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Design of Tunable Filter using Combination of Inductively and Capacitively Loaded Coupled Sections

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Abstract- Microwave filters is a device which is allowing the transmission at frequency within the pass band of the filter and attenuation within the stop band of the filter. Usually in a band pass filter, it will be operated in one frequency centre, within one range of frequency depends on its bandwidth within the pass band and stop band. By tuning the frequency, the filter could be operated for more than one frequency range. These microwave filters is the basic building blocks with frequency-selective or filtering functionality in the development of various wireless systems that operate at frequency ranges 300MHz. Electronically tunable microwave filter have wide application in modern devices application. This project will develop tunable band pass filter Using Advance Design System (ADS).

Keywords- Prototype Low Pass Filter, Tunable filter, Reflection Coefficient, Transmission Coefficient

I. INTRODUCTION

Filter is a frequency selective circuit that passes specified band of frequencies and attenuates signals outside this band. Filter is highly desirable in communication system. Microwave filters used to control the frequency response in Radio Frequency (RF) and microwave. It is a device which is allowing the transmission at frequency within the pass band of the filter and attenuation within the stop band of the filter. Usually in a band pass filter, it will be operated in one frequency centre, within one range of frequency depends on its bandwidth within the pass band and stop band. Band Pass Filter circuits can be designed by combining the properties of low-pass and high-pass into a single filter, or band pass filter with lumped elements is formed by taking a low pass filter prototype and transforming this into BPF.

Chebyshev Response has a steeper roll-off and has ripples in pass band and stop band than Butterworth. As the ripple increases, the roll-off becomes sharper. The 0 dB ripple curve is equivalent to Butterworth response.

II. DESIGN OF PROTOTYPE LOW PASS FILTER

Before implementing the bandpass filter we have first implemented a low pass filter with Chebyshev response whose cut off frequency is 4.5 GHz and its order is 5. For implementing a low pass filter first we have to find out the elements values corresponding to order 5 (i.e. N=5) which we can simply get from table: so the elements values are

g_1=0.6180, g_2=1.6180, g_3=2.0000, g_4=1.6180, g_5=0.6180 and g_6=1.0000

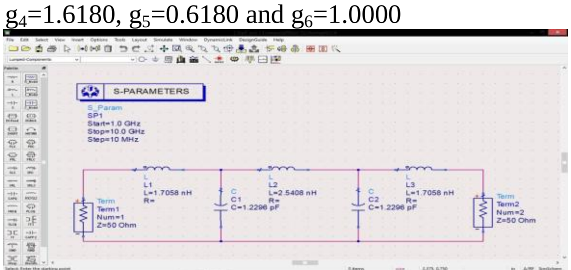

Figure 2.1 ADS Schematic of Low pass filter using lumped elements

By using frequency and impedance scaling we calculate the lumped elements values:

L_1 = 1.7058 nH, L_2=2.5408 nH,

L_3 = 1.7058 nH, C_1=1.2296 pF and C_2 = 1.2296 pF

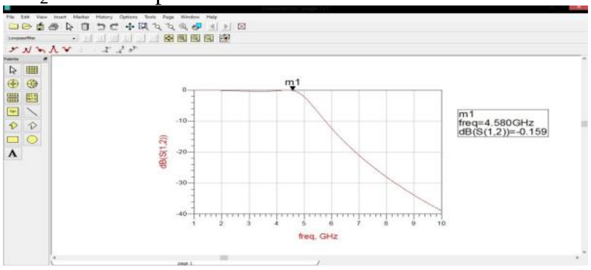

Figure 2.2: Output response of low pass filter using lumped elements

III. DESIGN OF PROTOTYPE BAND PASS FILTER USING LUMPED ELEMENTS

After implementing low pass filter we have implemented bandpass filter centered at 2.4 GHz using lumped elements. We have to find out the elements values corresponding to order 5 (i.e N=5) which we can simply get from table: so the elements values are

