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Design and Fabrication of 456 MHz Bandpass Filter

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Abstract : *This paper presents the design and fabrication of bandpass filter for frequency-modulated continuous wave radar system. A bandpass filter was designed at the operating center frequency of 456 MHz, bandwidth of 60 MHz, 3 dB insertion loss, 1.1 VSWR, 50 ohm impedance. The design filter was simulated using ADS 2011. The outcome of this research was a prototype of a 456 MHz bandpass filter and the results of the measurement were approximately similar to the required specifications.*

Keywords : *bpf, bandwidth, insertion loss, vswr*

I. Introduction

Bandpass filter is a passive component which is able to select signals inside a specific bandwidth at a certain center frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere the information signals [1]. A bandpass filter must be used in transmitter and receiver to reject undesired signals [2].

In the previous research we have done the designed and simulated the bandpass filter as in [2] using Elsie Tonne version 2.4. This research, we simulated and fabricated lumped-element bandpass filter for the radar system at the operating center frequency of 456 MHz, bandwidth of 60 MHz. The simulation of bandpass filter in this research using ADS 2011. This bandpass filter would be used in receiver block which is used as an intermediate frequency (*IF*) and the center frequency of 456 MHz was obtained based on the rule RF – LO = IF [2].

A Bandpass prototype can be designed with low-pass filter and high-pass filter. Figure 1 shows one method of realizing bandpass prototype with low-pass filter prototype [2][3][4].

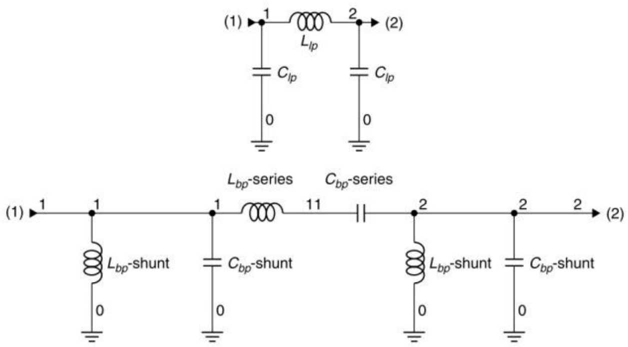

Figure 1. Bandpass filter prototype starting with low pass filter

In this method, we replace each series inductor with a series capacitor and inductor resonator and then replace each shunt capacitor with a shunt parallel resonant capacitor and inductor [2]. We can normalize bandpass filter with calculate shunt elements and series elements as follows [2][4]

$$BW = f_u - f_l = \text{absolute bandwidth} \quad (1)$$

$$f_0 = \sqrt{f_l f_u} = \text{geometric center frequency} \quad (2)$$

$$bw = \frac{BW}{f_0} = \text{fractional bandwidth} \quad (3)$$

For shunt elements:

$$C_{bp\text{-shunt}} = \frac{C_{lp}}{bw} \quad (4)$$

$$L_{bp\text{-shunt}} = \frac{1}{C_{bp\text{-shunt}}} \quad (5)$$

For series elements:

$$L\text{bp-series} = \frac{L\text{lp}}{bw} \qquad (6)$$

$$C\text{bp-series} = \frac{1}{L\text{bp-series}} \qquad (7)$$

To find the final design, we denormalize the elements with the following rules [2]

$$L\text{i} = \frac{g\text{i}Z\mathbf{0}}{2\pi f\mathbf{0}} \qquad (8)$$

$$C\text{i} = \frac{g\text{i}}{Z\mathbf{0}2\pi f\mathbf{0}} \qquad (9)$$

II. Filter Design and Simulation

The designs of bandpass filter in this research same with [2]. Figure 2 shows the bandpass filter prototype with the order *N* is 7 [2].

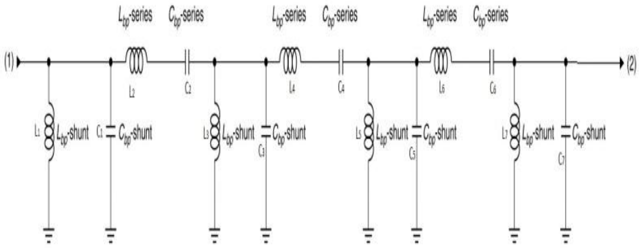

Figure 2. Bandpass filter with N=7

The results of denormalized all elements are the values of *L* and *C* components for final bandpass filter design which have calculated in [2]: C_1 = 23.6019 pF, C_2 = 0.7401 pF, C_3 = 95.5681 pF, C_4 = 0.4617 pF, C_5 = 95.5681 pF, C_6 = 0.7401 pF, C_7 = 23.6019 pF, L_1 = 5.1838 nH, L_2 = 0.1653 µH, L_3 = 1.2802 nH, L_4 = 0.2652 µH, L_5 = 1.2802 nH, L_6 = 0.1653 µH, L_7 = 5.1838 nH.

The values of components *L* and *C* which were obtained from calculations in the filter design were simulated using ADS 2011. This software has also been used to design bandpass filter [5]. The filter structure and 50 ohm transmission in ports, input and output are shown in Figure 3.

