RF TRANCEIVER PROJECT ON MICROSTRIP COMBLINE BANDPASS FILTER

Submitted By

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PROBLEM STATEMENT

Designing of a microstrip combline bandpass filter for center frequency of 2.4GHz and 5.4GHz. Passband bandwidth is 200MHz.

ACKNOWLEDGEMENT

It is difficult to acknowledge the precious debt of knowledge and learning. But we can only repay it through our gratitude. I, Asish Nayak, a M.tech student in RF and Microwave Engineering , would like to convey my heartfelt gratitude to my professor ***Dr. M.V Kartikeyan*** *, for blessing us with his immense knowledge of Microwave Engineering and being a constant source of inspiration for me.*

I would also like to thank Mr. ***Mr. Sai Haranadh(PhD Scholar, IIT Tirupati)*** *for his valuable instruction and support through this project by clarifying my doubts and guiding me with his novel ideas.*

Regards,

Asish Nayak

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INTRODUCTION

In the run of the filters, Combline filter immersed after Interdigital filter so as to overcome some disadvantages of interdigital filter at the cost of its response. The interdigital filter has the advantages of broad stopband and a highly symmetrical response but from physical point of view it has certain disadvantages like it is quite large: the resonators are quarter wavelength long and are well separated for narrow bandwidths. The combline filter overcomes the disadvantages at the cost of asymmetrical response.

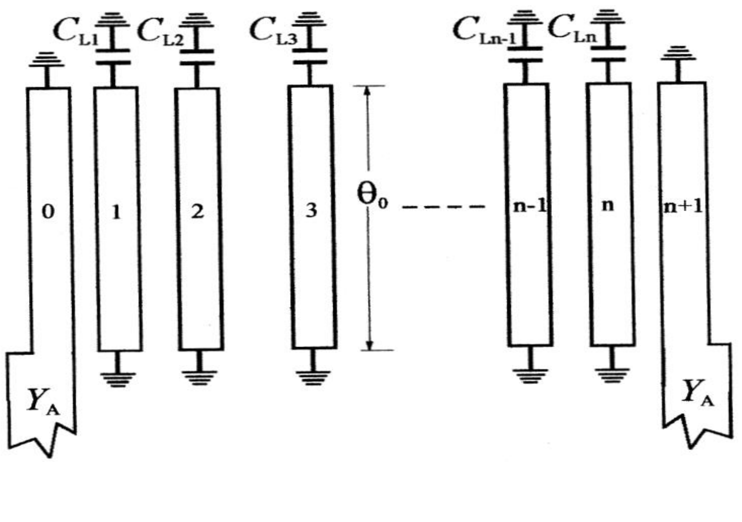
The principle of operation of combline filter is that if the shunt capacitors were removed then the shunt microstrip lines will resonate at their quarter wave frequencies. However, the electric and magnetic coupling would also resonate at this frequency and cancel out each other for pure TEM transmission lines and will produce and all-stop network. As the capacitors are increased, the shunt lines will behave as inductive element and resonate with capacitors at frequencies below quarter wave frequencies. The coupling would be finite but will be weak compared to that of interdigital filters with same resonator spacings. Hence, the combline filter is compact because the resonators may be shorter than quarter wavelength and are closer together than that of an interdigital filter with same bandwidth and ground plane spacing.

The software that has been used in this project is ***Cadence AWR design Environment platform, specifically Cadence AWR Microwave Office Circuit Design software.*** *The whole circuit is designed on a patch of substrate of dielectric constant 3.2 and height 1.524mm. The concept of Microstrip line is used for designing of Transmission line. The circuit is designed keeping a center frequency of 2.4GHz and after the simulation* **S_{11} (reflection coefficient of port 1)** *and* **S_{21} (Transmission coefficient of port 1)** *plots are plotted.*

THEORY

Combline Filters

The combline bandpass filter is comprised of an array of coupled resonators. The resonators consist of line elements 1 to n, which are short-circuited at one end, with a lumped capacitance CLi loaded between the other end of each resonator line element and ground. The input and output of the filter are through coupled-line elements 0 and n + 1, which are not resonators. With the lumped capacitors present, the resonator lines will be less than λ/4 long at resonance, where λ/4 is the guided wavelength in the medium of propagation at the midband frequency of filter. It is interesting that if the capacitors were not present, the resonator lines would be a full λ/4 long at resonance, and the filter structure in following figure would have no passband at all when the line elements are constructed from a pure TEM-mode transmission line such as stripline. This is because the magnetic and electric couplings totally cancel each other out in this case. The larger the loading capacitances CLi, the shorter the resonator lines, which results in a more compact filter structure with a wider stopband between the first passband (desired) and the second passband (unwanted). For instance, if the resonator lines are λ/4 long at the primary passband, the second passband will be centered at somewhat over four times the midband frequency of the first passband. In practice, the minimum resonator line length could be limited by the decrease of the unloaded quality factor of resonator and a requirement for heavy capacitive loading. The lumped capacitors may offer a convenient means for filter tuning, which may be required particularly for narrow-band filters.



