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Design of BandPass Filter for L-Band Weather Satellites

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ABSTRACT: The high resolution picture transmission (HRPT) data transmitted by the lower earth orbiting weather satellites at L-band (1.67GHz-1.72GHz) was received by satellite ground stations across the world. In this paper Band pass filter was designed in order to filter the received data. Micro strip edge coupled band pass filter was designed and simulated using ANSOFT DESIGNER SV at centre frequency of 1.695GHz.

KEYWORDS: HRPT, Band Pass filter, ANSOFT DESIGNER SV.

I. INTRODUCTION

The numerical weather prediction models are being used for day to day weather forecasting and research. These models are integrated on regional global scale. To initialize these models the information of initial conditions of weather parameters such as pressure, temperature, relative humidity etc. are required in real time. The various satellite instruments observed them in real time and transmit the information using direct transmission type communication system. Satellite ground stations across the world receive their observations. The many Lower Earth Orbiting Satellites (LEOS) such as METOP-A,METOP-B,METOP-CNOAA-15, NOAA-18, etc. [1] at L-band are being used to transmit weather information to ground station (Profiles of Relative humidity and temperature).

Band Pass Filter:

In this paper for designing band pass filter micro strip edge coupled technology was used. Figure 1 illustrates the cross section of a pair of coupled micro strip lines. The two micro strip lines of width W,are in the parallel- or edge-coupled configuration with a separation s [2].

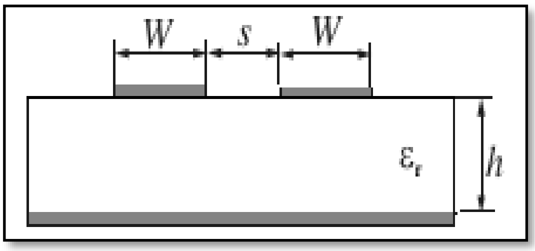

Figure1: Cross Section of Coupled Micro Strip Lines

Waveguides systems are bulky and expensive [3],whereas Strip line requires three layers of conductors where the internal conductor is commonly called the “hot conductor,” while the other two, always connected at signal ground, are called “cold” or “ground” conductors [4] , hence we go for micro strip configuration for realising band pass filter. Micro strip band pass filters that use half-wavelength line resonators. They 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, and thus, this filter structure is particularly convenient for constructing filters having a

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wider bandwidth as compared to the structure for the end-coupled micro strip filters[3].General structure of parallel (edge)-coupled micro strip band pass filter is shown in figure2.

