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Abstract- This paper presents design and analysis of a simple and compact ultra-wideband (UWB) band-pass-filter using parallel-coupled micro strip line with DGS.A two poles filter is designed by a parallel couple micro strip line. A rectangular defective ground plane is used to enhance coupling between lines i.e. better return loss in UWB range. Simulation of this proposed filter is carried out on CST MWS software, and fabricated using microwave laminate GML 1000 of dielectric constant 3.2 and height 0.762mm with loss tangent 0.001.Measured results are compared with simulation results with good agreement. The electrical equivalent model of this filter is also presented in this paper.

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Design and Analysis of Compact UWB BPF Using Parallel Coupled Microstrip Line With DGS

Satish Chand Gupta[α], Mithlesh Kumar[σ] & Ramswaroop Meena[ρ]

Abstract- This paper presents design and analysis of a simple and compact ultra-wideband (UWB) band-pass-filter using parallel-coupled micro strip line with DGS.A two poles filter is designed by a parallel couple micro strip line. A rectangular defective ground plane is used to enhance coupling between lines i.e. better return loss in UWB range. Simulation of this proposed filter is carried out on CST MWS software, and fabricated using microwave laminate GML 1000 of dielectric constant 3.2 and height 0.762mm with loss tangent 0.001.Measured results are compared with simulation results with good agreement. The electrical equivalent model of this filter is also presented in this paper. The equivalent model of this filter is verified by comparing the frequency response of equivalent circuit of the filter and simulated frequency response of this filter.

Keywords: multi-mode resonator (MMR), fractional bandwidth (FBW), ultra-wide band (UWB), band pass filter (BPF), parallel-coupled micro strip line(PCML),defective ground plane structure (dgs).

I. 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 filters with a pass band of the frequency range (3.1 GHz - 10.6 GHz), and a fractional bandwidth of 110% for conventional 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 researcher reported various techniques, like aperture compensation, micro strip-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 structure with open circuited stubs [11],tunable harmonic stepped-impedance resonators [12] and parallel coupled line micro strip structure [13] were used to design the UWB filter.

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The synthesis of UWB filter has been carried out by various approaches presented in [14-15].

The transfer function of the proposed UWB was synthesized having two short circuited stubs with two stages of stepped impedance resonators (SIRs)[14].In[15],series multi conductor transmission lines (MTLs) and ashunt MTL were used to design various UWB filters and a new approach was presented to synthesize the transfer function of UWB filter.

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 single PCML and DGS is demonstrated. The electrical analysis of the filter is mentioned in section 3.Finally paper is concluded in section.4.

II. Design of UWB Filter

The layout of the proposed structure is shown in Fig.1 which consist a quarter wavelength parallel coupled micro strip line (PCML) with a rectangular shaped DGS. The designed structure of filter is optimized by using CST Microwave Studio software on the 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 1.

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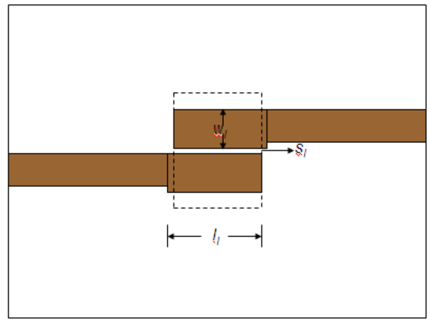
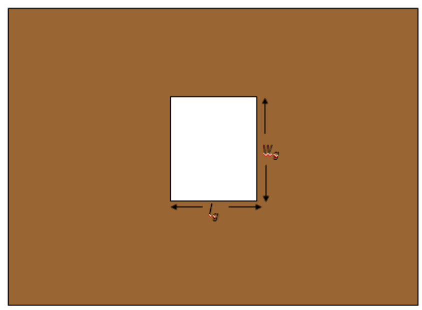


(a)



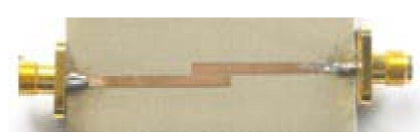
(b)

