Design of Microstrip Combline Bandpass Filter on Different Substrates

M.Monika, V.Poonkulali, R.Thandaiah Prabu, V.Yokesh

ABSTRACT--- In this contribution, microstrip combline filter with 5th order for the C band frequency is designed. Combline filter is derived from parallel coupled filter by placing a capacitor in the resonator at one terminal and ground at the opposite terminal. The filter is designed for FR4, RT/Duroid 6010 and Roger RO3010 substrates having different dielectric constants using an ADS2009. The characteristics like insertion loss and return loss has been discussed. From the simulation results, high dielectric constant substrate provides better return loss and smaller insertion loss for the selected material.

Keywords— Microstrip, bandpass filter, Combline, dielectric constant, insertion loss, return loss, substrate.

I. INTRODUCTION

A filter is a device that permits the signal transmission within area of pass band and attenuates the signal at the remaining area. Due to the recent advancement in mobile communication, low profile, lighter weight and low cost devices like microstrip patch antenna and filters are required. To differentiate between the wanted and unwanted signal frequencies, Microwave filters are commonly deployed in communication field. Microstrip bandpass filters are used in many applications to limits the frequency of the signal and to avoid various issues like licensing.

Even though there are many filters available in the society, few filters has certain technical difficulties. For excellent rejection, Lumped-element filter cannot be the best choice because of its less 'Q' value. Excellent attainment can be provided by surface acoustic wave filter but its shortcoming is lossy. Helical filters provides sharp rejection but its disadvantages are big size, tuning and assembly problems. [1]

To characterize any filter performance, Return loss and insertion loss are the major parameters. In this proposed method, the design of microstrip combline filter with different substrates has been obsessed.

Microstrip combline filter is a commonly used coaxial filter. From parallel coupled filter, Combline filter is figured by assigning a capacitor at one end and ground at the other end of the resonator.

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To design combline filter ADS 2009 EM simulator has been deployed which shows good results for active and passive lumped model using method of moment (MoM). The proposed work compares S_{11} and S_{12} parameters for three different configurations with the different materials (FR4, RT/Duroid 6010 and Roger RO3010) with the resonant frequency of 4.8 GHz.

II. DESIGN METHODOLOGY

Insertion loss and Image parameter are the two methods for designing the Microstrip bandpass filters. Insertion loss method is used in this paper since it affords more control over stopband and passband phase and amplitude characteristics [3]. It also provides more accuracy and flexibility. Network synthesis technique is used for this method.

Initially low pass filter elements are calculated for the design of microstrip bandpass filter. For five pole Chebyshev response, inductance and capacitance values are calculated for designing the low pass and it is converted to the bandpass filter with same order. The proposed combline filter is derived from designed parallel coupled line microstrip filters with the help of resonators .

A. Design procedure

Element values for the low pass filter are evaluated based upon the filter specifications given in Table I. The procedures involved in the design of combline filter are.

- Five pole low pass filter is designed using calculated prototype values.
- Designed lowpass filter is transformed to bandpass filter.
- Using equations of even and odd mode impedances, Parallel coupled line filter is designed.
- By modifying the parallel coupled line microstrip filter, combline filter is derived.

B. Design Equations

In Table II, calculated prototype values for low pass filter are given. For lowpass filter, Lumped element values are calculated using $g_{0,}g_1\ldots..g_6$. Parallel resonators replaces all capacitors in lowpass and series resonators replaces all inductors in lowpass for the transformation to bandpass filter.

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TABLE I
FILTER SPECIFICATIONS

Filter type	Chebyshev
Order(n)	5
Resonant frequency (f_0)	4.8 GHz
Fractional bandwidth (FBW)	0.1%
Substrate	**Dielectric Constants (ε_r)**
FR4	4.4
RT/Duroid 6010	10.2
RO3010	11.4

TABLE II
LOW PASS FILTER ELEMENT VALUES

Filter Order (n)	g_0	g_1	g_2	g_3	g_4	g_5	g_6
5	1	1.1468	1.3712	1.9750	1.3712	1.1468	1

In parallel coupled line bandpass filter, resonators are fixed in parallel manner along half of their wavelength. This design yields more coupling than end coupled filter structure. J-inverters helps to transform a filter configuration into an equivalent structure. The inverter constants are found using equations (1) & (2) [4]:

$$Z_O J_1 = \sqrt{\frac{\pi\Delta}{2g_1}} \qquad (1)$$

$$Z_O J_n = \frac{\pi\Delta}{2\sqrt{g_{n-1}g_n}} \qquad n=2,..,5 \qquad (2)$$

where $g_0, g_1, \ldots g_n$ are the prototype values of low pass filter design, $J_1, J_2 \ldots J_n$ are the characteristics admittance of the resonator and Z_0 is the characteristic impedance of the microstrip lines. From these calculated values, the odd and even impedances can be manipulated using equations (3) & (4) [4].

$$Z_{0o} = Z_0[\,1 - JZ_0 + (JZ_o)^2\,] \qquad (3)$$

$$Z_{0e} = Z_0[\,1 + JZ_0 + (JZ_o)^2\,] \qquad (4)$$

Using a tool named as LineCalc in ADS, the length, width and spacing of the microstrip lines are manipulated for FR4, RT/Duroid 6010, RO3010.