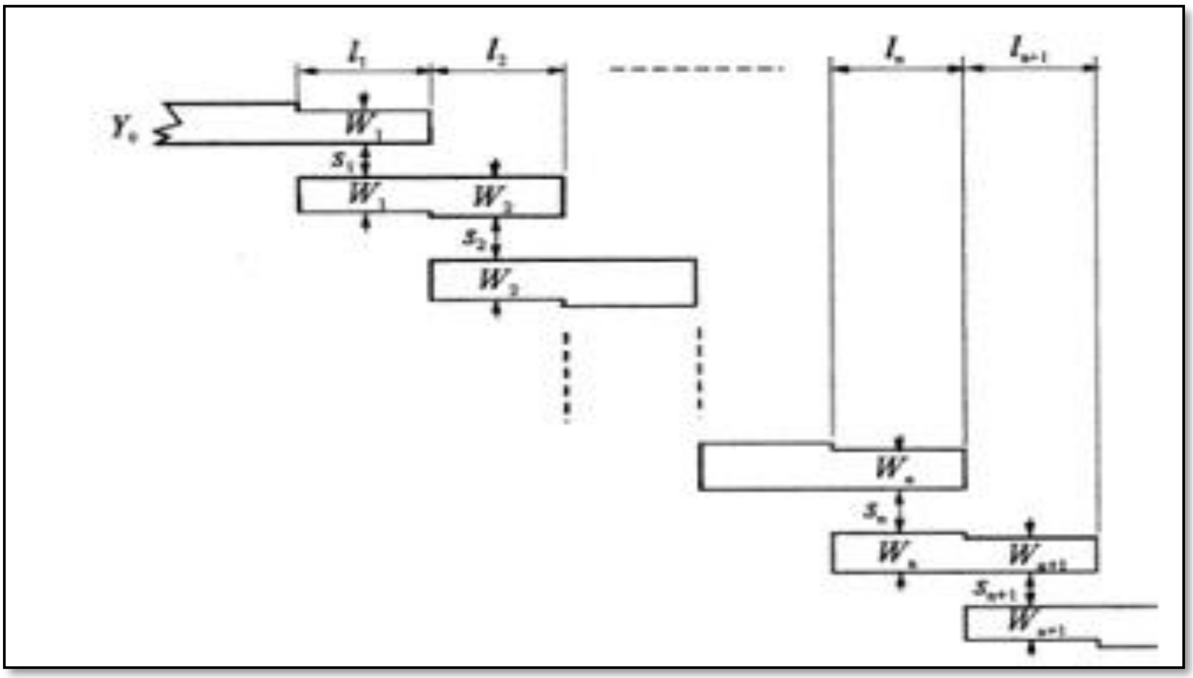

Figure2: General Structure of Parallel (Edge)-Coupled Micro strip Band Pass Filter.

II. DESIGN OF BAND PASS FILTER

In order to design the filter, initially it is necessary to have the knowledge about the specifications of the filter to be designed. Based on the specifications of the filter, the filter is realised in order to full fill the requirements of the application. The following table illustrates the specifications and requirements of the filter to be designed.

Specifications and Requirements:

Centre frequency	1.695 GHZ
Pass Band width(BW_P)	0.05 GHZ
Pass band edge frequencies	f1=1.67GHZ and f2=1.72GHZ
Stop band edge frequencies (Ω_S)	(1.65&1.74)GHZ
Stop band attenuation(L_{As})	40dB
Pass band ripple(L_{Ar})	0.5 dB
Return loss	>-10 dB

Table 1: Specifications and Requirements for Designing Band Pass Filter.

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In this paper,chebyshev type band pass filter is taken for consideration toattain the required results. The BPF is designed and simulated using ANSOFTDESIGNER SV software.Micro strip edge coupled line is used to realize the filter at required frequencies. The following steps are involved in designing of BPF.

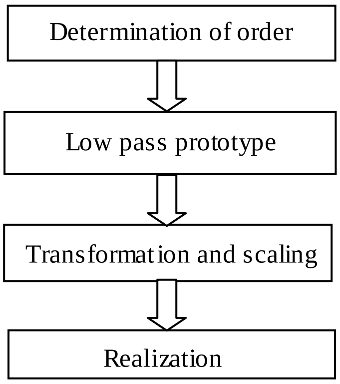

Figure3:Flow Chart for Designing BPF.

(A)Determination of Order of the Filter:

The order of the filter can be determined by using the following formula,

$$n \geq \frac{\cosh^{-1}\sqrt{\frac{10^{0.1L_{As}}-1}{10^{0.1L_{Ar}}-1}}}{\cosh^{-1}\Omega_s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Based on the given specifications, the parameter values are substituted in equation (1) and order of the filter is determined as **5**.

(B)Low Pass Prototype:

For Chebyshev low pass prototype filters with a pass band ripple of L_{Ar} dB and the cutoff frequency Ωc= 1, the element values for the two-port networks may be computed by using the following formulas [2].

