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Performance Comparison of Parallel Coupled Microstrip Bandpass Filter

KEYWORDS: Bandpass filter, microstrip, dielectric Constant, fractional bandwidth, substrate, insertion loss, return loss.

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ABSTRACT This paper discusses a parallel coupled microstrip bandpass filter at frequency 1 GHz, using various dielectric substrates, having different dielectric constants. They are simulated using the Ansoft Designer software and their performances are compared. The comparison is made for two dielectric substrates: FR4, PTFE (Teflon) . The simulated results show that the filter is operating well for desired specifications and shows that design with Teflon substrate provides higher return loss and lower ripple.

I. INTRODUCTION

A filter is a network which allows the transmission of signal frequencies within the pass band and rejects at the stop band region.Mobile communication market which is developing very fast needs huge compact and inexpensive communication devices such as microwave filters and antenna.Microwave /RF filters are widely used in wireless communication systems in order to discriminate between the desired and undesired signal frequencies. Microstrip bandpass filters confine the Radio Frequency signals within the assigned spectral limits since the electromagnetic spectrum is limited by various reasons such as licensing issues.

RF and microwave filters may be designed as lumped element or distributed element circuits; depending on the requirements and specifications .They may be realized in various transmission line structures, such as waveguide, coaxial line, and microstrip lines .

Based on filter response a filter can be classified in four basic types: Low pass filter, high pass filter, band pass filter and band stop filter. Microstrip consists of a single dielectric substrate with ground plane on one side and a stripline on the other face. Microstrip filter offers various advantages such as smaller size and light weight for compatibility,

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For any high frequency filter design the performance measurement parameters are Return loss and insertion loss. Our proposed work focuses on the design and performance comparison of parallel coupled microstrip bandpass filter when implemented using various substrate.

To design these filter and to perform simulation results ,EM simulation tools can be used.The filter design is chosen in L band frequency segment and the simulation is done for different substrate using 'Ansoft Designer' simulation tool. The filter performance are simulated in terms of insertion loss and return loss. Simulated results are represented in terms of S-parameters such as transmission coefficient(S12) and reflection coefficient(S11).

Microstrip Filters

Microstrip filters are being used in microwave, wireless and satellite communication systems. It is required to design compact filter for communication applications. In microwave communication systems, bandpass filter is an essential component, which is usually used in both receivers and transmitters. Thus, the quality of bandpass filters is extremely important. Planar filters are currently popular structure because they can be fabricated using printed circuit technology and are suitable for commercial applications due to their small size and lower fabrication cost. With the advent of widespread applications of mobile communication systems, the development of bandpass filters has emphasized compact size and high performance. To get a compact size, several types of resonators such as stepped impedance resonator (SIR), U-shaped hairpin resonator, the open-loop resonator, and the folded open-line resonator have been proposed to design different kinds of Band pass filters. Among these popular resonators, the most frequently used is the SIR as it is presented not only to get a compact size, but also control the resonant frequencies by changing its structure parameters. [5]

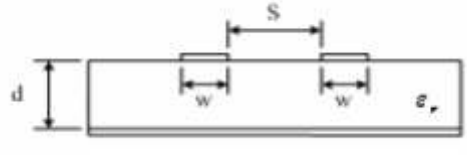


Fig.1 Coupled microstrip line

where
L= Length of the element.
W =Width of the element
d = Height of the dielectric element.
S = Spacing between the element

IMMITTANCE INVERTER

Immittance inverters play a very important role in filter

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design. They are used to transform a filter circuit into an equivalent form that can be easily implemented using various microwave structures. Immittance inverters are either impedance or admittance inverters. Because of the inverting action, a series inductance with an inverter on each side looks like a shunt capacitance and a shunt capacitance with an inverter on each side looks like a series inductance. Immittance inverters are shown in Fig.2.

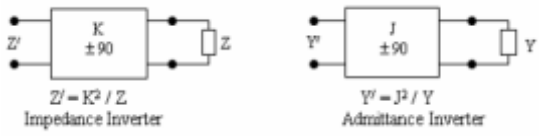


Fig.2.

