Design And Implementation Of Microstrip Bandpass Filter Using Parallel Coupled Line For ISM Band

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ABSTRACT

In this paper, the design of 2.4 GHz parallel line coupled band pass filter with 0.5dB ripple factor and 10% bandwidth has been elaborated. The coupled line bandpass filter has been simulated using Ansys HFSS simulation software on a FR4 substrate with εr = 4.4 and thickness of 1.6mm. The development of band pass filter includes calculation, simulation, testing and measurement of the filter parameters process has been presented.

Keyword- *Filters, coupled line bandpass filters, transmission lines…..etc.*

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1. INTRODUCTION

A Filter is a two-port Network used to control the frequency response at a certain point in an RF or Microwave systems by providing transmission at frequencies within the pass band of the filter and attenuation in the stopband of the filter [1].Coupled transmission structures are critical components in distributed RF and microwave passive circuits design. Their application in design of directional couplers and filters are well known, as the coupled sections play important role in the design of Capacitor, Inductor, Transformer, and Balun. Availability of high dielectric constant materials has extended the usage of coupled sections to lower microwave and RF frequencies [2].

The work of development of filter theory and practice began in the year's preceding World War II. The image parameter method of filter design was developed in the late 1930s and was useful for low-frequency filters in radio and telephony. The main drawback of Image parameter method was ,it doesn't allowed a specification of particular frequency response over complete operating range.So,even though the design looks to be simple, the method should be iterated many times to obtained the desired results. At Stanford Research Institute, group consisting of G. Matthaei, L. Young, E. Jones, S. Cohn, and others, became very active in microwave filter and coupler development. Today, most microwave filter design is done with sophisticated computer-aided design (CAD) packages based on the insertion loss method. Because of continuing advances in network synthesis with distributed elements, the use of low temperature superconductors and other new materials, and the incorporation of active devices in filter circuits, microwave filter design remains an Active research area. To ease the integration between bandpass filters and other active devices many previous works on planer filter design is reported in [5]. Various types of coupled structures like as Strip lines, Micro strip lines, coplanar waveguides, image guides, Insular and inverted strip guides are used .Practical spacing limitations between lines in TEM and Quasi TEM limits the tight coupling achievable to about 8 dB over λ/4 sections. The first three types use TEM or Quasi TEM modes whereas later two uses Non TEM modes [2]. The types of coupled lines are unevenly coupled, periodically non-uniform, meandered, cross coupled, Step impedance resonators, DGS (Defected Ground Structure. Hairpin Filters are used for wide band applications. Here demand on the selectivity is not severe. Hairpin and comb line filters use dielectric constant ε_r = 80 and 90.For Dual band communications applications of mainly WLAN and Ultra-wide band Structure. WLAN uses HTS, LTCC, LCP types of structure and UWB uses DGS. The primary parameters of interest in a filter are frequency range, Bandwidth, Insertion loss, stop band attenuation, Input and Output Impedances, Group Delay and Transient Response. The subject of microwave filters is quite extensive due to the importance of the components in practical systems and the wide variety of possible implementations.

1.1 Insertion Loss Method

The insertion loss method, however, allows a high degree of control over the pass band and stop band amplitude and phase characteristics, with a systematic way to synthesize a desired response. The necessary design trade-offs can be evaluated to best meet the application requirements. To have, , a minimum insertion loss, a binomial response could be used; for the requirement of sharpest cut-off a Chebyshev response could satisfy a requirement.. If it is possible to sacrifice the attenuation rate, a better phase response can be obtained by using a linear phase filter design. In addition, in all cases, the insertion loss method allows filter performance to be improved in a straightforward manner, at the expense of a higher order filter [1].

1.2 Impedance and admittance inverters

The Impedance and admittance inverters are two port network, those has a phase shift of +-90 degrees. The inverters have the ability to shift load impedance or admittance levels depending on the values of K or J parameters. These property enable to transform series-connected element to shunt-connected elements, or vice versa to convert a filter circuit to equivalent form for the implementation. Such inverters are especially useful for Bandpass or Band stop filters with narrow (<10%) Bandwidth [3]

2. Filter Design Procedure

1) The first thing is to find the order of the filter. For the Chebyshev response, with 0.5 ripple in passband and 15dB attenuation at 2 GHz, we calculate the order of filter from graph of normalized frequency versus attenuation. So Order for our filter is (N=2).

