

Design, Simulation and Development of Filter in S band

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ABSTRACT - The objective of this paper is to design bandpass filter suitable with center at 2.5 GHz. This application is in the S band range at 2.5 GHz center frequency currently being used for Indian Regional Navigation Satellite System (IRNSS) receiver. The filter covers the centre frequency 2.5 GHz and the bandwidth is 80 MHz. This project was initiated with theoretical understanding of various types of filter and their applications. And suitable type was selected. It functions to pass through the desired frequencies within the range and block unwanted frequencies. In addition, filters are also needed to remove out harmonics that are present in the communication system. It was design and simulated using ADS (Advanced Design System) software

Keywords- BandPass Filter, Chebyshev, Fractional Bandwidth, Advanced Design System (ADS)

1. INTRODUCTION

Microstrip BPF is widely used in recent years because it's characteristics that small in size, that easy to integrate and that can use different substrate to change frequency. Parallel coupled microstrip lines can realize narrow-band filters while stub lines can realize broad-band filters [2]. At preset the method called "prototype filter design" is usually adopted, which begins at the low-pass filter prototype and confirms the stage of the filter according to the attenuation required in a specified frequency after the type like butterworth, Chebyshev, ellipse etc is chosen, then we can get the unitary resistances in a experiential table and derive the length, width, gap of the coupled microstrip in different stage by calculation on a set of equations. Owing to the round of the parameters when we calculate and the approximation of conventional formulas, the performance of the filter is usually dissatisfied. So in engineering, the design is usually carried out using microwave ADS (Advanced Design System). ADS are an excellent software tool produced by Agilent corporation for high frequency circuit design which can make thorough analysis from circuit design to circuit realization.

1.1 MOTIVATIONS

In any communication system, filters are used at many places. Thus the selection and design of the suitable filter depends upon the application and specifications. However the basic function remains the same i.e. rejection of unwanted signal and allow passing the desired signal. A band pass filter at the input of front end of receiver is required in communication systems mainly to restrict the out of band noise and allow passing the desired signal. Beside this their other criteria such as to reject interfering signals is to be considered for the design. An S-band receiver for receiving the navigational signal is likely to be affected by Interfering signals from the Radar transmission. This has motivated me to design a band pass filter at S- band which can be used with receiver for optimization of its performance.

1.2 FILTERS

Filters are the most important passive components used in the microwave subsystems and instruments. Most microwave systems consist of many active and passive components that are difficult to design and manufacture with precise frequency characteristics. In contrast, microwave passive filter can be designed and manufactured with remarkably predictable performance. Consequently, microwave systems are usually designed so that all of the troublesome components are relatively wide in frequency response with filters being incorporated to obtain the precise system frequency response. Because filters are the narrowest bandwidth components in the system, it is usually the filters that limit such system parameters as gain and group delay flatness over frequency. The most popular filter types are parallel coupled line, interdigital, and hairpin line. All these filters are of the bandpass and bandstop type. Low Pass filters can be designed from the classical lumped element low-pass prototype circuits and may either be fabricated in lumped element form or transformed into equivalent transmission line networks. Band-pass filters require precise transmission characteristics that allow a desired band of signals to pass through the two-port network.

2. FILTER SPECIFICATION

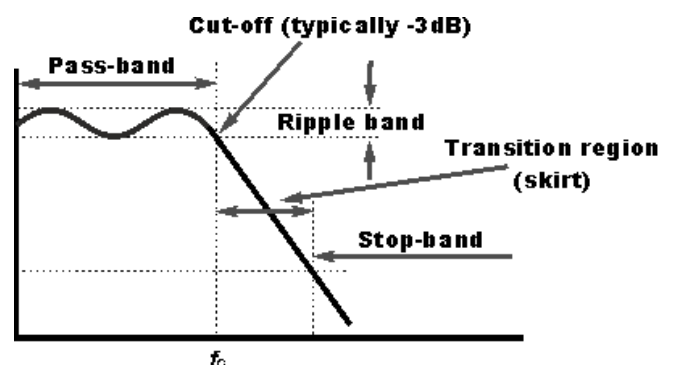


Figure 1 Frequency Filter specifications

2.1 INSERTION LOSS

Ideally, a perfect filter would have zero insertion loss in reality due to a certain amount of power loss associated with the filter is expected. The insertion loss quantifies how much below the zero dB line the power amplitude^[9]

$$IL = 10 \log \frac{P_{in}}{P_L} = -10 \log |1 - \Gamma_{in}|^2 \tag{1}$$

Where P_{in} is the input power from the source and P_L is the power delivered to the load. Γ_{in} is the reflection coefficient to the filter. This input coefficient is obtained by looking from the source into the transmission line of length $d = l$.

2.2 CUT-OFF FREQUENCY

This is normally taken to be the point at which the response of the filter has fallen by 3 dB. With certain filters, typically equal-ripple types such as the Chebyshev or inverse Chebyshev, the cut-off point has to be defined differently. It is often designated f_c .

