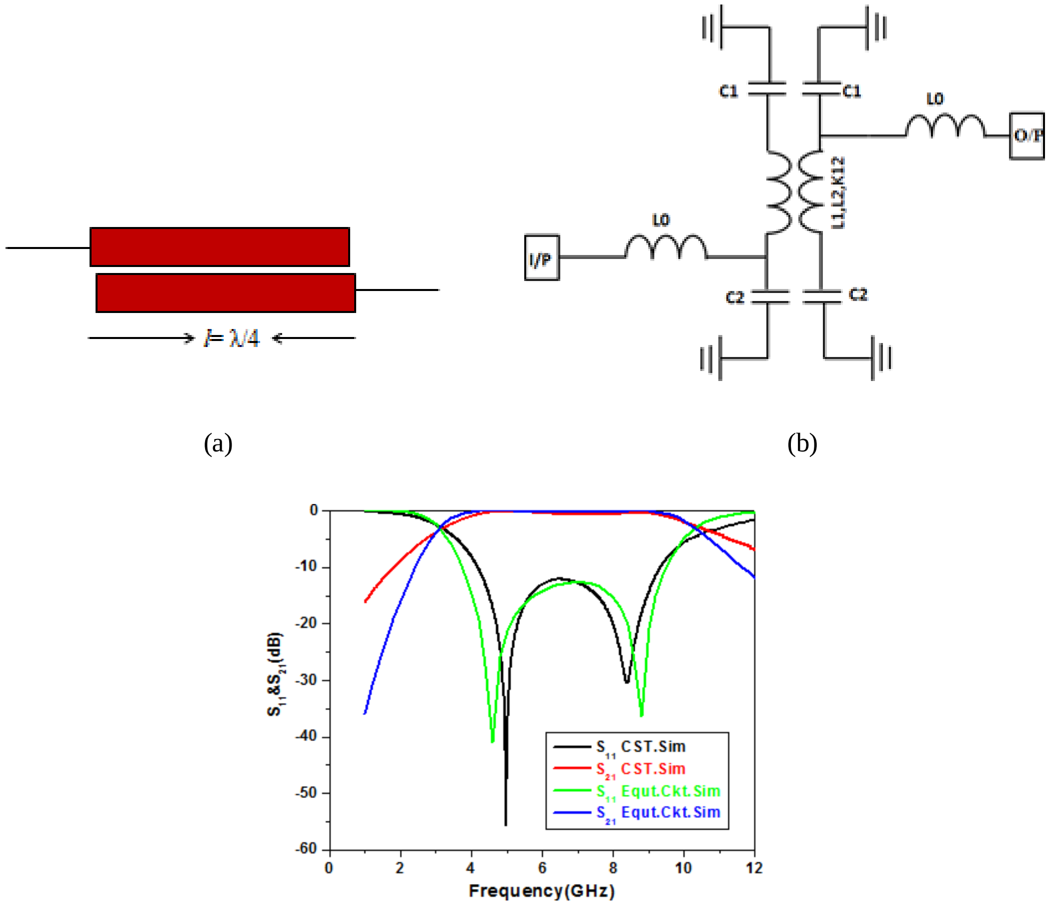
(a) (b)

(c)

Fig.4 (a) Small section of feed line 50 ohm (b) Equivalent circuit of feed line of L0=0.8215 nH (c) Comparison of results

3.2 Equivalent Circuit of Pcml

Parallel coupled microstrip line equivalent circuit can be explained by two mutually coupled inductors and capacitors between line and ground [13]. L1 & L2 are self-inductance of the lines and K12 is coupling coefficient between the lines. Capacitance between the line and ground are indicated by C1 & C2 values. Comparison between the circuit simulation and physical line simulation results is shown in Fig.5.