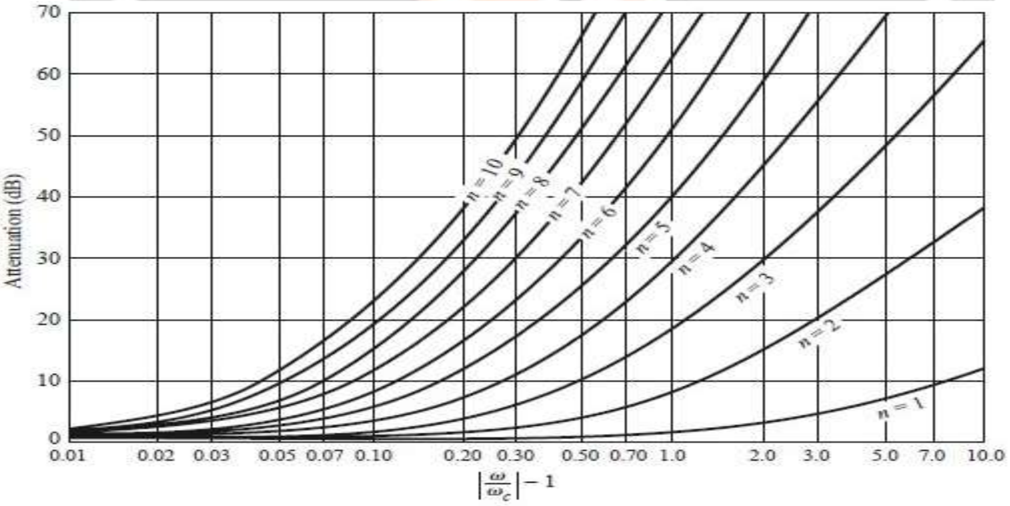

Fig. 1: Graph of Normalized Frequency Vs Attenuation

2) The design is simplified by beginning with low-pass filter prototypes that are normalized in terms of impedance and frequency. The low-pass prototype filter design can be transformed to have the bandpass response as $\omega = 1/\Delta\,(\omega/\omega_0 - \omega_0/\omega)$ ……………………………………………………..………… (1)
Where $\Delta = \omega_2 - \omega_1/\omega_0$

3) To change the cut off frequency of low prototype from unity to ω_c,we required to scale the frequency dependent of the filter by the factor $1/\omega_c$ which is accomplished by replacing ω/ω_c.

4) For microwave applications, designs usually must be modified to employ distributed elements using Richard's Transformation. Richard's transformation allows the inductors and capacitors of lumped-element filter to be replaced with short-circuited and open –circuited transmission line stubs.

5) To derive the equation for the Coupled line filter design, show that a single line section can be approximately modeled by the equivalent circuit shown in figure.

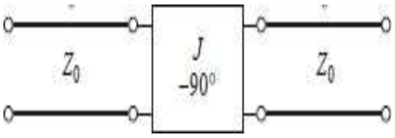

Fig.2: Equivalent Circuit Of the Coupled Line Section

6) Then by calculating the image impedance and propagation constant of the equivalent circuit and showing that they are approximately equal to those of the coupled line section for $\theta = \pi/2$. will correspond to the center frequency of the band pass response.

7) The equations of Image impedance and propagation at($\theta = \pi/2$) cab be solved to give an even and odd mode line characteristics impedances as given,

$$Z_0e = Z_0 [1 + J Z_0 + (J Z_0)2] \quad \text{.....(2)}$$

$$Z_0o = Z_0 [1 - J Z_0 + (J Z_0)2] \quad \text{.....(3)}$$

8) The design equations for a bandpass filter with N+1 coupled line are given as from [1]

$$Z_0 J_1 = \sqrt{\frac{\pi\Delta}{2g_1}} \quad \text{.....(4)}$$

$$Z_0 J_n = \frac{\pi\Delta}{2\sqrt{g_{n-1} g_n}} \; for\ n = 2,3,\dots\dots n \quad \text{.....(5)}$$

$$Z_0 J_{N+1} = \sqrt{\frac{\pi\Delta}{2 g_N g_{N+1}}} \quad \text{.....(6)}$$

9) After J_N are found, Calculate the Z_{oe} and Z_{oo} for each coupled line section.

Where J = Admittance Inverters

Here, we have obtained the optimize values of the dimensions for coupled line filter design on Ansoft Software 13.0 as shown in the table 1.