2.3 STOP-BAND

This is the band where the filter has reached its required out of band rejection. The stop-band rejection may be defined as a required number of decibels

2.4 PASS-BAND

This is the region in which the signal passes through relatively un-attenuated. It is the band in a low pass filter, extends up to the cut-off frequency. For high pass filters it is designated as the band above which signal pass through, or for a bandpass filter, it is the band between the two cut-off frequencies.

2.5 RIPPLE

The flatness of the signal in the pass band can be quantified by specifying the ripple or difference between maximum and minimum amplitude response either in dB or ripple.

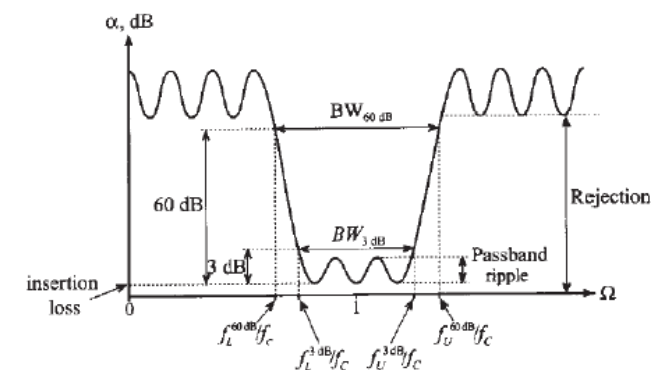


Figure 2 Region Between the Passband and the Stopband^[9]

2.6 BANDWIDTH

Bandwidth defines the difference between upper and lower frequencies typically recorded at the 3 dB attenuation point above the pass band.

$$BW^{3db} = f_U^{3db} - f_L^{3db} \tag{2}$$

2.7 SHAPE FACTOR

This factor describe the sharpness of the filter response by taking the ratio between the 60 dB and 3 dB bandwidth^[9]

$$SF = \frac{BW^{60db}}{BW^{3db}} = \frac{f_u^{60db} - f_L^{60db}}{f_u^{3db} - f_L^{3db}} \tag{3}$$

2.8 TRANSITION BAND

Once the RF filter response has gone beyond the cut-off point, the response falls away in a region known as the transition band. It is the region between the pass-band and the stop-band.

2.9 RETURN LOSS

Circuit realizations always suffer a certain degree of mismatch between the source and the power delivered to the transmission line. This mismatch is called return loss and is the ratio of reflected power to incident power:

3. DESIGN

The centre operating frequency for the filter is 2.5 GHz with a bandwidth of 3.2%. The maximum ripple allowed in the pass band is 0.1 dB^[20], and -20dB attenuation at 2.6GHz. According to the filter design specifications, Chebyshev response with a passband ripple of 0.1 dB can satisfy these requirements. The greatest characteristic of chebyshev filter is that it has a better stopband performance.

3.1 CALCULATE FRACTION BANDWIDTH AND NORMALIZED FREQUENCY^[10]

Now first, we calculate center frequency as following Method^{[13][15]}

Here, We have, $f_1 = 2.46$ GHz, $f_2 = 2.54$ GHz, so

$$f_0 = \sqrt{f_1 * f_2} \tag{4}$$

$$f_0 = 2.5 \text{ GHz}$$

So we get center frequency $f_0 = 2.5$ GHz, now fraction bandwidth Δ

$$\Delta = \frac{\omega_2 - \omega_1}{\omega_0} \tag{5}$$

$$a_k = \sin\left(\frac{(2k - 1)\pi}{2 * n}\right) \tag{8}$$

$$\Delta = \frac{2.54 - 2.46}{2.5}$$

$$b_k = \gamma^2 + \sin^2\left(\frac{k\pi}{n}\right) \tag{9}$$

$$\Delta = 0.032$$

$$\beta = \ln\left[\coth\left(\frac{L_{ar}}{17.37}\right)\right] \tag{10}$$

Normalized frequency given by following method

$$\frac{\omega}{\omega_c} = \frac{1}{\Delta} \left(\frac{\omega}{\omega_c} - \frac{\omega_c}{\omega}\right) \tag{6}$$

$$\gamma = \sinh\left(\frac{\beta}{2 * n}\right) \tag{11}$$

$$\frac{\omega}{\omega_c} = \frac{1}{0.032} \left(\frac{2.6}{2.5} - \frac{2.5}{2.6}\right)$$

$$g_0 = 1 \tag{12}$$

$$\frac{\omega}{\omega_c} = 2.451923$$

$$g_1 = \frac{2 * a_1}{\gamma} \tag{13}$$

3.2 CALCULATE NUMBER OF ORDER OF FILTER

The analytical procedure for designing a Chebychev band pass filter (BPF) requires the initial design of a prototype Chebychev low pass filter (LPF)^[5] The first step for designing any Chebychev filter is to determine the order of the filter. The filter order is number of inductive and capacitive elements that should be included in the filter design. This can be done by following formulation ^{[7][14]}

$$g_k = \frac{4 * a_{k-1} * a_k}{b_{k-1} * g_{k-1}} \tag{14}$$

$$g_{n+1} = 1 \tag{15}$$

In above equations k = 1,2,3,4.....