$$g_0 = 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$g_1 = \frac{2}{\gamma} \sin(\pi / 2n) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$g_i = \frac{1}{g_{i-1}} \frac{4\sin[\frac{(2i-1)\pi}{2n}]\sin[\frac{(2i-3)\pi}{2n}]}{\gamma^2 + (\sin[\frac{(i-1)\pi}{2n}])^2} \quad for \ \ i = 1,2,3..n \ldots\ldots\ldots (4)$$

$$g_{n+1} = \begin{cases} 1 & for\ n = odd \\ (coth[\frac{\beta}{4}])^2 & for\ n = even \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

$$\beta = \ln[\coth(\frac{L_{Ar}}{17.37})] \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\gamma = \sinh[^{\beta}/_{2n}] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

g_0	g_1	g_2	g_3	g_4	g_5	g_6
1	1.7058	1.2296	2.5408	1.2296	1.7058	1

Table 2: Element values for Chebyshev low pass prototype filters (Ωc= 1, L_{Ar}=0.5 dB)

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(C)Transformation and Scaling:

After computing the low pass prototype values, then the low pass prototype filter is transformed to band pass filter by transforming all shunt elements to parallel resonant circuit and series elements to series resonant circuit. Then the transformed filter is frequency scaled and impedance scaled by using the following formulas [2].

$$\omega_o = \sqrt{\omega_2 \omega_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$FBW = \frac{\omega_2 - \omega_1}{\omega_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$\left.\begin{aligned} L_S &= \left(\frac{\Omega_c}{FBW * \omega_o}\right) * \gamma_o * g \\ C_S &= \left(\frac{FBW}{\Omega_c * \omega_o}\right) * \left(\frac{1}{\gamma_o * g}\right) \end{aligned}\right\} \text{for } g \text{ representing inductance} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$\left.\begin{aligned} L_p &= \left(\frac{FBW}{\Omega_c * \omega_o}\right) * \left(\frac{\gamma_o}{g}\right) \\ C_p &= \left(\frac{\Omega_c}{FBW * \omega_o}\right) * \left(\frac{g}{\gamma_o}\right) \end{aligned}\right\} \text{for } g \text{ representing capacitance} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

By substituting the values from table 1, we get

$$FBW = \frac{2\pi \times 1.72 \times 10^9 - 2\pi \times 1.67 \times 10^9}{2\pi \times 1.695 \times 10^9} = 0.0294$$

The capacitance and inductance values for designing lumped element band pass filter is listed in table 3.

g_1		g_2		g_3		g_4		g_5	
L_1(nH)	C_1 (pF)	L_2 (nH)	C_2 (pF)	L_3 (nH)	C_3 (pF)	L_4 (nH)	C_4 (pF)	L_5 (nH)	C_5 (pF)
271.5	0.03248	0.1127	78.28	404.4	0.0218	0.1127	78.28	271.5	0.03248