(a) (b)

(c)

Fig.5 (a) Physical line (b) Electrical Equivalent circuit of PCML(L1 = L2 = 3.58nH and K12 = 0.613) (c) Comparison of results

The multi-mode resonator in microstrip structure is represented by an inductor. The overall equivalent circuit of the UWB filter can determine by including the equivalent circuit of the individual components of the filter, and it is shown in Fig.6

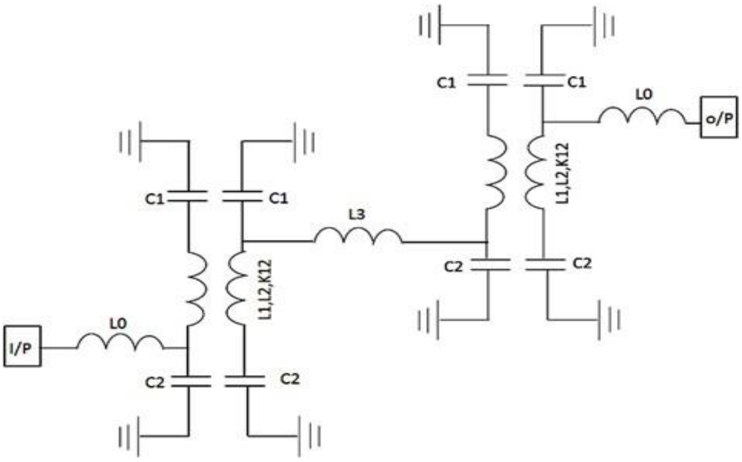


Fig.6 Electrical equivalent circuit of the UWB filter where L3 is assumed of value 1.81nH

The electrical equivalent circuit of the filter shown in Fig.6 is simulated on SERENIDE SV 8.5 circuit simulator and its frequency response is shown in Fig.7.The equivalent circuit shown in Fig.7 can be simplified by considering two circuits connected in cascade fashion shown in Fig.8.

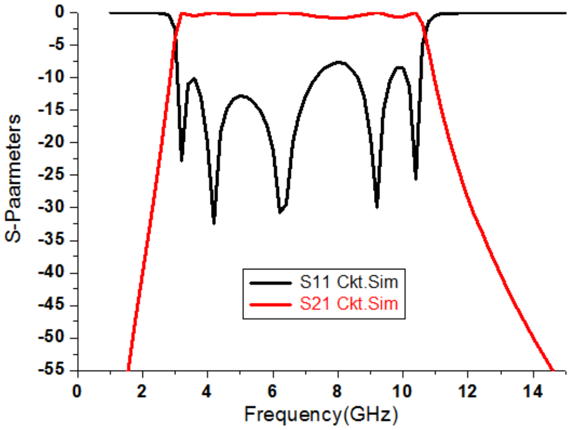


Fig.7 Frequency response of electrical equivalent circuit of UWB filter.

3.3 Electrical Analysis of the Uwb Filter

The equivalent circuit of the UWB filter shown in Fig.6 can be analyzed by simple network theory. The overall equivalent circuit is divided into two symmetrical circuits by splitting the middle inductor into half of its value which is shown in Fig.7 the simplified version of the equivalent circuit is shown in Fig.9.