Now we can get following table for 0.1 dB ripple level with the help of equation (8) to (15) for various

$$n = \frac{\cosh^{-1} \sqrt{\frac{10^{\frac{L_T}{10}} - 1}{K - 1}}}{\cosh^{-1} \left(\frac{\omega}{\omega_0}\right)} \tag{7}$$

Table 1 Element Values for Equal-Ripple low-pass Filter Prototypes

$$n \cong 3$$

TABLE I LOW PASS PROTOTYPE VALUES FOR A 0.1 dB PASSBAND RIPPLE CHEBYCHEV FOR ORDER N = 2 TO 9											
N	g(0)	g(1)	g(2)	g(3)	g(4)	g(5)	g(6)	g(7)	g(8)	g(9)	g(N+1)
2	1	0.843	0.622								1.335
3	1	1.032	1/147	1.032							1.000
4	1	1.109	1.306	1.770	0.818						1.335
5	1	1.147	1.371	1.975	1.371	1.147					1.000
6	1	1.168	1.404	2.056	1.517	1.903	0.962				1.335
7	1	1.181	1.423	2.097	1.573	2.097	1.423	1.181			1.000
8	1	1.190	1.435	2.120	1.601	2.170	1.564	1.944	0.878		1.335
9	1	1.196	1.443	2.135	1.617	2.205	1.617	2.135	1.443	1.196	1.000

Where L_T is the minimum attenuation at frequency ω_T , and $K = 10^{\frac{L_{ar}}{10}}$ with L_{ar} being the maximum ripple in 0.1 dB allowed in the pass band which is 0.1 dB ^[3], Normalized frequency given by equation (6). The order of the filter is a measure of the minimum number of elements to be included in the filter to realize the required amount of ripple in the pass band and attenuation at a frequency outside of the pass band. Additional elements may be included in the filter which will further improve the filter response at the cost of size and increased design time.

From above Table 1, for n=3 order, the element values obtained are ^[17]

3.3 CALCULATE ELEMENTS VALUES OF LOW-PASS FILTER PROTOTYPES

The following equations are used to calculate the Element values for equal-ripple low-pass filter prototypes (0.1 dB ripple) ^{[18],[19]}

$$g_1 = 1.0315 = L'_1$$

$$g_2 = 1.1474 = C'_2$$

$$g_3 = 1.0315 = L'_3$$

3.4 CALCULATE LUMPED VALUES OF THE BANDPASS FILTER

Lumped Values of the Bandpass Filter calculate as following method. The low-pass prototype elements values obtained can be represented as shown in Figure 3

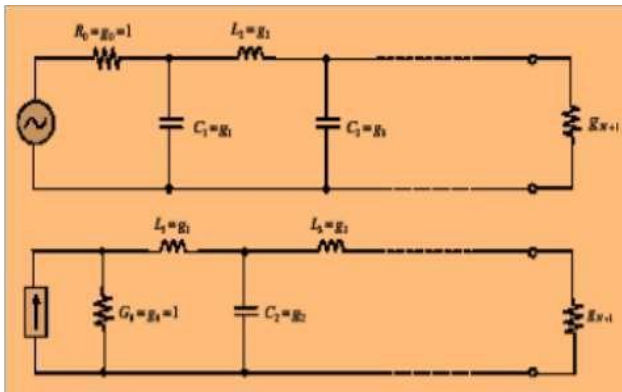


Figure 3 Low pass filter prototype [12]

$$L_2 = 0.0887945 \text{ nH}$$

$$C_2 = 45.689268 \text{ pF}$$

4. ADS OVERVIEW

ADS are used as the simulation software. Advanced Design System (ADS) is electronic design automation software. It provides an integrated design environment to designers of RF electronic products such as mobile phones, pagers, wireless networks, satellite communications, radar systems, and high speed data links. Agilent ADS supports every step of the design process—schematic capture, layout, frequency-domain and time-domain circuit simulation

4.1 ADS SIMULATION

Now put all values if Series and Shunt elements value in Following Bandpass filter design in ADS (Advanced Design System) [16]

For Series L&C

$$L_K = \frac{Z_0 * L'_K}{\omega_0 * \Delta} \tag{16}$$

$$C_K = \frac{\Delta}{Z_0 * L'_K * \omega_0} \tag{17}$$

For Shunt L&C

$$L_K = \frac{\Delta * Z_0}{\omega_0 * C'_K} \tag{18}$$

$$C_K = \frac{C'_K}{Z_0 * \omega_0 * \Delta} \tag{19}$$

Where $Z_0 = 50 \Omega$, $\Delta = 0.032$ and $f_0 = 2.5 \text{ GHz}$

Now The resulting lumped values are, For series L&C are given by putting $n=3$ values for equal-ripple low-pass filter prototypes (0.1 dB ripple) from Table 1 and put it into equation (16) and (17) and counting, we get following values

$$L_1 = L_3 = 102.61851 \text{ nH}$$

$$C_1 = C_3 = 0.0395343 \text{ pF}$$

For shunt L&C are given by putting $n=3$ values for equal-ripple low-pass filter prototypes (0.1 dB ripple) from Table 4.2 and put it into equation (18) and (19) and counting, we get following values