III. MICROSTRIP COMBLINE FILTER

Coaxial filter is the dominant application in combline filters. Depending upon the number of prototype values, the structure comprises of series of coupled resonator. By loading the capacitor at one terminal of the resonator, minimizes the filter size. The resonator length of the resonators can be made compact by selecting the proper choice of capacitor. Combline filter uses resonators of quarter wavelength. Using the following equations (5), (6) & (7) [4], an external quality factor and coupling coefficients are calculated.

The external quality factors at the input is

$$Q_{e1} = \frac{g_0 g_1}{FBW} \qquad (5)$$

The external quality factors at the output is

$$Q_{en} = \frac{g_0 g_{n+1}}{FBW} \qquad (6)$$

The copling coefficients between the resonators is

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}} \qquad \text{for i=1 to n-1} \qquad (7)$$

The benefits of combline filters are tempered, strong pass band, steep cut-off, sufficient coupling can be maintained between resonators.

TABLE III
DIMENSIONAL VALUES FOR MICROSTRIP COMBLINE FILTER

Substrate Materials	Width (mm)		Length (mm)		Spacing (mm)	
FR4(ε_r=4.4)	W_1	0.34892	L_1	8.00556	$S_{0,1}$	0.25520
	W_2	0.46093	L_2	7.79779	$S_{1,2}$	0.26404
	W_3	0.46830	L_3	7.77775	$S_{2,3}$	0.34930
	W_4	0.46830	L_4	7.77775	$S_{3,4}$	0.34930
	W_5	0.46093	L_5	7.79779	$S_{4,5}$	0.26404
	W_6	0.34892	L_6	8.00556	$S_{5,6}$	0.25520
RT/Duroid 6010(ε_r =10.2)	W_1	0.16132	L_1	5.61158	$S_{0,1}$	0.18440
	W_2	0.22014	L_2	5.62679	$S_{1,2}$	0.29541
	W_3	0.22381	L_3	5.61184	$S_{2,3}$	0.37320
	W_4	0.22381	L_4	5.61184	$S_{3,4}$	0.37320
	W_5	0.22014	L_5	5.62679	$S_{4,5}$	0.29541
	W_6	0.16132	L_6	5.61158	$S_{5,6}$	0.18440
RO3010(ε_r =11.4)	W_1	0.14226	L_1	5.34813	$S_{0,1}$	0.18806
	W_2	0.19583	L_2	5.20689	$S_{1,2}$	0.29908
	W_3	0.19916	L_3	5.19316	$S_{2,3}$	0.37606
	W_4	0.19916	L_4	5.19316	$S_{3,4}$	0.37606
	W_5	0.19583	L_5	5.20689	$S_{4,5}$	0.29908
	W_6	0.14226	L_6	5.34813	$S_{5,6}$	0.18806

IV. DESIGN AND SIMULATION RESULTS

To obtain the schematic and layout structure of parallel coupled line bandpass and combline filter, ADS simulation tool is deployed. The results shows that the higher dielectric constant substrate yields better performance than the lower dielectric constant substrate. Combline filter is designed from parallel coupled filter by placing a capacitor at one end of the coupled line and grounding at the other end. Fig. 1 and Fig. 2 infers the schematic and layout view of parallel coupled line microstrip bandpass filter.

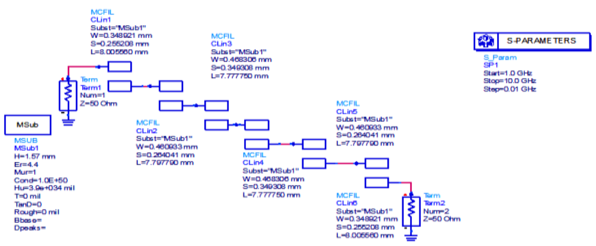

Fig. 1 Schematic structure of parallel coupled line filter

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Fig. 2 Layout structure of parallel coupled line filter