Table 3: Lumped Element values for Chebyshev Band pass filter

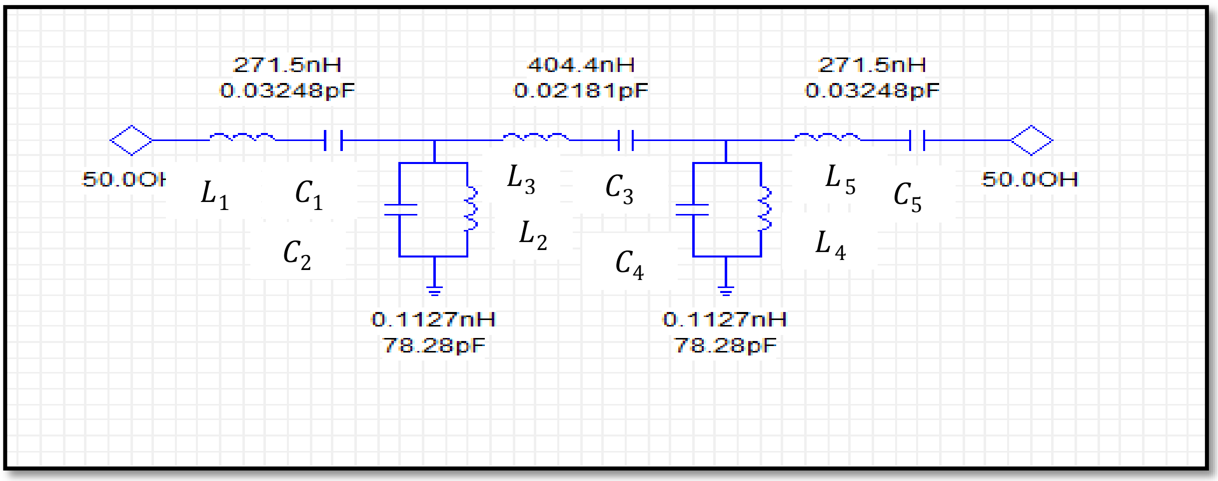

Figure4: Band Pass Filter Using Lumped Elements

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(D)Realization Using Edge Coupled Line:

The design equations for this type of filter is given by

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi * FBW}{2 * g_0 * g_1}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi}{2}\frac{1}{\sqrt{g_j\, g_{j+1}}} \quad j = 0\ to\ n-1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi * FBW}{2 * g_n * g_{n+1}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

Where, $J_{j,j+1}$ is the characteristic admittance of J-inverters and $Y_0$is the characteristic admittance of the terminating lines.
The odd and even mode impedances of micro strip coupled resonator is given by

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1 + \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \quad j = 0\ to\ n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \quad j = 0\ to\ n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

The odd and even mode impedances of micro strip coupled resonator arecomputed and listed in table4.

NUMBER OF THE SECTION(J)	1	2	3	4	5	6
$(Z_{0e})_{j,j+1}(\Omega)$	59.607	51.6535	51.347	51.347	51.6535	59.607
$(Z_{0o})_{j,j+1}(\Omega)$	43.113	48.449	48.721	48.721	48.449	43.113

Table 4: Even and Odd Mode Impedance Values for Chebyshev Band pass filter

The following substrate is used for designing micro strip coupled lines.

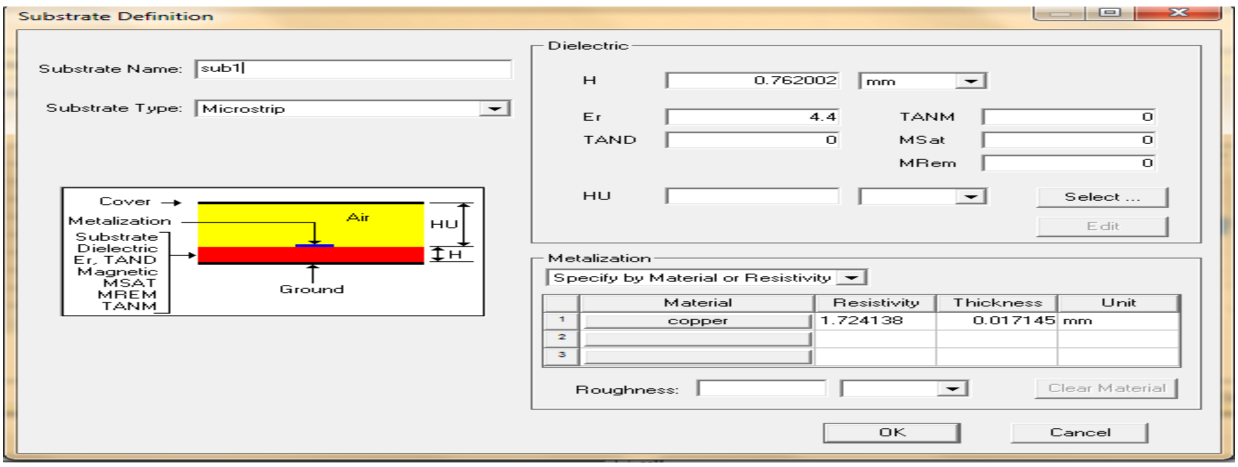

Figure5:Substrate for Micro Strip Coupled Line

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In ANSOFT DESIGNER SV [5], by substituting the values of odd and even mode impedances from the table 4, the length, width and spacing between the coupled lines are calculated and listed below in the table5 as follows.