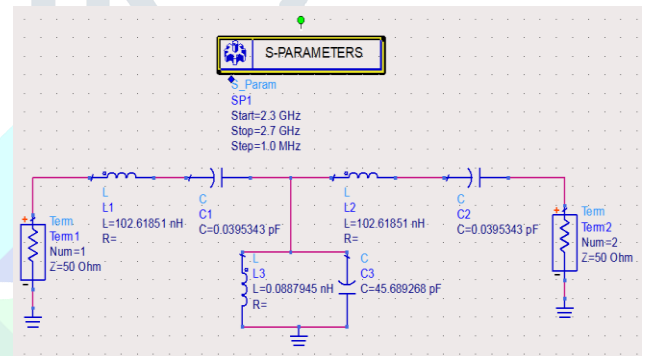


Figure 4 ADS diagram Of Lumped Elements

4.2 ADS SIMULATION RESULT

m4 freq=2.603GHz dB(S(2,1))=-19.154	m3 freq=2.499GHz dB(S(1,1))=50.440
m1 freq=2.479GHz dB(S(1,1))=-16.442	m2 freq=2.519GHz dB(S(1,1))=-16.445

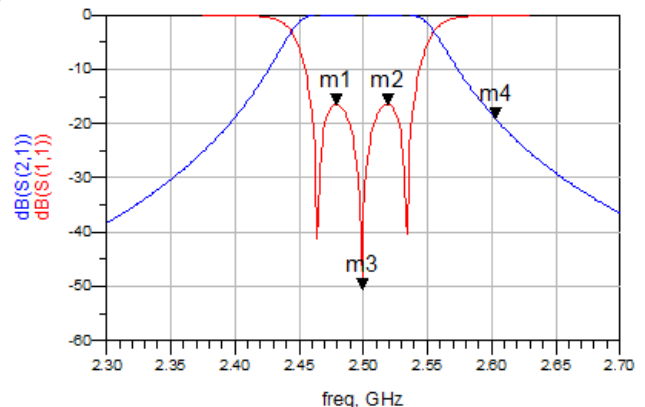


Figure 5 S-parameter Simulation Schematic of Filter

5. THEORIES OF PARALLEL COUPLED MICROSTRIP BAND PASS FILTERS

5.1 MICROSTRIP TRANSMISSION LINE

Now a day in one hand determines the characteristic impedance Z_c and on the other hand the rest of the whole parameters required to design the filter. Richard's transformation and Kuroda's identities are used to accomplish the conversion from the lumped and distributed circuit designs

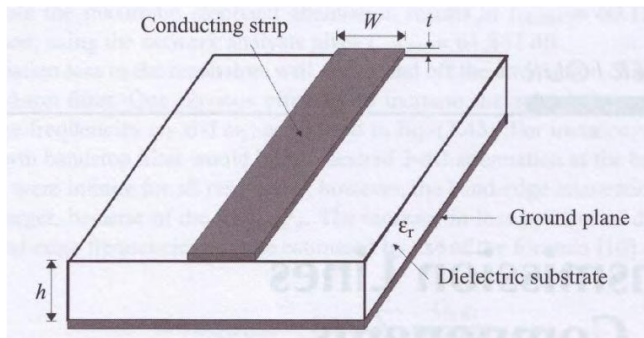


Figure 6 General microstrip structure [9]

5.2 PARALLEL COUPLED MICROSTRIP FILTER

A general structure of parallel-coupled microstrip band-pass filters shown in Figure 7 that use half-wavelength line resonators. These lines are positioned so that adjacent resonators are parallel to each other along half of their length. This parallel arrangement gives relatively large coupling for a given spacing between resonators. Furthermore, and in comparison with the structures for the end-coupled microstrip filters, the lines distribution structure demonstrated in Figure 7 is particularly convenient for constructing filters having a large bandwidth

The coupling gaps correspond to the admittance inverters in the low-pass prototype circuit Even and Odd mode characteristic impedances of parallel-coupled half-wave resonators are computed using admittance inverters. These even and odd mode impedances are then used to compute physical dimension of the filter [6]. In this way, the required parallel coupled microstrip filter parameters can be easily derived for Chebyshev prototypes.