Making use of the properties of immittance inverters ,bandpass filters may be realized by series (L-C) resonant circuits separated by impedance inverters (K) or shunt (L-C) parallel resonant circuits separated by admittance inverters (J). To design a bandpass filter, first of all a low-pass prototype circuit is modified to include immittance inverters. These low pass structures are then converted to bandpass circuits by applying conventional low-pass to bandpass transformation. [1]

II. DESIGN METHODOLOGY

Generally filters are of two types, one is with lumped elements and another one is with distributed elements. The performance of distributed elements is effective at microwave frequencies .Due to this reason, most of the microwave band pass filters are based on distributed elements(e.g. waveguides , microstrip lines, and coplanar waveguides). Microstrip bandpass filters can be designed by two methods : (i)image parameter method (ii) insertion loss method.

A. Design Steps

Based on the design specification given in Table I, prototype values are calculated. The following steps are generally involved in the design of filter topologies.

- Design of third order low pass filter using filter prototype element values.
- Transformation of lowpass to bandpass
- Design of parallel coupled filter based on even and odd mode impedances.

B. Design Equation

The BPF circuit is simulated with Ansoft Designer Software in order to predict the performance of the filter. Few parameters in the circuit are analyzed and have a good relationship to microwave theory. An optimization process has been introduced along the simulation procedure focusing on the filter dimension in order to improve the response of the filter. Refer to the filter tables given in D.M Pozar and G. L. Matther to find the following coefficients for a third order Chebyshev filter.[8]

Table I
Element values for equal ripple band-pass filter prototypes ($g0 = 1$, $\omega c = 1$, n = 1 to 10 and 0.5 dB ripple)

Filter Order (n)	g_0	g_1	g_2	g_3	g_4
3	1	1.5963	1.0967	1.5963	1

Table II
Design specifications

Filter type	Chebyshev
Order of filter(n)	3
Centre Frequency(fo)	1GH_z
Fractional bandwidth(FBW)	0.2%
Dielectric constant(εre)	4.4 (FR4) 2.08(TEFLON)

Even and odd modes in a coupled transmission line

Calculation of Odd and Even Resistances to design the stripline filter, an approximate calculation is made based on the design equations. The no of stages (n) = 3. The characteristic impedance Z0 is typically 50 Ohms. The unitary bandwidth BW is given by
Where is

$$FBW = \frac{\omega_2 - \omega_1}{\omega_0} \qquad (1)$$

where FBW is fractional bandwidth

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi}{2} * \frac{FBW}{g_0 g_1}} \qquad (2)$$

$$\frac{J_{j,j+1}}{Y_0} = \left(\frac{\pi FBW}{2}\right) * \frac{1}{\sqrt{g_0 g_1}} \qquad \text{for j=1 to n-1} \quad (3)$$

$$\frac{J_{j,j+1}}{Y_0} = \sqrt{\frac{\pi}{2} * \frac{FBW}{g_n g_{n+1}}} \qquad (4)$$

TABLE III
Calculation of Z_{oe}, Z_{oe}

Where g0, g1… gn are the element of a ladder-type low-pass prototype with a Normalized cutoff Ωc = 1, and FBW is the fractional bandwidth of band-pass filter. J j, j+1 are the characteristic admittances of J-inverters and Y0 is the characteristic admittance of the terminating lines. The equation above will be used in end-coupled line filter because the both types of filter can have the same low-pass network representation. However, the implementation will be different. To realize the J-inverters obtained above, the even- and odd-mode characteristic impedances of the coupled strip line bandpass filter are determined by[3][4]

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1 + \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \qquad (5)$$

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right]$$

III. DESIGN AND SIMULATION RESULTS

Order of filter (n)	admittance inverters Jj,j+1/Y0	Even-mode impedance Zoe (Ohms)	Odd-mode impedance Zoo (Ohms)	Simulated Zoe (Ohms)	Simulated Zoo (Ohms)
1	0.4463	82.116	37.653	83.12	37.60
2	0.2385	64.770	40.918	65.62	40.63
3	0.2385	64.770	40.918	65.62	40.63
4	0.4463	82.116	37.653	83.12	37.60