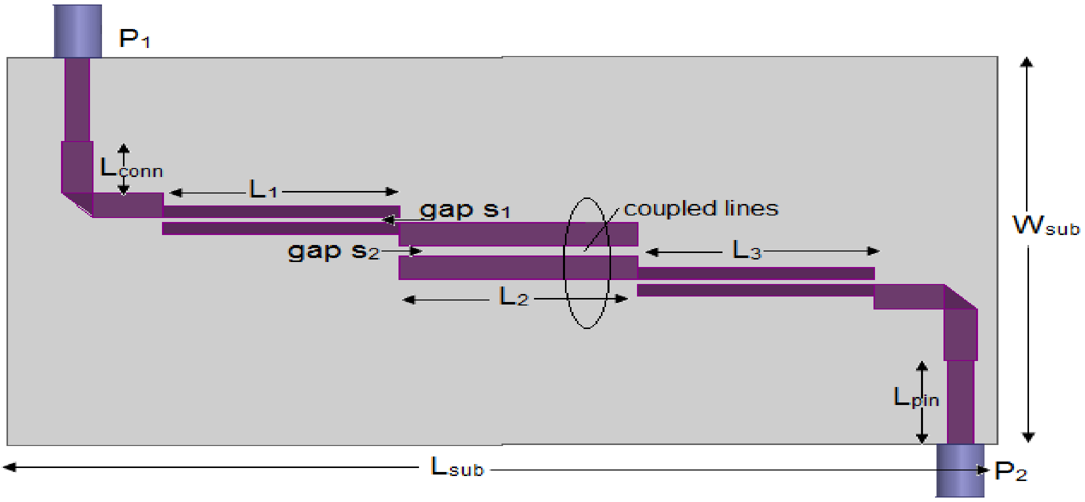

Fig.:3 Geometry of Coupled Line Bandpass Filter

Table 1: Optimized values of coupled line bandpass filter (all values in mm)

L_1	17 × 1.1	Gap s_1	0.5
L_2	17 × 2.2	Gap s_2	1
L_3	17 × 1.1	L_{sub}	71
L_{conn}	2.3 × 5	W_{sub}	37
L_{pin}	1.8 × 8	Thickness of substrate	1.6

4. RESULTS AND DISCUSSION

The proposed coupled line filter is fabricated on a FR4 substrate of thickness 1.6mm and dielectric constant $\varepsilon_r = 4.4$. The fabricated filter prototype is then measured using Spectrum Analyzer. Figure 5 shows the simulated reflection coefficient and transmission coefficient bandwidth of the coupled line bandpass filter. The filter has simulated reflection coefficient and transmission coefficient bandwidth of 149 MHz and 288 MHz respectively which covering the ISM frequency band of 2.4 GHz. Figure 4 shows the fabricated prototype of the coupled line bandpass filter.

