

## Development of Fifth Order Coupled Line Bandpass Filter using ADS

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**Abstract:** This paper presents the design of fifth order microstrip parallel coupled line bandpass filters with center frequency of 3.5 GHz and bandwidth of 200MHz. Bandpass filter plays as an essential role in wireless communication system. The simulation is performed by using ADS (Advanced Design System) tool. The filter is designed with FR4 substrate with dielectric constant of 4.4. FR4 can easily get from market. It is low cost and high performance substrate for microstrip device. The filter performance is determined in terms of insertion loss and return loss results. The filter presented in this paper is used in WiMax application.

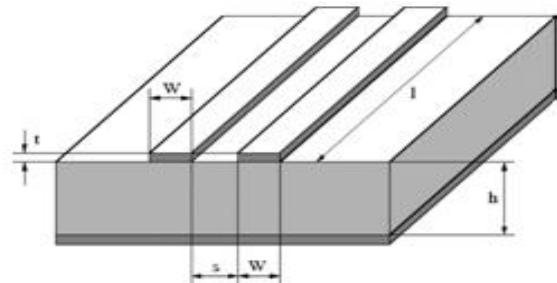
**Keywords:** Bandpass Filter, Microstrip Coupled Lines, ADS, Insertion Loss, Return Loss and WiMax.

### I. INTRODUCTION

Filters are essential part of telecommunication and radar system. The parallel coupled-line/edge-coupled filters are widely used in microwave microstrip circuits. They have low cost fabrication, easy integration and simple designing procedure. Many types of filters are constructed with parallel coupled structure. Bandpass or bandstop coupled line filters are easy for fabrication of microstrip or stripline form [1]. Tightly coupled lines are required for wider bandwidth filters. Tightly coupled lines are difficult to fabricate. Twoport network is formed from a coupled line section because the four ports are terminated to two ports with either open or short circuits, or by connecting two ends. A bandpass filter only passes the frequencies within a desired band and rejects others signals that are either below a lower cutoff frequency or above an upper cutoff frequency. Passband is defined as the range of frequency that a bandpass filter pass through. A typical Bandpass filter is a combination of lowpass and bandpass filter or transformation of conventional lowpass to bandpass filter [2]. Coupled line type filter is the most practical and common type of filter which can meet the stated specifications. Microwave filter used in electronic system is a two port network. Microstrip bandpass filter transmits transmission of desired signals over the passband and rejects undesired harmonics within the stopband. At the RF front end of microwave and wireless communication systems parallel-coupled microstrip bandpass filters are extensively used. The parallel coupled line filters are based on the odd and even wave coupling of transmission lines through a common ground plane, which results in odd and even characteristic line impedances.

The even and odd mode impedance sets the coupling between two strip lines and their input/output impedances are part of a two port chain matrix representation. Cascading these elements form bandpass filter structures [3] [4]. A

simple structure of coupled microstrip line construction is shown in Figure 1. Many types of filters are constructed from parallel coupled microstrip lines. To have a relatively fast signal cut off between passband and stopband, microstrip parallel coupled line filter structure is based on the half-wavelength resonator selectivity. Chebyshev filter is a high Q filter. Chebyshev type filter is used when (a) steeper initial descent into the stopband is required and (b) the passband response does not required to be flat. Butterworth response give more rounded attenuation curve when compared to the Chebyshev response. Chebyshev type filter has increase initial slope at the beginning of the stopband. Chebyshev filter have a relatively fast signal cut off between passband and stopband. Therefore Chebyshev type filters are popular for their high selectivity. The Chebyshev approach lead higher slope at the stopband region but it show certain ripple in the passband region [5]. To obtain the desired frequency response in distributed transmission line structure, gigahertz frequency range are required in microstrip filter [6]. Published formula or simulation software capability is used to derive the dimensions of the coupled transmission lines.



**Figure 1: The parallel coupled lines microstrip geometry and structure.**

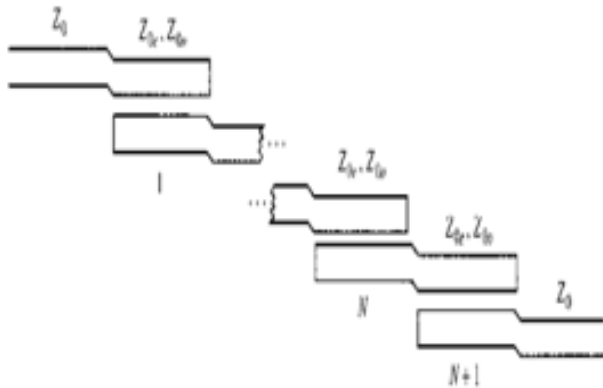
### II. RELATED WORK

This paper present the design of a parallel-coupled microstrip bandpass filter for WiMax application. Resonators and admittance inverters are used as the basic of the use of

half wavelength long resonator. The center frequencies of 3.5 GHz is selected for WiMax application, the bandwidth (BW) is chosen as about 1.7% and the passband ripple is 0.1dBattenuation. The design technique, parameter analysis and simulation result of a fifth order coupled line bandpass filter at center frequencies of 3.5GHz is presented in this paper.