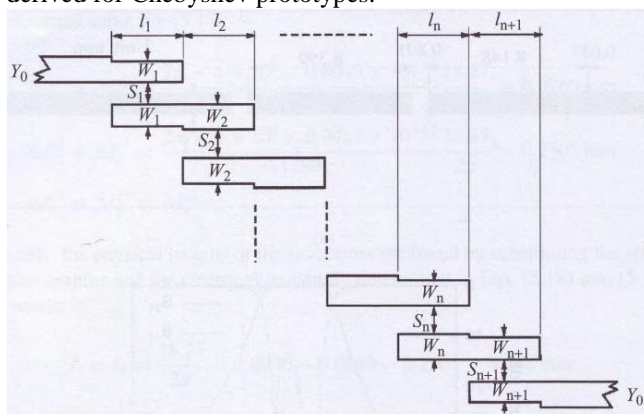


Figure 7 Common structure of microstrip parallel coupled line bandpass filter

The strips are arranged parallel close to each other, so that they are coupled with certain coupling factors. We use the following equations for designing the parallel-coupled filter

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi * FBW}{2 * g_0 * g_1}} \tag{20}$$

For j=1 to n-1:

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi * FBW}{2} \frac{1}{\sqrt{g_j * g_{j+1}}} \tag{21}$$

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi * FBW}{2 * g_n * g_{n+1}}} \tag{22}$$

Where $g_0, g_1 \dots g_n$ are the element of a ladder-type low-pass prototype with a normalized cut-off $\Omega_c = 1$, and FBW is the fractional bandwidth of band-pass filter. $J_{j,j+1}$ are the characteristic admittances of J-inverters and Y_0 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 microstrip line resonators are determined by

For j=0 to n

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0} \left[1 + \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0} \right)^2 \right] \tag{23}$$

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0} \left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0} \right)^2 \right] \tag{24}$$

Table 2 Calculated Values of Even and Odd Resistances

Stage(i,i+1)	$Z_{0e} \Omega$	$Z_{0o} \Omega$
1,4	63.4729	41.3994
2,3	52.4178	47.7975

The next step of the filter design is to find the dimensions of coupled microstrip lines that exhibit the desired evenmode and odd-mode impedances. Firstly, we determine the equivalent single microstrip shape ratios $\frac{W}{H}$ essentially responsible to relate the coupled line ratios to single line ratios.

For a single microstrip line,

$$Z_{0so} = \frac{(Z_{0o})_{j,j+1}}{2} \tag{25}$$

$$Z_{0se} = \frac{(Z_{0e})_{j,j+1}}{2} \tag{26}$$

For a single microstrip line, The approximate expressions for W/h (Figure 1) in terms of Z_c and ϵ_r , derived by Wheeler and Hammerstad, are available

For $\frac{W}{H} \leq 2$

$$\frac{W}{H} = \frac{8 * \exp(A)}{\exp(2 * A) - 2} \tag{27}$$

Where

$$A = \frac{Z_c}{60} \sqrt{\frac{\epsilon_r + 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1} \left\{ 0.23 + \frac{0.11}{\epsilon_r} \right\} \tag{28}$$

For

$\frac{W}{H} \geq 2$

$$\frac{W}{H} = \frac{2}{\pi} \left\{ (B - 1) - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right] \right\} \tag{29}$$

Where

$$B = \frac{60\pi^2}{Z_c \sqrt{\epsilon_r}} \tag{30}$$

At that point, it's able to find $\left(\frac{W}{H}\right)_{se}$ and $\left(\frac{W}{H}\right)_{so}$ by applying Z_{se} and Z_{so} (as Z_c) to the single line microstrip equations. Now it comes to a point where it reaches the $\frac{W}{H}$ and $\frac{S}{H}$ for the desired coupled microstrip line using a family of approximate equations as following

$$\frac{S}{H} = \frac{2}{\pi} \cosh^{-1} \left[\frac{\cosh\left(\frac{\pi}{2}\right)\left(\frac{W}{H}\right)_{se} + \cosh\left(\frac{\pi}{2}\right)\left(\frac{W}{H}\right)_{so} - 2}{\cosh\left(\frac{\pi}{2}\right)\left(\frac{W}{H}\right)_{se} + \cosh\left(\frac{\pi}{2}\right)\left(\frac{W}{H}\right)_{so}} \right] \tag{31}$$

$$\frac{W}{H} = \frac{1}{\pi} \left[\cosh^{-1} \left(\frac{1}{2} \left[\cosh\left(\frac{\pi S}{2H}\right) - 1 \right] + \left[\cosh\left(\frac{\pi S}{2H}\right) + 1 \right] \cosh\left(\frac{\pi}{2}\right)\left(\frac{W}{H}\right)_{se} \right) \right] - \left(\frac{\pi}{2}\right)\left(\frac{S}{H}\right) \tag{32}$$

Table 3 Calculated Dimensions Of Transmission Line Sections

Line Description	W(mm)	L(mm)	S(mm)
50 ohm-line	3.0594	16.3649	-
Coupled line 1 and 4	2.7086	16.6568	0.8039
Coupled line 2 and 3	3.0365	16.4164	4.0505

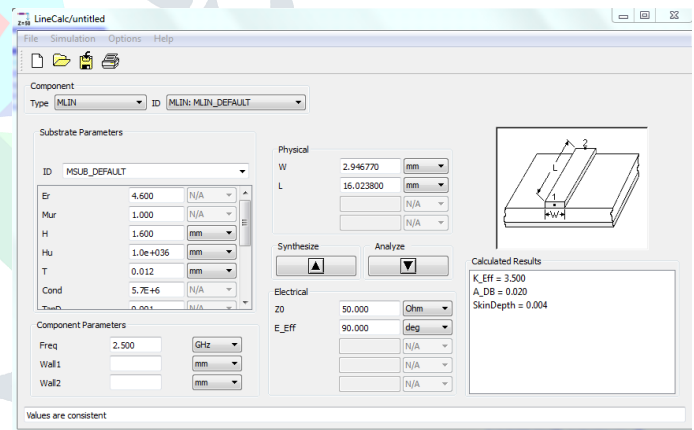


Figure 8 Determination of W, S and L Linecale.