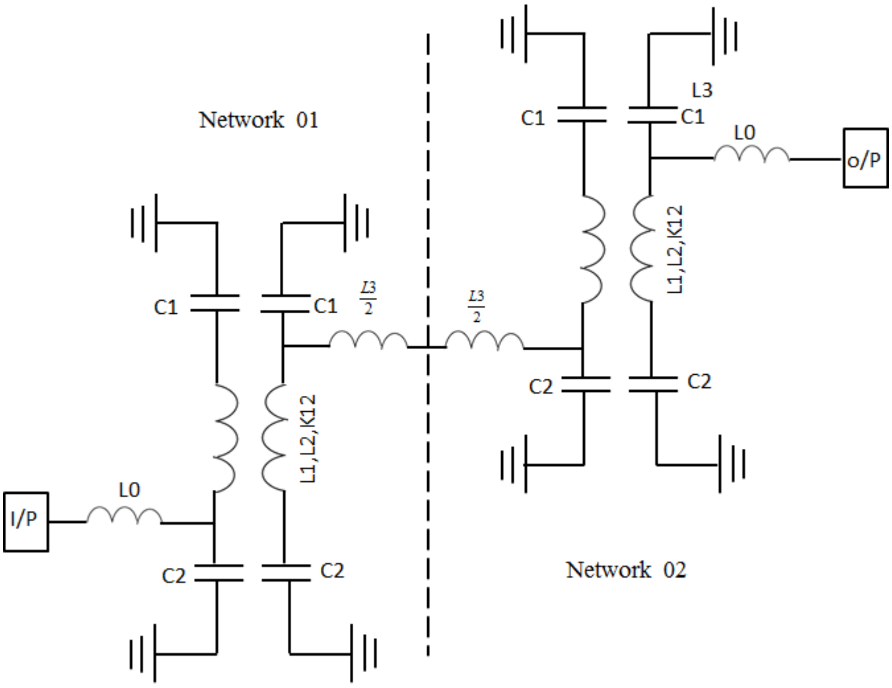


Fig.8 Symmetrical equivalent circuit of UWB filter

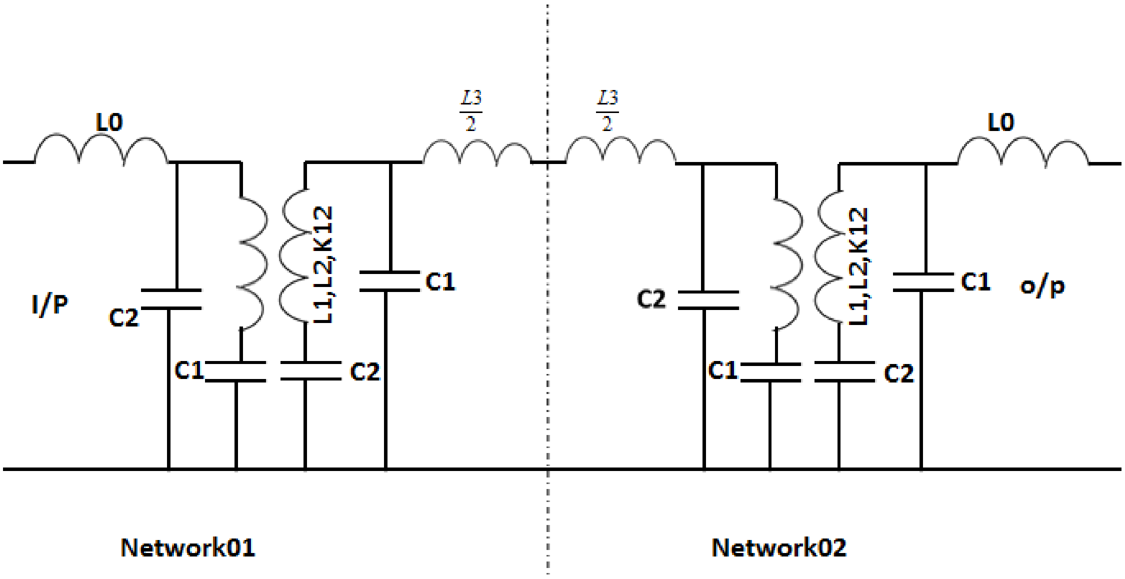


Fig.9 Simplified equivalent circuit of UWB filter

The circuit shown in Fig.8 can be considered as cascaded connection of two networks. Overall [ABCD] parameters of the circuit are calculated by matrix multiplication of [ABCD] parameters of each network.

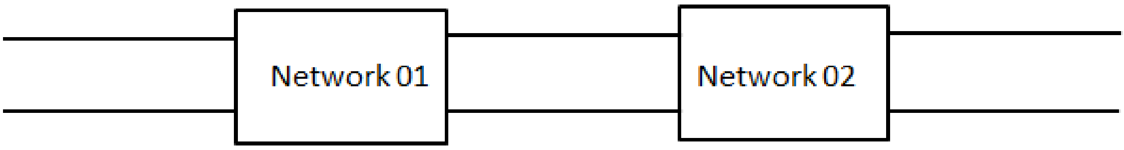


Fig.10 Network Equivalent circuit of the UWB filter

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix}_{overall} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{network\ 01} \times \begin{bmatrix} A & B \\ C & D \end{bmatrix}_{network\ 02} \text{--------------} (1)$$