No of the section(j) / parameter	1	2	3	4	5	6
Width(w_j)	1.3401	1.4313	1.4313	1.4313	1.4313	1.3401
Length(p_j)	24.4696	24.1799	24.1799	24.1799	24.1799	24.4696
Spacing(s_j)	0.5598	2.2866	2.525	2.525	2.2866	0.5598

Table 5: Circuit Design Parameter Values for Chebyshev Band pass filter.

The schematic of the 5th orderchebyshev band pass filteris shown in figure 6.

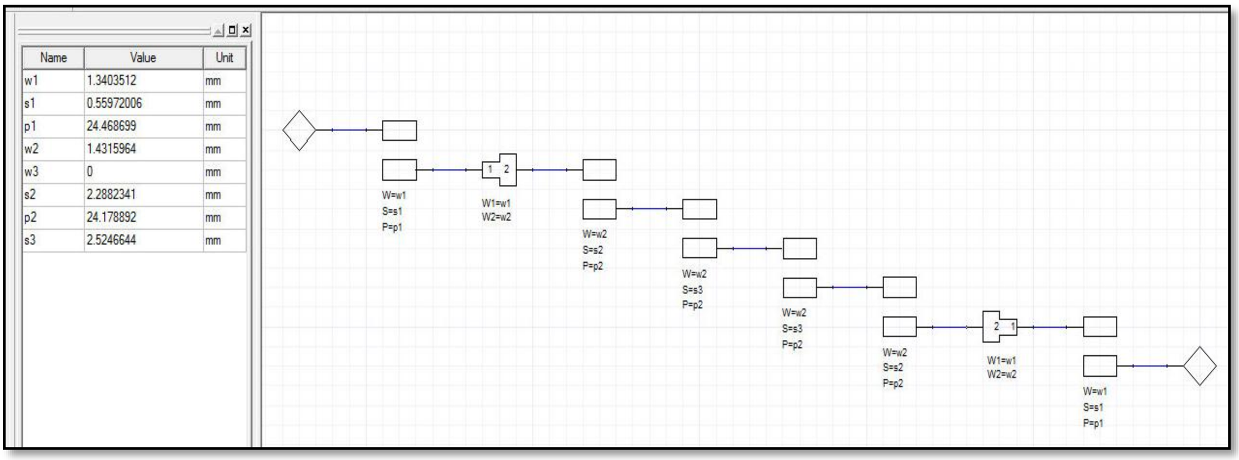

Figure6:Band Pass Filter Using Edge Coupled Line.

The layout of the 5th order chebyshev band pass filter is shown in figure 7.