Using LineCalc tool in ADS, the dimension of the microstrip line viz. length (L), width (W) and gap(S) between each other are calculated for the given odd and even resistances at the design as shown in Fig. 8. Copper is used asconductor and FR4 with thickness 1.6 mm is used as substrate. The width, gap and length of each stage of the MCLIN(Microstrip Coupled-Line Filter Section) are derived, as illustrated in Table 3. To match with the 50 ohm circuit, MLIN (Microstrip Line) components are added to both sides of the filter whose characteristic impedance is 50 ohm

6 DESIGN AND OPTIMIZATION OF CHEBYSHEV BAND PASS FILTER

6.1 DESIGN SPECIFICATION

The filter was modelled in ADS as shown in Figure 9. The Parameters of the substrate set in MSub controller are:

- 1) H: substrate thickness (1.6 mm)
- 2) Er: substrate relative dielectric constant (4.4)
- 3) Cond: metal conductivity (5.8e7)
- 4) Hu: upper ground substrate spacing (1.0E+36mm)
- 5) T: the thickness of metal layer (0.0127 mm)
- 6) TanD: dielectric loss tangent (0.01)
- 7) Rough: RMS surface roughness (0 mm).

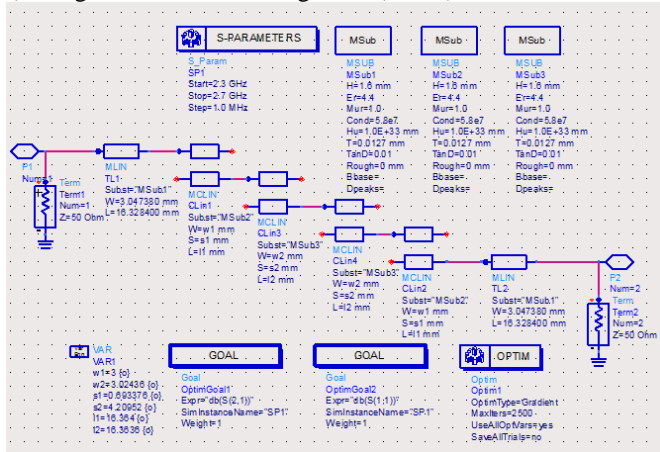


Figure 9 Model of the band pass filter in ADS

6.2 GENERATING LAYOUT

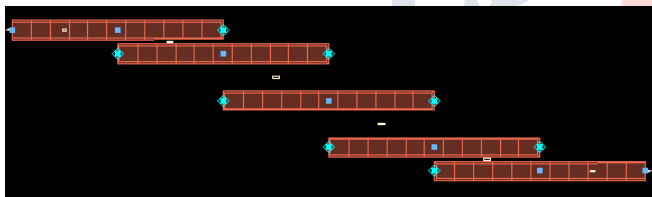


Figure 10 Layout of parallel-coupled microstrip bandpass filter

6.3 SIMULATION RESULT AFTER OPTIMIZATION

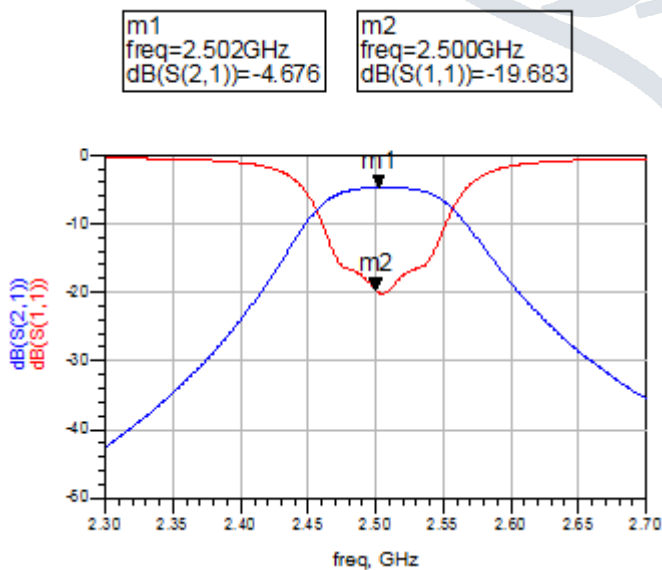
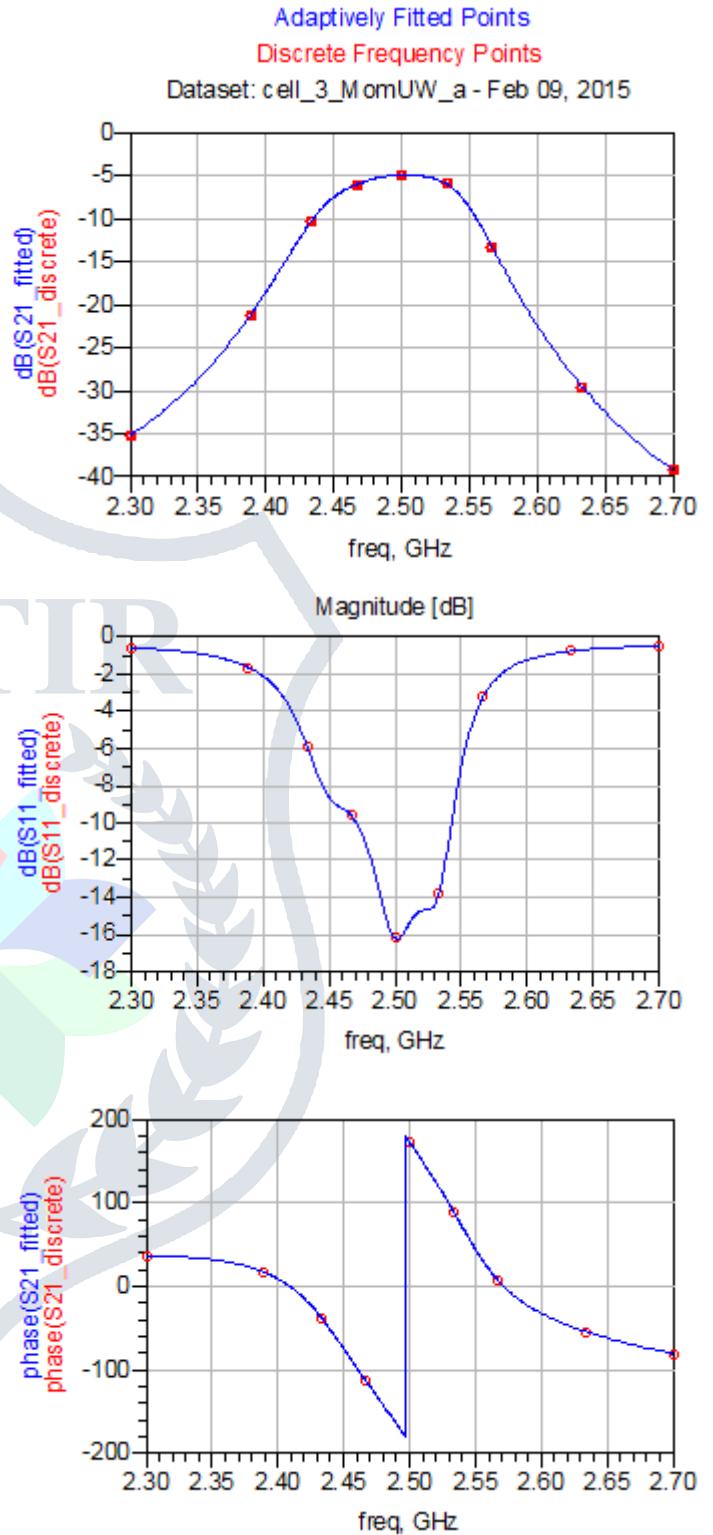


Figure 11 Scattering parameters of the designed and optimized bandpass filter.

6.4 SIMULATION RESULT IN MOMENTUM



7. CONCLUSIONS

In this paper the detail procedures for designing a parallel-coupled bandpass filter for IRNSS Application, has been presented. For the selected center frequency of 2.5 GHz and on a substrate with a dielectric constant of 4.6, our filter is designed and optimized. Half wavelength long resonators and admittance inverters are used to design the bandpass filter. The optimization function owing by ADS software is an efficient tool to amend the drawback of conventional method with

theoretic formulas. we get result as Insertion loss around -1dB and Return loss is -17db in passband which is desirable.