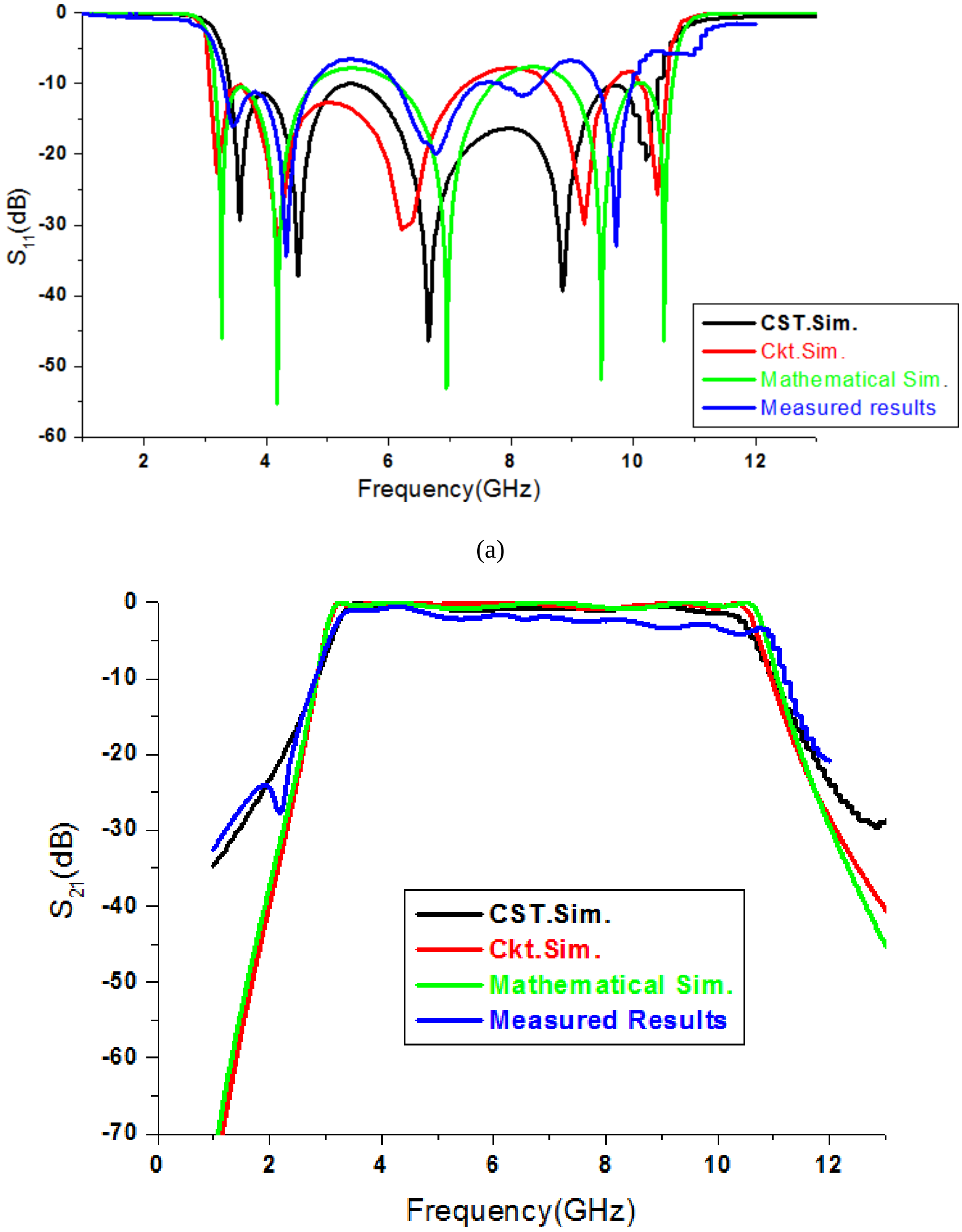
The overall ABCD parameters obtained by equation 1 are converted into S-parameters by the following equations

$$S_{11} = \frac{A + BY_0 - CZ_0 - D}{A + BY_0 + CZ_0 + D} \text{------------------------} (2)$$

$$S_{21} = \frac{2}{A + BY_0 + CZ_0 + D} \text{--------------------------} (3)$$

$$\text{Where } Z_0 = \frac{1}{Y_0} = 50\Omega$$

The S-parameters obtained from equation 2&3 are calculated by using MATLAB and simulation results are compared with CST simulation results and the SERENIDE circuit simulation results. The close resemblance among the results shown in Fig.11 verifies the proposed method of obtaining equivalent circuit of the filter.



(a)

(b)

Fig.11 Comparison of results (a) Return loss (S_{11}) (b) Insertion Loss (S_{21})

4. CONCLUSIONS

A microstrip line UW BPF filter using parallel coupled microstrip line and multi-mode resonator is presented in this paper. For demonstration the UWB BPF is designed, simulated and fabricated. The measured frequency response of the filter shows band pass behavior in frequency range from 3.1 GHz to 10.6 GHz with insertion loss less than -2.0 dB and return loss better than -10.0 dB. The electrical equivalent circuit of the filter is also reported is this paper. The proposed filter may be useful for wireless communication systems.

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