**III. THEORY**

A general layout of a parallel coupled microstrip bandpass filter is shown in Fig2. Open circuited coupled microstrip lines are cascaded to get the parallel filter structure. The cascaded coupled lines with  $(\lambda/4)$  long are quarter wave length and are equivalent to shunt resonant circuits [7]. A series inductance with an inverter on each side looks like a shunt capacitance from its external terminals. A shunt capacitance with an inverter on each side equivalent a series inductance from its external terminals. Inverters shifts impedance or admittance levels depending on the choice of  $K$  or  $J$  parameters. These properties of inverter circuit are more convenient for implementation filter with microwave structures. Admittance inverters are used to compute the Even- and Odd- mode characteristic impedances of parallel-coupled half wavelength resonators. Physical dimensions of a filter are computed from the Even and Odd mode characteristic impedance.



**Fig2. General Layout of an (N + 1)-section coupled line bandpass filter.**

The cascaded coupled line sections are numbered from right to left, with the load to left, but the filter can be reversed without affecting the response [8]. The equivalent circuit of the cascade structure is as shown in Fig3.



**Fig3. Equivalent circuit for each coupled line section.**

**A. Admittance Inverter**

In designing microstrip filter, admittance inverter is important factor. They are used to transform a filter circuit into an equivalent form. Admittance inverters are either

impedance or admittance inverters. They are especially useful for bandpass or bandstop filters with narrow (<10%) bandwidths. Admittance inverter are used to transform series-connected elements to shunt-connected elements, or vice versa. By using Admittance inverter, bandpass filters is realized by either series (L-C) resonant circuits separated by impedance inverters (K) or shunt (L-C) parallel resonant circuits separated by admittance inverters (J). Firstly, lowpass prototype circuit is prepared to include admittance inverters. Bandpass circuits are converted from lowpass structure by applying conventional low-pass to bandpass transformation [9].

$$n = \frac{\cosh^{-1} \sqrt{(10^{\frac{G}{10}} - 1) / (10^{\frac{G}{10}} - 1)}}{\cosh^{-1}(\frac{f}{f_c})} \tag{1}$$



**Fig4. Equivalent circuit of the admittance inverters.**

**IV. FILTER DESIGN PROCEDURE**

The order (n) of the filter is calculated at the center frequency of 3.5 GHz and the passband ripple amplitude (G) of 0.1dB. The fractional bandwidth  $\Delta = 1.7\%$ . The upper cutoff frequency of the passband is 3.6 GHz and the lower cutoff frequency is 3.4GHz. This gives us  $n = 5$ . The element values for equal-ripple (0.1dB) lowpass filter prototype [10] are used from the table.

**Table 1: Element value for equal ripple lowpass filter (0.1dB)**

N	g <sub>1</sub>	g <sub>2</sub>	g <sub>3</sub>	g <sub>4</sub>	g <sub>5</sub>	g <sub>6</sub>	g <sub>7</sub>	g <sub>8</sub>
1	0.3052	1.000						
2	0.8430	0.6220	1.3554					
3	1.0315	1.1476	1.0315	1.000				
4	1.1088	1.3061	1.7703	0.8180	1.3554			
5	1.1468	1.3712	1.9750	1.3712	1.1468	1.000		
6	1.1681	1.4039	2.0562	1.5170	1.9029	0.8618	1.3554	
7	1.1811	1.4228	2.0966	1.5733	2.0966	1.4228	1.1811	1.000

$$Z_0 J_1 = \frac{\sqrt{\Pi \Delta}}{\sqrt{2g_1}} \tag{2}$$

$$Z_0 J_n = \frac{\Pi \Delta}{\sqrt[2]{g_{n-1} g_n}} ; n=2,3,4,...N \tag{3}$$

$$Z_0 J_{n+1} = \sqrt{\frac{\Pi \Delta}{2g_n g_{n+1}}} ; n=2,3,4,...N \tag{4}$$

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The event and odd mode impedances [11] are calculated as following;