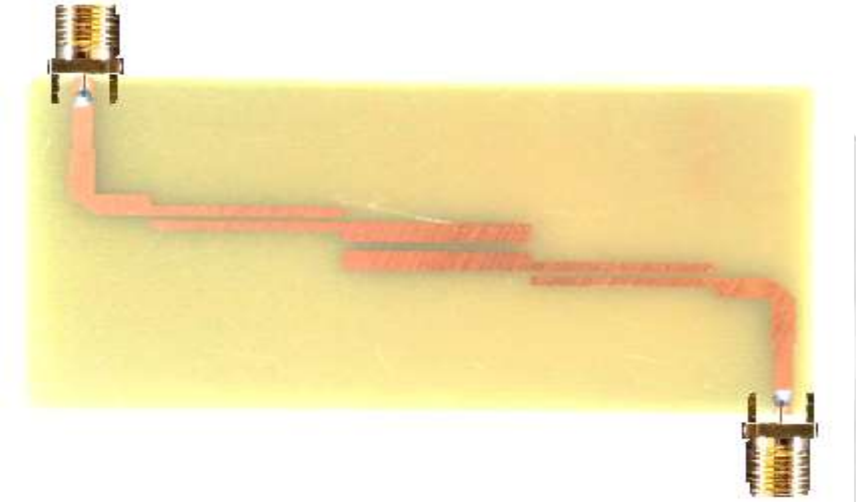

Fig.4 : Fabricated Prototype Of the Proposed Coupled Line Bandpass Filter

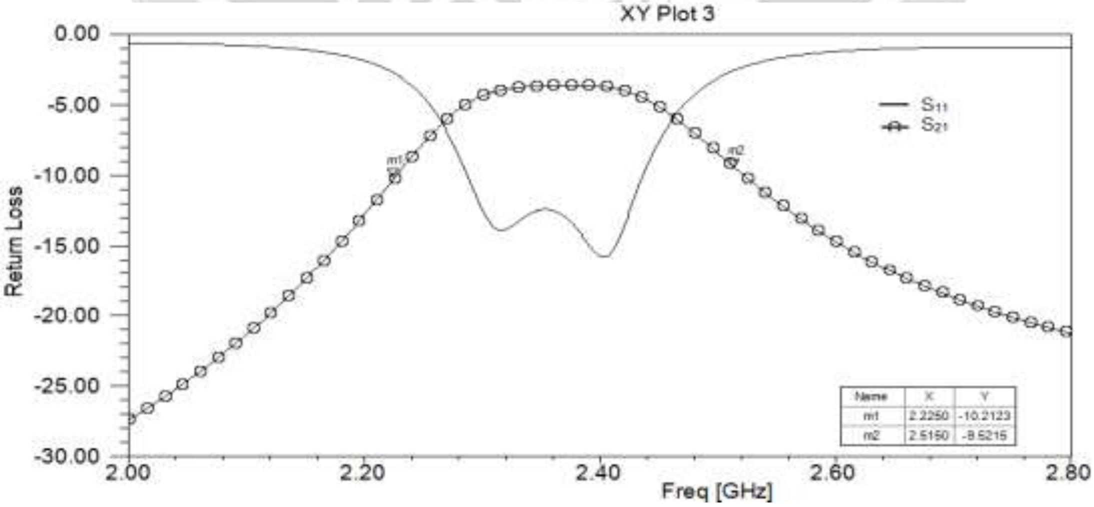

Fig.5: Simulated Reflection (S_{11}) and Transmission (S_{21}) Return Loss Of the Coupled Line Bandpass Filter.

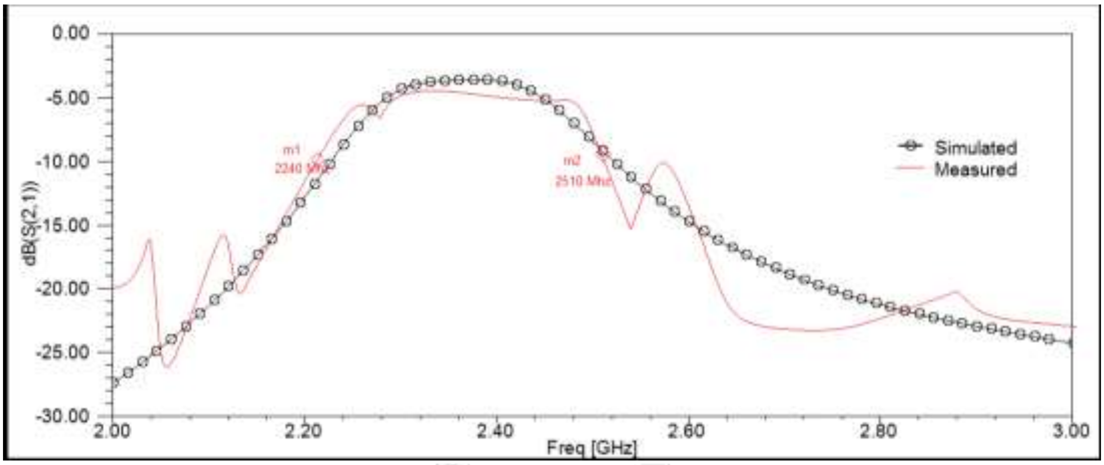

Fig.6: Measured Reflection (S_{11}) and Transmission (S_{21}) Return Loss Of the Coupled Line Bandpass Filter.

5. CONCLUSIONS

In this article, design of coupled line bandpass filter for filtering the ISM band frequency is illustrated using HFSS EM simulation software. The presented coupled line bandpass filter provides a transmission bandwidth of 288 MHz covering the ISM band frequency of 2.4 GHz with -10dB return loss. The prototype coupled line bandpass is fabricated on a FR4 substrate and tested. The simulated and measured results are in good agreement with each other.

6. REFERENCES

[1]. David M. Pozar. 2000, *“Microwave Engineering”*,N.Y.: John Wiley & Sons, Inc

[2]. R. K. Mongia,I. J. Bahl,P. Bhartia,J. Hong , “ RF and Coupled line circuits” Artech House Inc 2007.

[3]. Jia shen G.Hong and M.J.Lancaster, “Micro Strip Filters for RF/Microwave Applications” John Wiley and Sons Inc.,2001.

[4]. G.Mathaei,L.Young and E.M.T.Jones, “Microwave Filter Impedance matching networks and coupling structures,” Artech house,Norwood,MA,1980.

[5]. S.B.Cohn, “ Parallel Coupled transmission line resonator filters” IRE Tranction Microwave Theory Tech,Vol,pp 223-231,April 1958.

[6]. O.A.R Ibrahim,I.M.Selamat,M.Samingan,M.Aziz,A.Halim, “ 5.75 GHZ micro strip band pass filter for ISM band,” Applied Electromagnetics,2007 Asia-Pacific Conference on December 20 07,pp.1- 5.

[7]. A.E.Vandenbosch and Alexander Vasylchenko, “ A Practical Guide to 3D Electromagnetic Software Tools”.