$g_1=0.6180$, $g_2=1.6180$, $g_3=2.0000$, $g_4=1.6180$, $g_5=0.6180$ and $g_6=1.0000$

By using band pass transformation we have calculated lumped elements values:

$$\omega \leftarrow \omega_0/(\omega_2-\omega_1)\,(\omega/\omega_0-\omega_0/\omega)$$
$$= 1/\Delta\,(\omega/\omega_0-\omega_0/\omega)$$

Where, $\Delta=(\omega_2-\omega_1)/\omega_0$ is the fractional bandwidth of the pass-band.

$\omega_0=\sqrt{(\omega_1\omega_2)}$ is the center frequency.

The series inductors and capacitor of the low-pass prototype are converted to series LC circuits having element values given by

$$L_K' = L_K/\Delta\omega_0$$
$$C_K' = \Delta/\omega_0 L_K$$

The shunt capacitor and inductor of the low-pass prototype is converted to parallel LC circuits having element values given by

$$L_K' = \Delta/\omega_0 C_K$$
$$C_K' = C_K/\Delta\omega_0$$

So, now by using above transformation we can calculate the lumped elements as:

L_1=1.07305 nH	C_1=4.09824pF
L_2=26.8242nH	C_2=0.16394pF
L_3=0.33157nH	C_3=13.2629pF
L_4=26.82424nH	C_4=0.16394pF
L_5=1.07305nH	C_5=4.09824pF

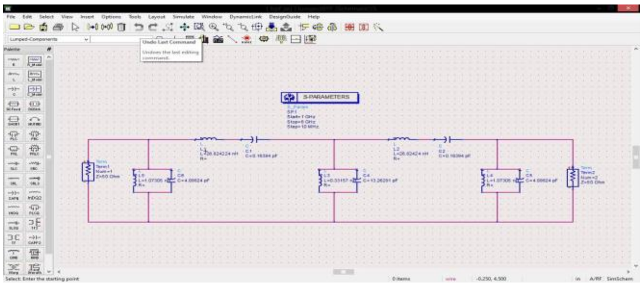

Figure 3.1: ADS Schematic of Band pass filter using lumped elements

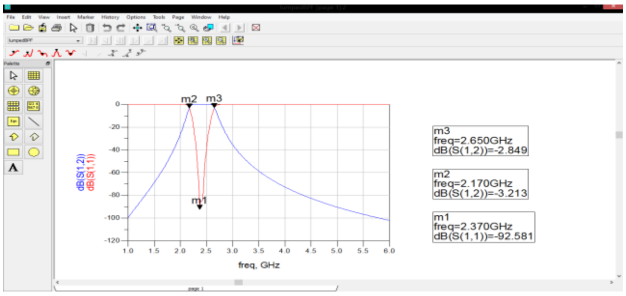

Figure 3.2: Output response of Band pass filter using lumped elements

dB[S(1,2)]- Transmission Coefficient Vs frequency

dB[S(1,1)]- Reflection Coefficient Vs frequency)

IV. DESIGN OF PROTOTYPE BAND PASS FILTER USING MICROSTRIP LINES

After calculating the lumped elements values, we have to transform the lumped model into the distributed model, and corresponding to that we have to calculate the even and odd mode impedances of all N+1sections using the equations

$Z_0J_1 = (\pi\Delta/2g_1)$^1/2

$Z_0J_N = \pi\Delta/2(gn-1\ gn)$^1/2

$Z_0J_{N+1} = (\pi\Delta/2gn-1gn)$^1/2 Zod=Zo[1−JZo+(JZo)2] Zoe=Zo[1+JZo+(JZo)^2]

We found even and odd impedances for different sections as:

Table 4.1: Values of characteristic impedance, even and odd impedances used for design of BPF