$$Z_{oe} = Z_0[1 + J Z_0 + (J Z_0)^2] \quad (5)$$

$$Z_{oo} = Z_0[1 + J Z_0 + (J Z_0)^2] \quad (6)$$

The results of these calculations are tabulated as below;  
**Table 2:**

Line Description	Admittance Inverter	Even mode Impedance (Z <sub>oe</sub> )	Odd Mode Impedance
			(Z <sub>oo</sub> )
Coupled Line 1	5.595×10 <sup>-3</sup>	67.9Ω	39.92Ω
Coupled Line 2	1.432×10 <sup>-3</sup>	53.84 Ω	46.67 Ω
Coupled Line 3	1.0908×10 <sup>-3</sup>	52.88 Ω	47.42 Ω
Coupled Line 4	1.0908×10 <sup>-3</sup>	52.88 Ω	47.42 Ω
Coupled Line 5	1.432×10 <sup>-3</sup>	53.84 Ω	46.67 Ω
Coupled Line 6	5.595×10 <sup>-3</sup>	67.9Ω	39.92Ω

Line Calc in ADS is used to calculate the width, length and spacing of each couple lines. FR4 substrate [12] with Er = 4.4 is used. Conductor height H = 1.6mm, T = 0.02mm, T and = 0.002.

**Table 3: Physical Dimension of Coupled Line**

Line Description	Width (mm)	Length(mm)	Spacing(mm)
50Ω Line	3.049	11.617	
Coupled Line 1	2.695	11.88	0.543
Coupled Line 2	3.008	11.658	2.964
Coupled Line 3	3.017	11.653	2.683
Coupled Line 4	3.017	11.653	2.683
Coupled Line 5	3.008	11.658	2.964
Coupled Line 6	2.695	11.88	0.543
50Ω Line	3.049	11.617	

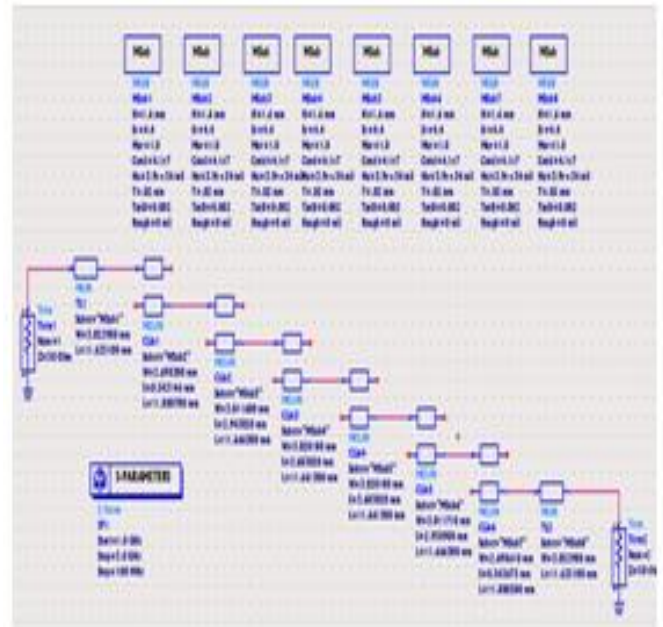
### V. EQUATIONS, SIMULATION, RESULTS AND DISCUSSION

Commercial electromagnetic simulator (ADS) is used to implement fifth order parallel-coupled bandpass filter. The center frequency of the implemented microstrip bandpass filter is 3.5GHz. The dimension of the microstrip line such as length (L), width (W) and gap (S) are determined by using LineCalc tool in ADS. To match with the 50 Ω circuit, MLIN (Microstrip Line) components are added on both sides

of the filter. The characteristic impedance of MLIN is 50 Ω [13]. The Parameters of the substrate set in M Sub controller are:

1. H: substrate thickness (1.6 mm)
2. Er: substrate relative dielectric constant (4.4)
3. Cond: metal conductivity (4.1e7)
4. Hu: upper ground substrate spacing (3.9e34 mil)
5. T: the thickness of metal layer (0.02 mm)
6. TanD: dielectric loss tangent (0.002)

The circuit dimensions are based on Table 3.