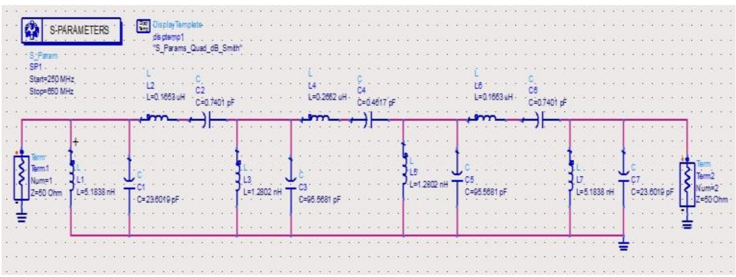

Figure 3. Schematic of bandpass filter

The results of simulation which have been done using ADS 2011 are shown below.

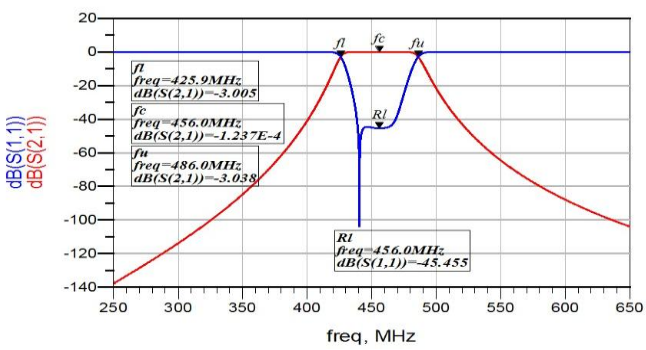

Figure 4. S-Paramaters result from ADS 2011

Figure 4 show the simulation result either insertion loss and return loss. The S21 characteristic depict the value of insertion loss and the S11 characteristic depict the value of return loss. The insertion loss at frequency of 456 MHz is -1.237E-4 dB, -3.005 dB of insertion loss at lower frequency and -3.038 dB of insertion loss at upper frequency. At the frequency of 456 MHz the return loss is -45.455 dB. From the value of return loss at frequency of 456 MHz, we find the value of VSWR is 1.01. The result of insertion loss and VSWR using Elsie Tones version 2.4 were 0.4 and 1.0, respectively [2]. The results of simulation using both of the software were still in the specification and could be fabricated.

III. Fabrication and Measurement

The values of components must be approximately equal to the values of components are traded. So we must consider the traded components of *L* and *C* to realize the design [2]. The bandpass filter is fabricated on Duroid 5880 and using the SMD components.
The values of insertion loss at center, lower and upper frequency from measurement are shown in Figure 5.

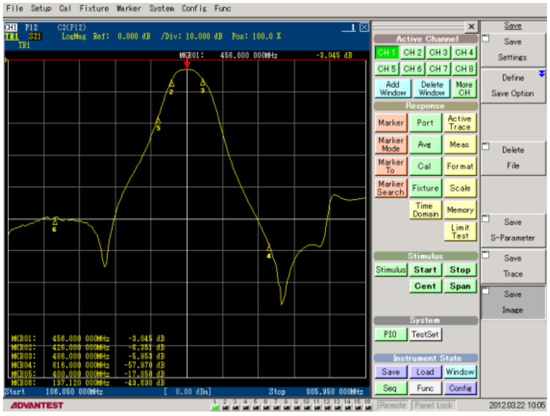

Figure 5. The S21 characteristic

From the figure above we find a resonant at frequency of 456 MHz. The insertion loss values at center, lower and upper frequency are -3.045 dB, -6.351 dB and -5.953 dB, respectively. The value of VSWR is depicted on Figure 6.

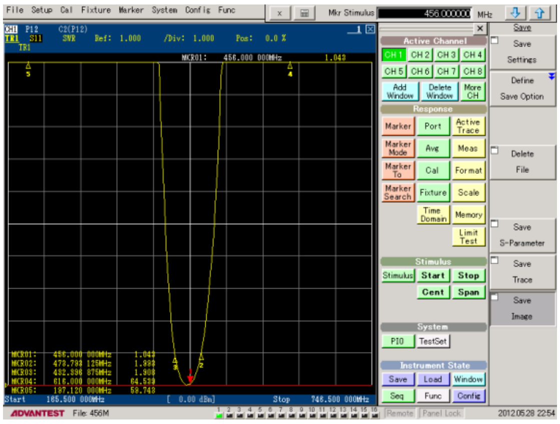

Figure 6. The S11 characteristic

From Figure 6 we obtain the value of VSWR at frequency of 456 MHz is 1.042. It is equal to -33.736 dB of the value of return loss. The VSWR represents the reflection factor. Figure 7 shows the photograph of bandpass filter with the package.

Figure 7. Photograph of bandpass filter with package

There are any different results of the filter performance between simulation and fabrication. We see that the value of insertion loss at center frequency in simulation is about 3 dB better than filter which is fabricated. And the value of return loss in simulation is 11.719 dB better than filter which is fabricated. The different of filter characteristics are caused by the value of components are not equal to the calculation results. The value of components used in fabrication is approach to the calculation results and consider the traded components too. Furthermore, we must consider the losses of connectors. The bandwidth with the 3 dB boundary is about 60 MHz. It is conforming to the design.

IV. Conclusion

The S-parameter characteristics of the simulation and measurement shows good filter performance. The measurement has the larger of insertion loss and return loss, -3.045 dB and -33.736 dB, respectively. It is caused the value of components not equal to the design. On the other hand, the simulation does not compute the losses of connector and poor connection between transmission line and connector. On the whole, the performance of bandpass filter approximately suitable with required specification.

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