Sections	Z_oJ_N	Z_{oe}	Z_{od}
Section1	0.3474	73.4105	38.6633

Section2	0.1104	56.1295	45.0893
Section3	0.8411	54.5597	46.1447
Section4	0.8411	54.5597	46.1447
Section5	0.1104	56.1295	45.0893
Section6	0.3474	73.4105	38.6633

V. CALCULATION OF WIDTH LENGTH & SPACING OF DIFFERENT SECTIONS USING ADS

Now using the above values of even and odd impedances we can calculate the desired width, length and spacing of microstrip lines through ADS using the tool "line calc". Now for the characteristic impedances of 50Ω we normally use the MLIN (Normal single microstrip), but for distributed sections, as this is a coupled microstrip line filter we use MCLIN. We put the values of Z_0, Z_{oe}, Z_{od} and E_{eff}=90 and it gives the valve of width (W), length (L) and spacing for the respective sections as shown in below table.

Table 5.1: Values of L,W,S using line cal in ADS

Sections	W (mm)	L (mm)	Spacing (mm)
Section1	69.2315	6.232	904.465
Section2	89.4	36.96	884.252
Section3	90.572	49.82	883.063
Section4	90.572	49.82	883.063
Section5	89.4	36.96	884.252
Section6	69.2315	6.232	904.465

VI. ADS SCHEMATIC OF BANDPASS FILTER USING MICROSTRIP COUPLED LINES

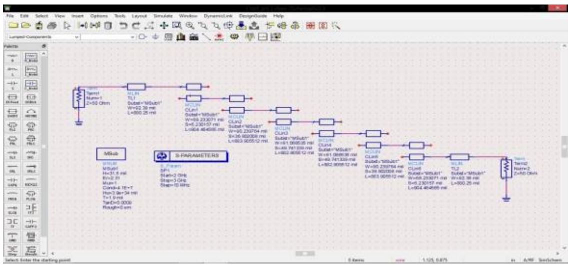

Figure 6.1: ADS Schematic of Bandpass filter using microstrip coupled lines

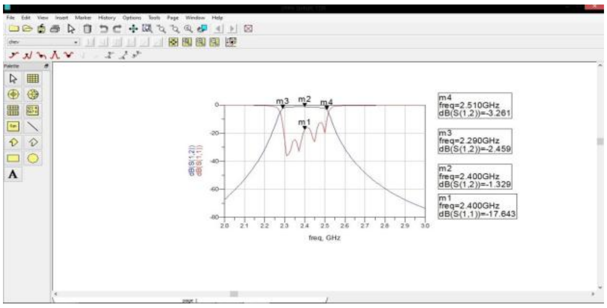

Figure 6.2: Output response of Bandpass filter using microstrip coupled lines
(dB(S(1,2))-Transmission Coefficient Vs frequency
(dB(S(1,1))- Reflection Coefficient Vs frequency)

VII. TUNABLE FILTER USING COMBINATION OF INDUCTIVELY AND CAPACITIVELY LOADED COUPLED SECTIONS

In an edge coupled filter each coupled sections has two open ends. Tunability was observed by loading both the end of each coupled sections into a varying inductors and varying capacitors as shown in figure 7.1.

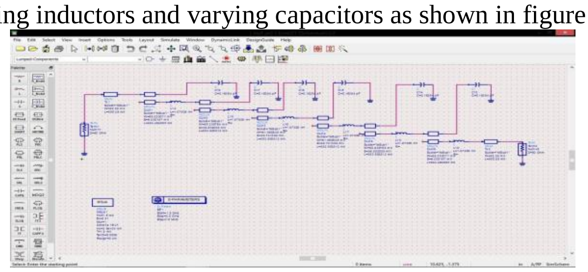

Figure 7.1: ADS schematic of tunable bandpass filter centered at 2.1 GHz with L=26.8 nH and C=0.16 Pf