Fig.1: Schematic of UWB filter (a) Front view (b) Back view

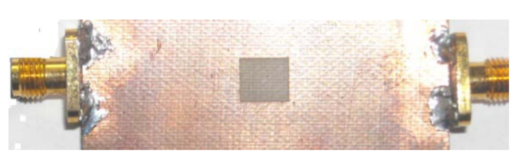
Table1: Design Parameters Of The UWB Filter

l_l (mm)	w_l (mm)	s_l (mm)	l_g(mm)	w_g(mm)
6.99	1.86	0.11	6.74	6.0

The optimized structure of this filter is fabricated using conventional microwave integrated circuits (MIC) technology, the photograph of the fabricated filter is shown in Fig.2.The frequency response (S_{11}&S_{21}) of this fabricated filter is measured on Agilent Tech. E5071C ENA Vector Network Analyzer. The measured frequency response is compared with simulated frequency response which is in close approximation, and it is shown in Fig.3 (a).It is observed from the frequency response of the fabricated filter, that the pass band of this filter exists from 3.1 GHz to 10.9 GHz, insertion loss (S_{21}) of -0.5 dB and return loss (S_{11}) better than 10 dB. The group delay is also measured and compared with simulation value, and it is observed that this filter having a flat group delay of value 0.35 ns approximately, which is shown in Fig.3 (b).A slight mismatch in the results is due to imperfection in fabrication process, quality of substrate and SMA connectors. The surface current distribution at center of the frequency 6.85 GHz is shown in Fig.3(c), which is uniform along the structure of the filter, from port 1 to port 2 indicates good pass band behavior of the filter.

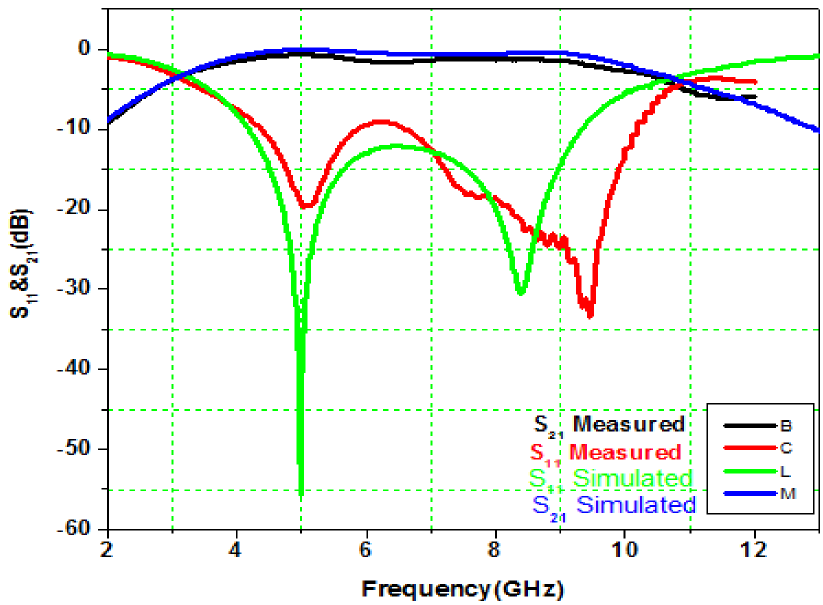


(a)



(b)