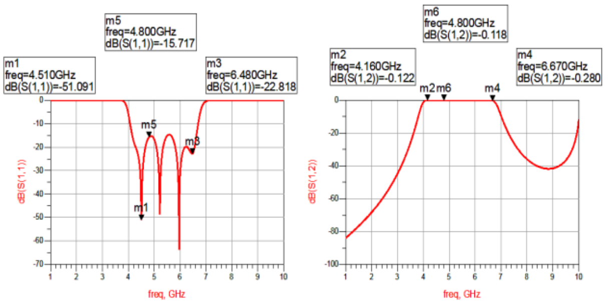

Fig. 3 Simulated result of parallel coupled line filter in FR4

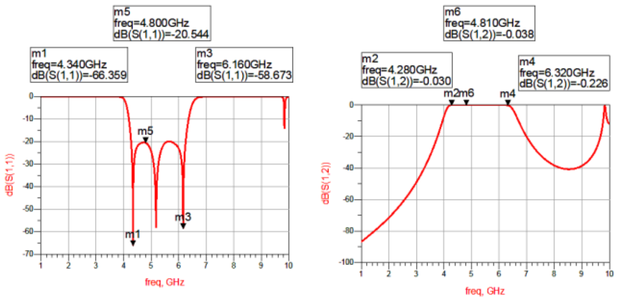

Fig. 4 Simulated result of parallel coupled line filter in RT/Duroid 6010

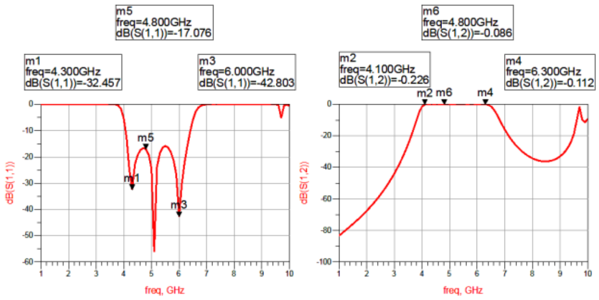

Fig .5 Simulated result of parallel coupled line filter in RO3010

From the above results, Roger RO3010 shows better results when compared to other materials. Fig 6 & 7 shows the schematic and layout view of microstrip combline filter.

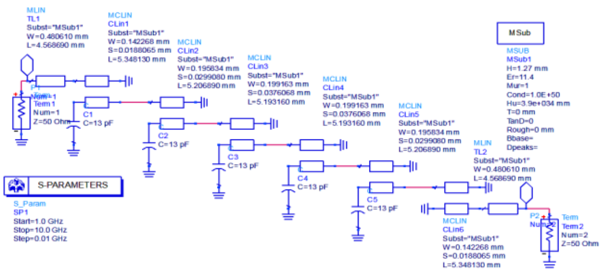

Fig. 6 Schematic structure of microstrip combline filter

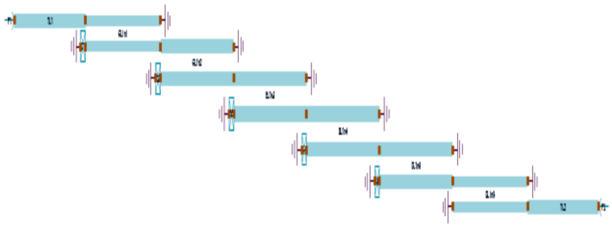

Fig. 7 Layout structure of microstrip combline filter

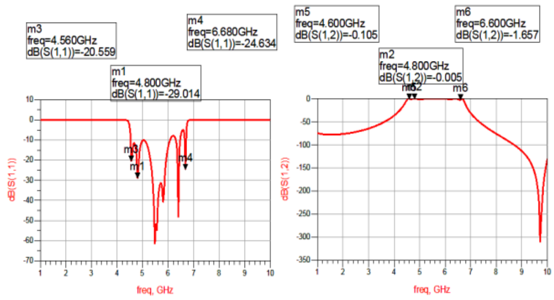

Fig .8 Simulated result of microstrip combline filter in FR4

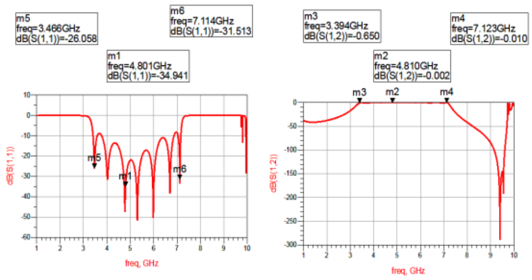

Fig. 9 Simulated result of microstrip combline filter in RT/Duroid 6010

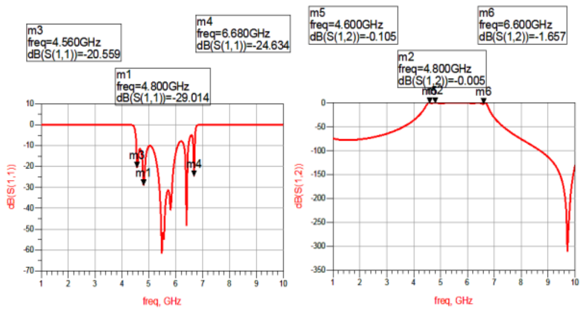

Fig. 10 Simulated result of microstrip combline filter in RO3010

TABLE IV
PERFORMANCE COMPARISON OF MICROSTRIP COMBLINE FILTER

Substrate Materials	Combline filter	
	Insertion loss(dB)	*Return loss (dB)*
FR4	0.005	29.014
RT/Duroid 6010	0.002	34.941
RO3010	0.003	40.043

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V. CONCLUSION

The filter has been designed and simulated for different substrates successfully for the selected frequency of 4.8 GHz. In table IV, the values of insertion loss and return loss are given for different substrates. From the above results, combline filter designed on Roger RO3010 substrate indicates better performance than RT/Duroid 6010 and FR4 substrates.

In future work, fabrication has to be done for the above substrates and their characteristics can be verified using network analyzer by measuring transmission and reflection coefficients. In order to obtain exact dimension values, further optimization can be made.

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