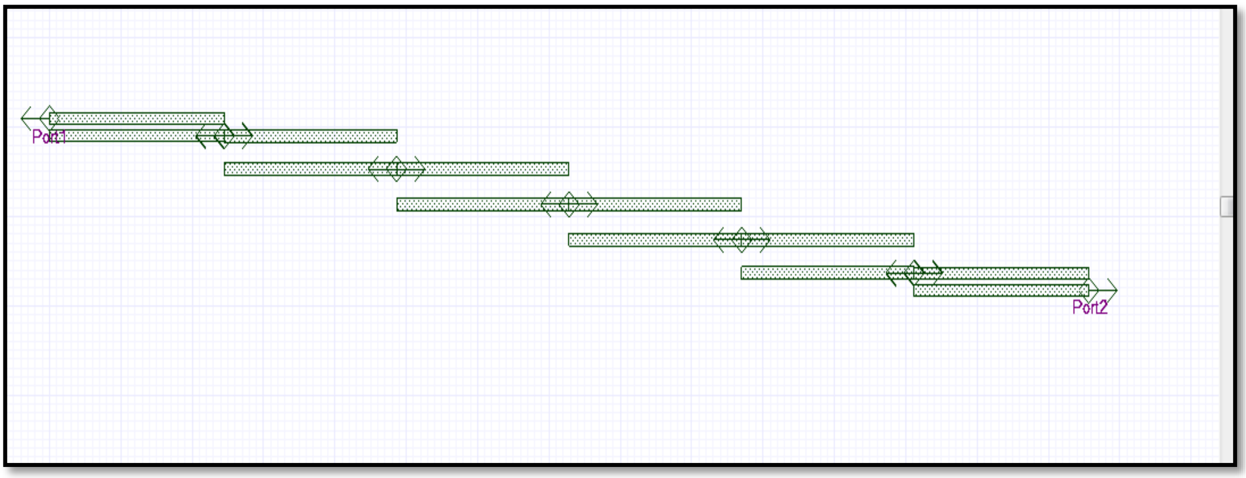

Figure7:Layout for Band Pass Filter Using Edge Coupled Line

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III. RESULTS AND DISCUSSIONS

From the figures 8, 9 it is observed that the simulated results are obtained approximately as same as expected results.From the figure 10, it is noted that the phase is linear over the desired frequency range.

PARAMETER	SIMULATED RESULT	EXPECTED RESULTS
Bandwidth	0.05GHz	0.05GHz
Return loss	-12.6dB	>-10dB
Stop band attenuation	38dB	40dB

Table 6: Results for Band Pass Filter

From the figure 8, it is noted the pass band ripple is around 0.5 dB , 3- dB bandwidth is about 0.05 GHz and stop band attenuation of 38 dB is attained.

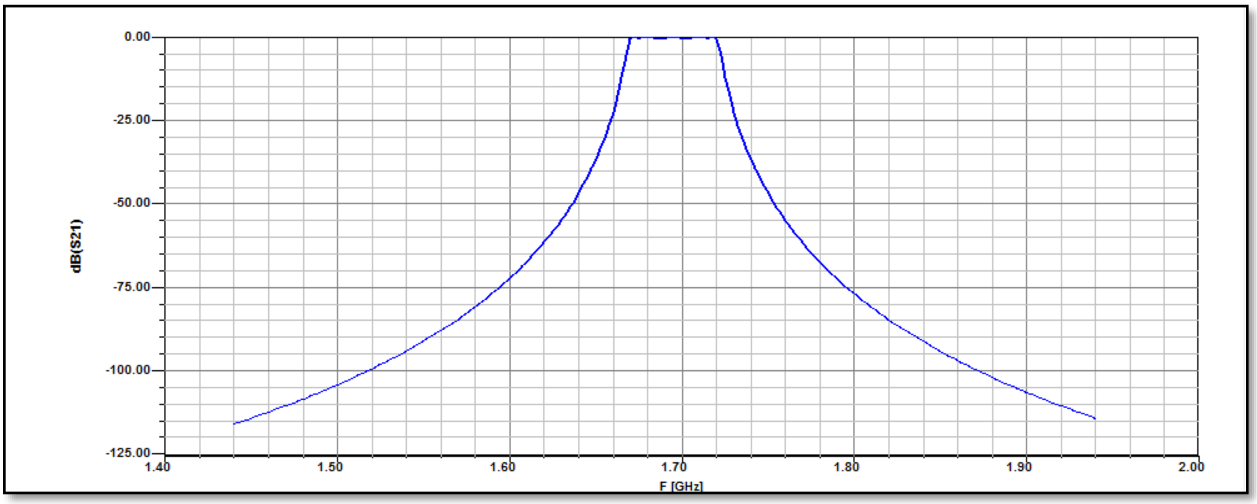

Figure8: Frequency Response of Designed Filter at Centre Frequency 1.695 GHz

From the figure 9, the return loss of the filter is noted around -13 dB at the centre frequency 1.695 GHz which is an acceptable level.