8. ACKNOWLEDGEMENT

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9. REFERENCE

- [1] Seghier, S.; Benahmed, N.; Bendimerad, F.T.; Benabdallah, N., "Design of parallel coupled microstrip bandpass filter for FM Wireless applications," Sciences of Electronics, Technologies of Information and Telecommunications (SETIT), 2012 6th International Conference, pp. 207-211, 21-24 March, 2012
- [2] Min Zhang; Yimin Zhao; Wei Zhang, "The simulation of microstrip Band Pass Filters based on ADS," Antennas, Propagation & EM Theory (ISAPE), 2012 10th International Symposium, pp. 909-912, 22-26 Oct. 2012
- [3] Ma, Jun; Sun, Zhengwen; Chen, Yong, "Design and simulation of L-band wideband microstrip filter," Information Science and Technology (ICIST), 2013 International Conference, pp. 183-186, 23-25 March 2013
- [4] Bey-Ling Su; Ray Yueh-Ming Huang, "5.8 GHz bandpass filter design using planar couple microstrip lines," Communications, Circuits and Systems, 2004. ICCAS 2004. 2004 International Conference, vol.2, pp. 1204-1207, 27-29 June 2004
- [5] Naghar, A.; Aghzout, O.; Vazquez Alejos, A.; Garcia Sanchez, M.; Essaaidi, M., "Development of a calculator for Edge and Parallel Coupled Microstrip band pass filters," Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE, pp. 2018-2019, 6-11 July 2014
- [6] Lolis, L.; Pelissier, M.; Bernier, C.; Dallet, D.; Begueret, J-B, "System design of bandpass sampling RF receivers," Electronics, Circuits, and Systems, 2009. ICECS 2009. 16th IEEE International Conference, pp. 691-694, 13-16 Dec. 2009
- [7] Zhou Jinchang; Xiao Xianghua; Liu Shiguo; Nagaya, K.; Tsuchiya, Y.; Mano, Y.; Khoo Yee Mong; Li Hongyu, "Band Pass Filter Design and Optimization on High-Resistivity Silicon for 5GHz RF Front End Receiver," Electronics Packaging Technology Conference, pp. 1011-1017, 9-12 Dec. 2008
- [8] Zalabsky, T., "Design and modeling of an output microwave filter for S band primary radar transmitter," Microwave Techniques (COMITE), 2013 Conference, pp. 121-124, 17-18 April 2013
- [9] A K. Sisodia; Nimesh M. Prabhakar, "Input Filter Design For Front-End Satellite Navigation Receiver," International Journal for Scientific Research & Development | Vol. 2, pp. 1188-1189, Issue 03, 2014 | ISSN (online): 2321-0613
- [10] Jolly Rajendran; Rakesh Peter; K. P. Soman, "Design and Optimization of Band Pass Filter for Software Defined Radio Telescope," International Journal of Information and Electronics Engineering, Vol. 2, pp 649-651, 4 July 2012
- [11] A. Naghar; O. Aghzout; F. Medin; M. Alaydrus; M. Essaaidi, "Study and Design of a Compact Parallel Coupled Microstrip Band-Pass Filter for a 5 GHz Unlicensed Mobile WiMAX Networks," International Journal of Science and Technology, Vol. 2, pp. 492-497, 6 June, 2013, ISSN: 2049-7318
- [12] Shreyasi Srivastava; R.K. Manjunath; Shanthi P., "Design, Simulation and Fabrication of a Microstrip Bandpass Filter," International Journal of Science and Engineering Applications, Vol. 3, pp. 154-158, Issue 5, 2014, ISSN: 2319-7560 (Online)
- [13] M.A. Othman; M. Sinnappa; M.N. Hussain; M.Z.A. Abd. Aziz; M.M. Ismail, "Development of 5.8 GHz Microstrip Parallel Coupled Line Bandpass Filter for Wireless Communication System," M.A. Othman et al / International Journal of Engineering and Technology (IJET), Vol 5, pp. 3227-3235, 4 Aug-Sep 2013, ISSN: 0975-4024
- [14] Pawan Shaktwippee, "Design and Simulation of Edge-Coupled Stripline Band Pass Filter for U band," International Journal of Innovation and Applied Studies, Vol. 3 pp. 1033-1044, 4 Aug. 2013, ISSN: 2028-932
- [15] Hnin Yu Wai; Zaw Min Naing; Kyaw Soe Lwin; Hla Myo Tun, "Design and Simulation of Edge-coupled Stripline Band Pass Filter for Ka Band Application," International Journal of Research in Engineering and Technology (IJRET), Vol. 1, pp. 125-128, March, 2012 ISSN: 2277-4378
- [16] Md. Rokunuzzaman; M.T. Islam; R. Azim; Radial Anwar; Mhd Fairos Asillam, "Design of a Coupled-Line Bandpass Filter for Satellite Dish Antenna Receiver," Australian Journal of Basic and Applied Sciences, pp. 571-577, 2013, ISSN: 1991-8178
- [17] Shilpi Gupta; Pooja Rani; R. K. Prasad, "Design & Optimization of Stepped Impedance Low Pass Filter using ADS Simulation tool at 5 GHz," International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 3, pp. 1813-1817, Issue 5, May 2014, ISSN: 2278-1323
- [18] Azzeddin Naghar; Otman Aghzout2; Jalal Naghar; Hafssaa Latioui; Mohamed Essaaidi, "A New Matlab Simulation Interface Based on the Transmission Line Theory Approach to Design a Microstrip Parallel Coupled Band Pass Filters," International Journal of Innovative Research in Computer and Communication Engineering, Vol. 1, pp. 1601-1610, Issue 8, October 2013, ISSN(Online): 2320-9801, ISSN(Print): 2320-9798
- [19] D. M. Pozar, Microwave Engineering, 3rd Ed. New York: Wiley, pp. 389-426, 2005
- [20] Annapurna Das and Sisir K Das, "Microwave Engineering", Mac Graw Hill, pp. 279-310, 2001