Fig.2: Photograph of fabricated filter (a) Front view (b) Back view



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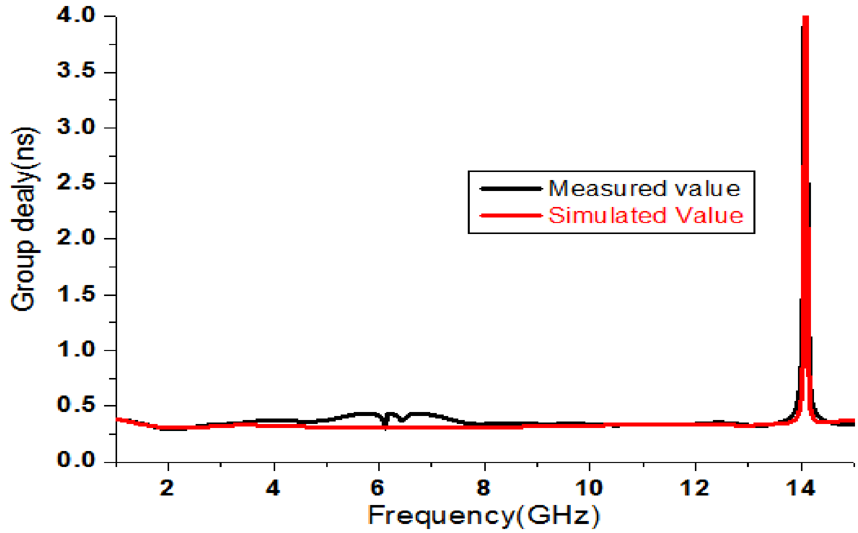
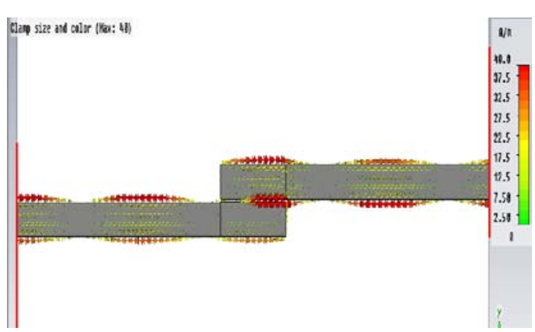
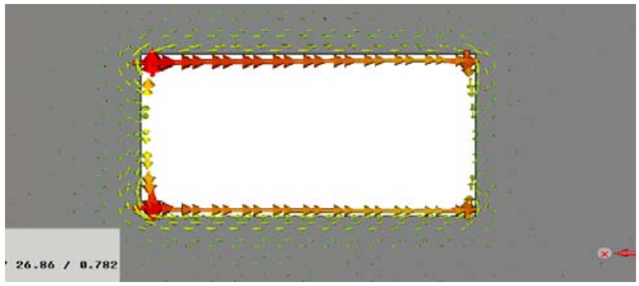


(b)

Fig.3: (a) Comparison of Frequency responses (b) Group delay



(c)

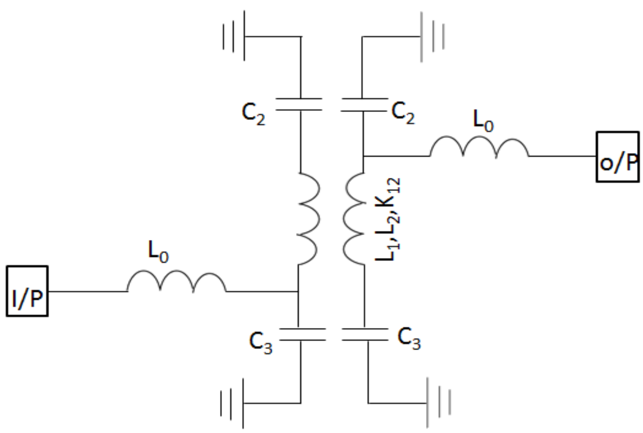


(d)

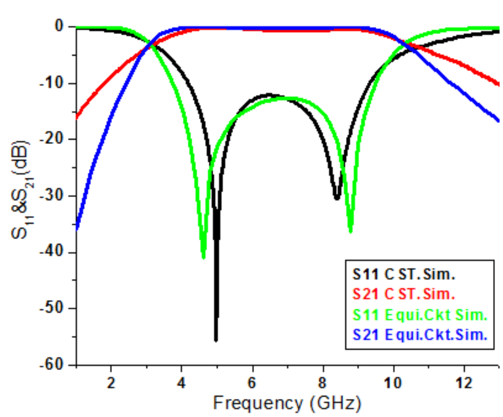
Fig.3: (c) Surface current density at center frequency 6.85 GHz (top View) (d) Bottom View

III. Electrical Analysis Of The Filter

The proposed filter consist one parallel coupled micro strip line with DGS and 50 ohm transmission line. The PCML can be represented by a two mutually coupled inductors (L_1, L2, K_{12}) and capacitance of the line Ci (between line and ground plane).The 50 ohms transmission feed line can be represented by a lumped value inductor L_0.The electrical equivalent circuit of the proposed UWB filter is shown in Fig.4(a).This circuit is optimized and simulated on circuit simulator SERENIDE SV8.5 for values L_0=0.8215 nH,K_{12}=0.6218 ,L_1=L_2=3.55 nH and C_2=C_3=0.456 pF. The comparison of frequency responses of this UWB filter is on CST MWS and equivalent circuit on SERENIDE SV 8.5 shown in Fig.4 (b).