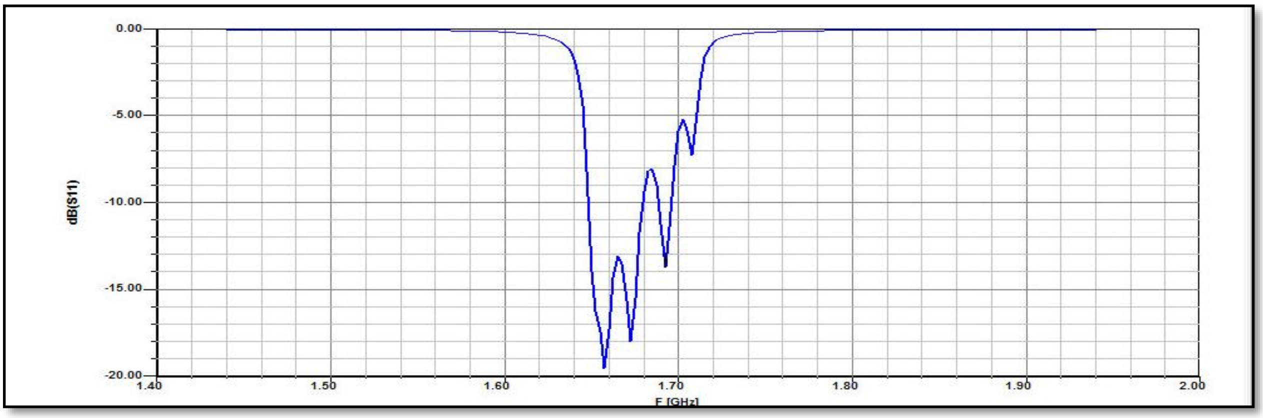

Figure9: Return loss of Designed Filter at Centre Frequency 1.695 GHz

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From the figure 10, it is shown that the phase response of the filter linear along the bandwidth which is desirable.

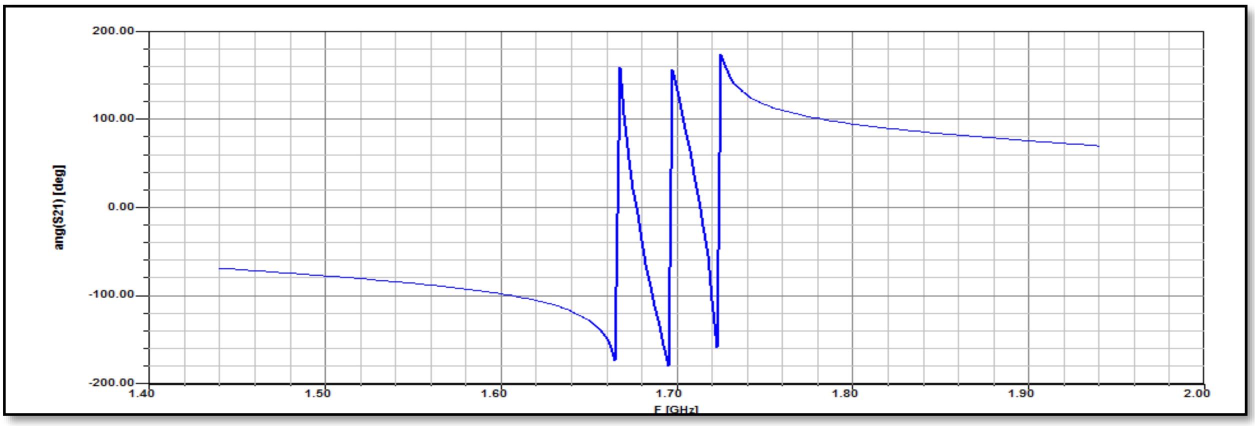

Figure10:Phase Response of Designed Filter at Centre Frequency 1.695 GHz

IV. CONCLUSION

The band pass filter was designed andits results are simulated at centre frequency of 1.695 GHz .It is observed that the results are attained as per our requirements. The designed band pass filter is used to filter the received noise contaminated HRPT data from different L-band weather satellites over the (1.67-1.72) GHzfrequency range.

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