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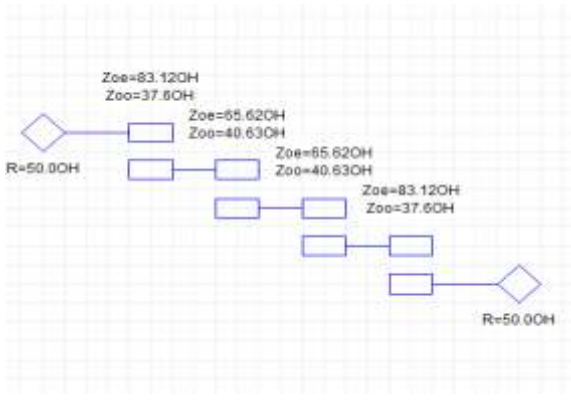


FIG 3:Design

Using a Filter Design Tool in Ansoft Designer, the width, length and line spacing for each coupled line was calculated: The substrate used is a standard FR4 substrate (MSUB) with εre = 4.4 , H = 1.52mm , T = 0.017mm and Tand = 0.02.Using a Design Tool in AnsoftDesigner, the width, length and line spacing for each coupled line was calculated:

TABLE IV
Dimensional Values(FR4)

Line	W(mm)	L(mm)	S(mm)
1	1.831	42.48	0.2185
2	2.473	41.74	0.6097
3	2.473	41.74	0.6097
4	1.831	42.48	0.2185

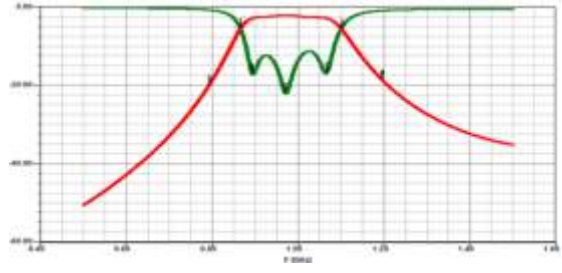


FIG 4:S_{11} and S_{21} of parameters in table IV

Using a Filter Design Tool in Ansoft Designer, the width, length and line spacing for each coupled line was calculated: The substrate used is a standard TEFLON substrate (MSUB) with εre = 2.08 , H = 1.52mm , T = 0.017mm and Tand = 0.001.
Using a Design Tool in Ansoft Designer, the width, length and line spacing for each coupled line was calculated:

TABLE V
Dimensional Values(TEFLON)

Line	W(mm)	L(mm)	S(mm)
1	3.146	57.1	0.1098
2	4.171	56.48	0.433
3	4.171	56.48	0.433
4	3.146	57.1	0.1098

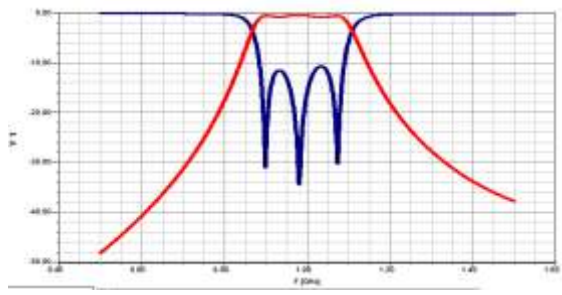


FIG 5: S_{11} and S_{21} of parameters in table V

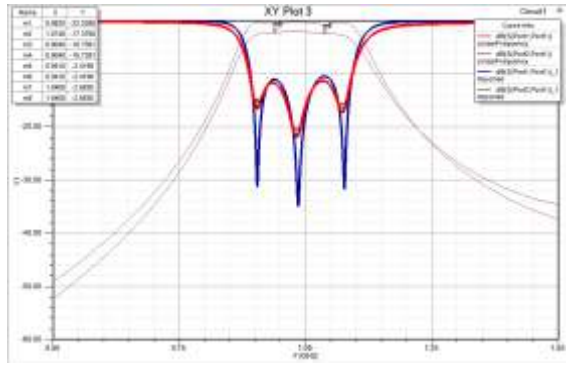


FIG 6: Comparision between return loss (S11) of different two substrate.

TABLE VI
Performance Parameter

Material	Returnloss (dB)	Ripple
Fr4	22.05	0.98
Teflon	34.34	0.78

IV. CONCLUSION

This paper shows the design of edge-coupled microstrip bandpass filter. Both the filters have been successfully designed and simulated for same center frequency 1 GHz.Their return loss and insertion loss values are given in Table VI for different substrates.It shows that the change in substrate changes the result.

The result shows that performance of using Teflon substrate is better than FR4 by having higher return loss and lower insertion loss.

V. ACKNOWLEDGMENT

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