(a)



(b)

Fig.4: (a) Electrical equivalent circuit of UWB filter (b) Comparison of frequency response

The circuit shown in Fig.4 (a) can be analyzed by network circuit theory, and it can be redraw in simplified form shown in Fig.5

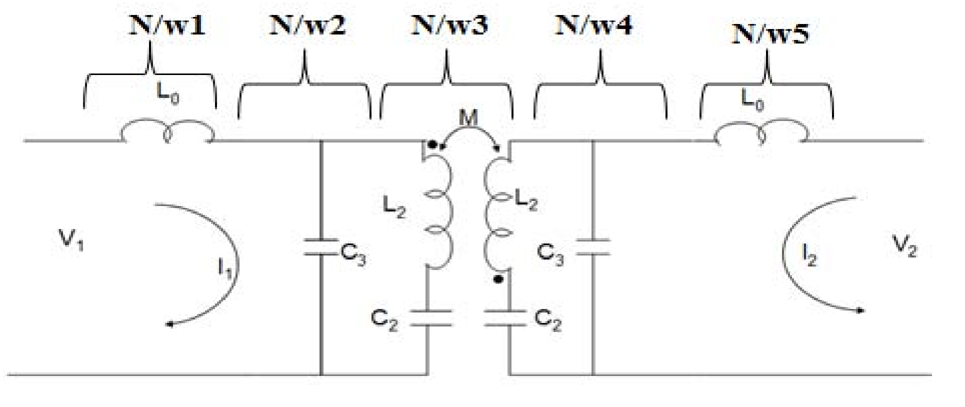


Fig.5: Simplified electrical equivalent of UWB filter.

ABCD-parameters of the circuit shown in Fig.5 can be determined by considering the cascade connection of the networks.

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & SL_0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC_3 & 1 \end{bmatrix} \begin{bmatrix} \dfrac{SL_2 + \dfrac{1}{SC_2}}{-SM} & \dfrac{\left(SL_2 + \dfrac{1}{SC_2}\right)^2 - (SM)^2}{-SM} \\ \dfrac{1}{-SM} & \dfrac{SL_2 + \dfrac{1}{SC_2}}{-SM} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC_3 & 1 \end{bmatrix} \begin{bmatrix} 1 & SL_0 \\ 0 & 1 \end{bmatrix} \quad \text{-- (1)}$$

For the simplification of the matrix multiplication, we have assumed some constant parameters.

Where S= j =j2πf

$$P = \frac{SL_2 + \dfrac{1}{SC_2}}{-SM}$$

And

$$Q = \frac{\left(SL_2 + \dfrac{1}{SC_2}\right)^2 - (SM)^2}{-SM}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & SL_0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC_3 & 1 \end{bmatrix} \begin{bmatrix} P & Q \\ \dfrac{1}{-SM} & P \end{bmatrix} \begin{bmatrix} 1 & 0 \\ SC_3 & 1 \end{bmatrix} \begin{bmatrix} 1 & SL_0 \\ 0 & 1 \end{bmatrix} \quad \text{......... (2)}$$

Let $R = 1 + S^2 L_0 C_3$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} R & SL_0 \\ SC_3 & 1 \end{bmatrix} \begin{bmatrix} P & Q \\ \frac{1}{-SM} & P \end{bmatrix} \begin{bmatrix} 1 & SL_0 \\ SC_3 & R \end{bmatrix} \quad \text{....... (3)}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} PR - \frac{L_0}{M} & QR + SPL_0 \\ SC_3P - \frac{1}{SM} & SC_3Q + P \end{bmatrix} \begin{bmatrix} 1 & SL_0 \\ SC_3 & R \end{bmatrix} \quad \text{....... (4)}$$