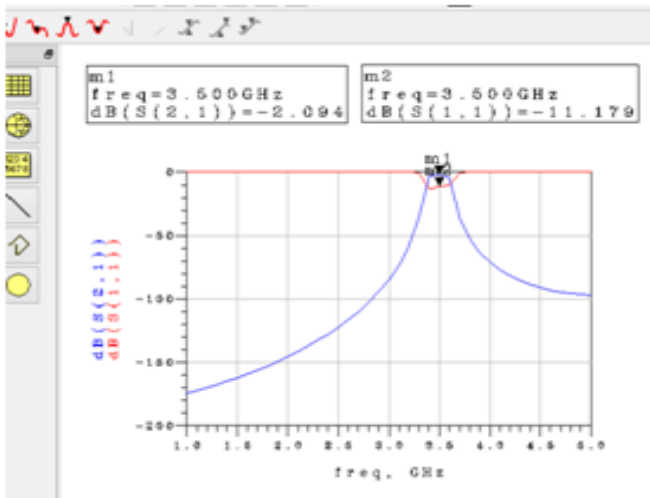


**Fig5. Simulation result of length, width and spacing in ADS.**

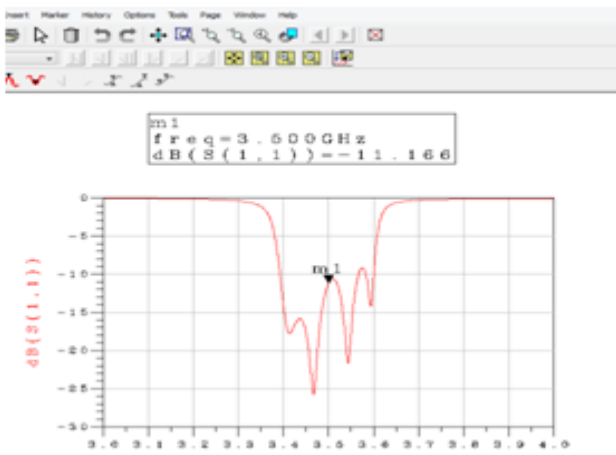
The simulation result is shown in fig6 and fig7. The center frequency is 3.5GHz, the bandwidth is 200MHz and the passband ripple is 0.1Db.



**Fig6. Layout of the coupled line band-pass filter in ADS.**



**Fig7.Insertion loss result of Coupled Line Bandpass Filter for FR4 at center frequency of 3.5 GHz.**



**Fig8. Return loss result of Coupled Line Bandpass Filter for FR4 at center frequency of 3.5 GHz.**

**VI. CONCLUSION**

In conclusion, fifth order microstrip parallel coupled line bandpass filter for WiMax application is well designed and simulated by using ADS. Chebyshev approach with parallel coupled microstrip line gives good filter response. If couple line separation is small, the even mode impedances is high. If couple line separation is high, the odd mode impedance is low. Dielectric constant of 4.4 is selected for FR4 to get high performance. FR4 is easily available in market, low cost and get very good result. For the selected center frequency of 3.5 GHz, the insertion loss result is (-2.138) dB and return loss result is (-11.166) dB. The limited bandwidth is 200MHz.

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**VIII. REFERENCES**

[1] M. L. Roy, ET. Al., “The continuously varying transmission-line technique-application to filter design,” IEEE Trans. Microwave Theory Tech., vol. 47, pp. 1680-1687, Sept. 1999.

[2] K. C. Lek and K. M. Lum, “Stepped Impedance Key-shaped Resonator for Bandpass and Bandstop Filters Design”, Progress in Electromagnetics Research Symposium Proceedings, KL Malaysia, March 27-30, 2012.

[3] Ian Hunter, “Theory and Design of Microwave Filters”, the Institution of Engineering and Technology, London, United Kingdom, 2006.

[4] George D. Vendelin, Anthony M. Pavoio and Ulrich, “Microwave Circuit Design Using Linear and Nonlinear Techniques”, Second Edition, A John Wiley & Sons, Inc., Publication, 2005.

[5] Jia-Sheng Hong, M. J. Lancaster, “Microstrip Filters for RF/Microwave Applications”, John Wiley & Sons, Inc, PP 109, 2001.

[6] D. M. Pozar, “Microwave Engineering”, John Wiley & Sons Inc., 1998.

[7] John T. Taylor and Qiuting Huang, “CRC Handbook of Electrical Filters”, CRC Press, pp. 22-23, 1997.

[8] R. Levy, S. B. Cohn, “A History of Microwave Filter Research, Design, and Development”, Microwave Theory and Techniques, IEEE Transactions, vol. 32, no. 9, pp. 1055,1067, Sep 1984.

[9] SinaAkhtarzard, Thomas R. Rowbotham, and Petter B. Johns, “The Design of Coupled Microstrip Lines”, IEEE Transactions on Microwave Theory and Techniques, vol. MTT-23, no. 6, pp. 486-492, June 1975.

[10] E. O. Hammerstad, “Equations for microstrip circuit design,” in Proceedings of the European Microwave Conference, Hamburg, Germany,

[11] Annapurna Das and Sisir K Das, “Microwave Engineering”, MacGraw Hill, p305, 2001.

[12] Hong, J.S., M.J, “Microstrip Filter for RF/Microwave Applications”, A Wiley- Inter science Publication, Canada, 2001.

[13] S. B. Cohn, “Parallel-Coupled Transmission-Line-Resonator Filters,” Microwave Theory and Techniques, IRE Transactions on, vol. 6, no. 2, pp. 223-231, April 1958.