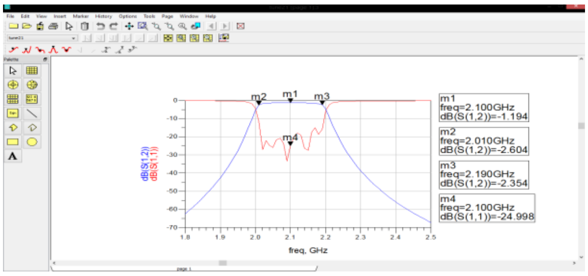

Figure 7.2: Output response of tunable bandpass filter centered at 2.1 GHz with L=26.8 nH and C=0.16 pF
dB[S(1,2)]-Transmission Coefficient Vs frequency
dB[S(1,1)]-Reflection Coefficient Vs frequency)

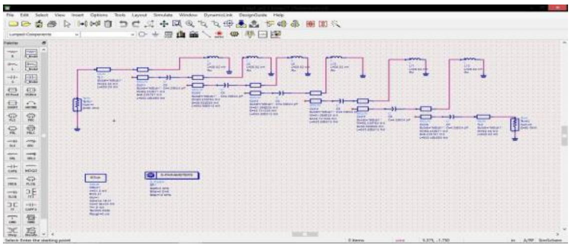

Figure 7.3: ADS schematic of tunable bandpass filter centered at 2.7 GHz with L=26.8 nH and C=0.16 pF

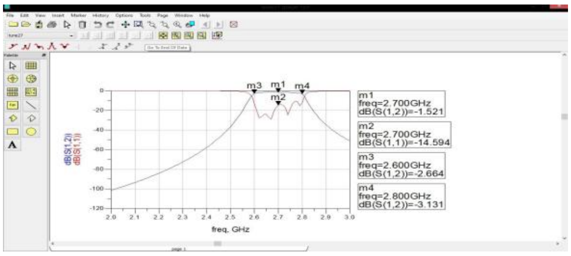

Figure 7.4: ADS schematic of tunable bandpass filter centered at 2.7 GHz with L=26.8 nH and C=0.16 pF
dB[S(1,2)]-Transmission Coefficient Vs frequency
dB[S(1,1)]-Reflection Coefficient Vs frequency

The tuning was investigated in ADS as when the tuning capacitor with C=0.16pF was applied in the one end of each coupled sections the center frequency is 2.3GHz and when the tuning capacitor with same value was applied at both the ends of each coupled section the center frequency is 2.2GHz.
The tuning was investigated in ADS as when the tuning inductor with L=26.8nH was applied in the one end of each coupled sections the center frequency is 2.5GHz and when the tuning capacitor with same value was applied at both the ends of each coupled section the center frequency is 2.58GHz.
The tuning was investigated in ADS as when the tuning inductor with L=26.8nH was applied in the series with each coupled sections and the tuning capacitor with C=0.16pF was applied in the one end of each coupled sections the center frequency is 2.1GHz and when the tuning capacitor with C=0.16pF was applied in the series with each coupled sections and the tuning inductor with L=26.8nH was applied in the one end of each coupled sections the center frequency is 2.7GHz.

VIII. CONCLUSION AND FUTURE SCOPE

VIII.1 Conclusion

A tuning technique was implemented through the use of passive elements. These filter design gave more design flexibility over the other designs. The design was simple and easy to fabricate.
The design with tuning elements attached to an open end of coupled sections required tunable matching sections in order to compensate for reflection across the tuning range.
The design involving a the tuning inductor in the series with each coupled sections and the tuning capacitor in the one end of each coupled sections have low return loss as compared to other designs.

VIII.2 Future Scope

As the designed tunable bandpass filters is accomplished with the help of tuning capacitor
and tuning inductor with only one value of inductor and capacitor i.e L=26.8nH and C=0.16pF at different positions in the filters, different values for tuning inductors and tuning capacitors can be found for tuning the filter at different frequencies, different type of filter response i.ebutterworth ,elliptical can be adopted, different substrate can also be adopted to design tunable bandpass filter.

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