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} PR - \frac{L_0}{M} + SC_3QR + S^2PL_0C_3 & SL_0PR - \frac{SL_0{}^2}{M} + QR^2 + SPRL_0 \\ 2SC_3P - \frac{1}{SM} + S^2C_3{}^2Q & S^2L_0C_3P - \frac{L_0}{M} + SC_3RQ + PR \end{bmatrix} \quad \text{----- (5)}$$

The insertion and return loss of UWB filter can be calculated by converting the ABCD-parameters into S-parameters. To calculate these, we assume $\Delta = A + BY_o + CZ_0 + D$

$$\Delta = \frac{Z_0{}^2\left\{2SC_3PR - \frac{1}{SM} + S^2C_3{}^2Q\right\} + 2Z_0\left\{PR - \frac{L_0}{M} + SC_3\left(QR + PL_0{}^2\right)\right\} + 2SPL_0R - \frac{SL_0{}^2}{M} + QR^2}{Z_0} \quad \text{-- (6)}$$

Similarly, we assume that $\Delta_1 = A + BY_0 - CZ_0 - D$

$$\Delta_1 = \frac{2SPL_0R - \frac{SL_0{}^2}{M} + QR^2 - Z_0{}^2\left(2SC_3P - \frac{1}{SM} + S^2C_3{}^2Q\right)}{Z_0} \quad \text{-------- (7)}$$

The S_{11} & S_{21} parameters to be calculated by using the final values of ABCD-parameters with help of following equations,

$$S_{11} = \frac{A + BY_0 - CZ_0 - D}{A + BY_0 + CZ_0 + D} = \frac{\Delta_1}{\Delta} \quad \text{------------------- (8)}$$

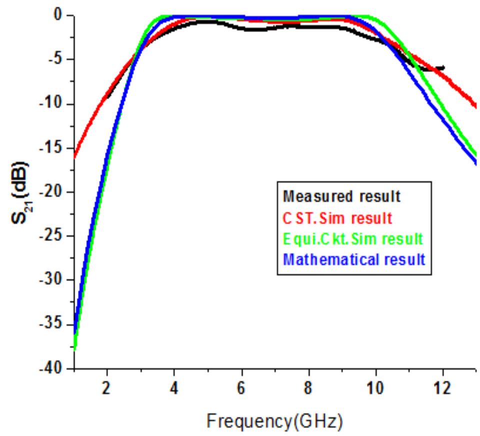
$$S_{21} = \frac{2}{A + BY_0 + CZ_0 + D} = \frac{2}{\Delta} \quad \text{------------------- (9)}$$

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

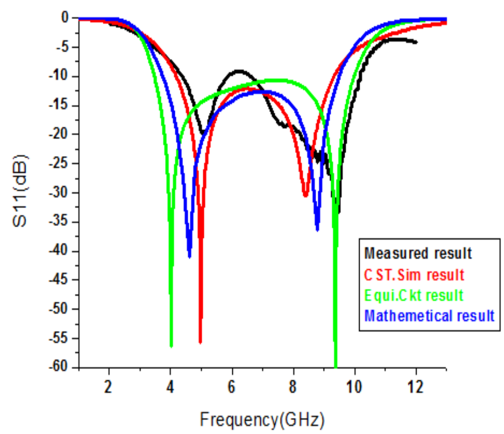
$$S_{11}\,(\text{dB}) = 20\log_{10}|S_{11}| \quad \text{---------------- (10)}$$

$$S_{21}\,(\text{dB}) = 20\log_{10}|S_{21}|$$

The expression of S11 and S21 obtained from equation 8-9 in terms of frequency is solved by using MATLA Band comparison among the responses(S11&S21) are shown in Fig.6.The close approximation in the measured response, CST simulation response, equivalent circuit response and its mathematical model response verify the approach of equivalent circuit of the proposed filter.



(a)



(b)

Fig.6: Comparison of results (a) S_{21}(b) S_{11}

IV. Conclusions

A simple and compact two poles UWB band pass filter using PCML with DGS is implemented. It is observed that the introduction of DGS in micro strip line circuit enhance the bandwidth of the system. The electrical analysis of this proposed filter is carried out by conventional circuit theory. The size of filter is of size (7.0mm ×6.0mm) and such filter may be useful for the systems of UWB communication.

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