Following design approach is to determine the dimensions in terms of another set of design parameters consisting of external quality factors and coupling coefficients. These design parameters are given by

$$Q_{e1} = \frac{b_1}{J_{0,1}^2/Y_A} = \frac{g_0 g_1}{FBW}, \qquad Q_{en} = \frac{b_n}{J_{n,n+1}^2/Y_A} = \frac{g_n g_{n+1}}{FBW}$$

$$M_{i,i+1} = \frac{J_{i,i+1}}{\sqrt{b_i b_{i+1}}} = \frac{FBW}{\sqrt{g_i g_{i+1}}} \qquad \text{for } i = 1 \text{ to } n-1$$

where Q_{e1} and Q_{en} are the external quality factors of the resonators at the input and output, and $M_{i,i+1}$ are the coupling coefficients between the adjacent resonators.

Respective physical dimensions of Combline filter can be found out using parameter extraction technique mentioned in chapter 8 of book mentioned in reference 1.

THEORETICAL CALCULATIONS

Since our problem statement was to design a combline filter of 2.4GHz, we start the calculations by writing lowpass prototype of order 5 and 0.1dB ripple Chebyshev response.

So, for 0.1dB ripple:

$$g_0 = g_6 = 1$$

$$g_1 = g_5 = 1.1468$$

$$g_2 = g_4 = 1.3712$$

$$g_3 = 1.9750$$

For 2.4GHz:

$$FBW = 200/2400 = 0.083$$

$$Q_{e1} = Q_{e5} = 13.8168$$

$$Q_{e2} = Q_{e4} = 18.9456$$

$$Q_{e3} = 32.6279$$

$$M_{01} = M_{56} = 0.07782$$

$$M_{12} = M_{45} = 0.04491$$

$$M_{23} = M_{34} = 0.02496$$

Physical dimensions from above:

$$S_{01} = S_{56} = 1.4088mm$$

$$S_{12} = S_{45} = 4.9775mm$$

$$S_{23} = S_{34} = 9.5453mm$$

$$W_0 = W_1 = \cdots = W_6 = W = 3.6276mm$$

$$C_1 = C_2 = \cdots = C_5 = 1.3262pF$$

$$L = 6.5032mm$$

Where, S = spacing between adjacent lines

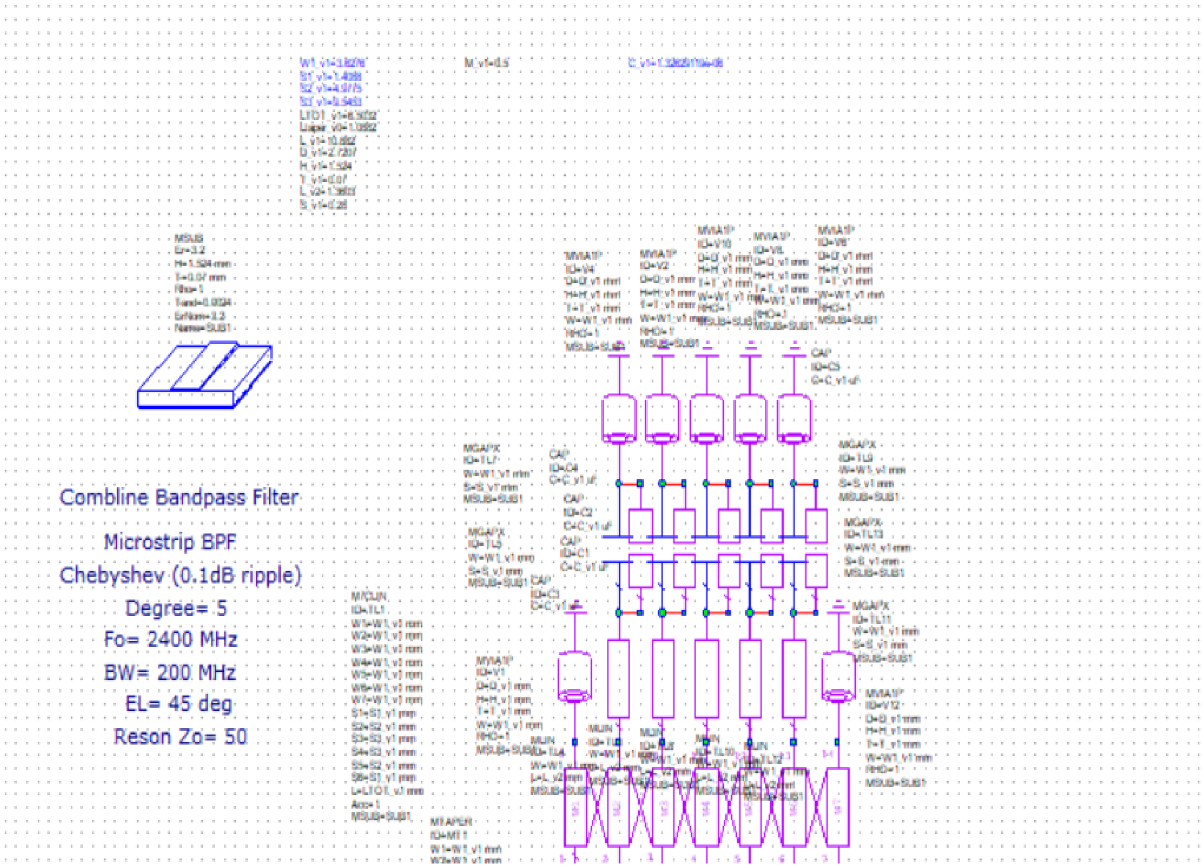
W = width of each line

C = Capacitance connected to each line except source and load

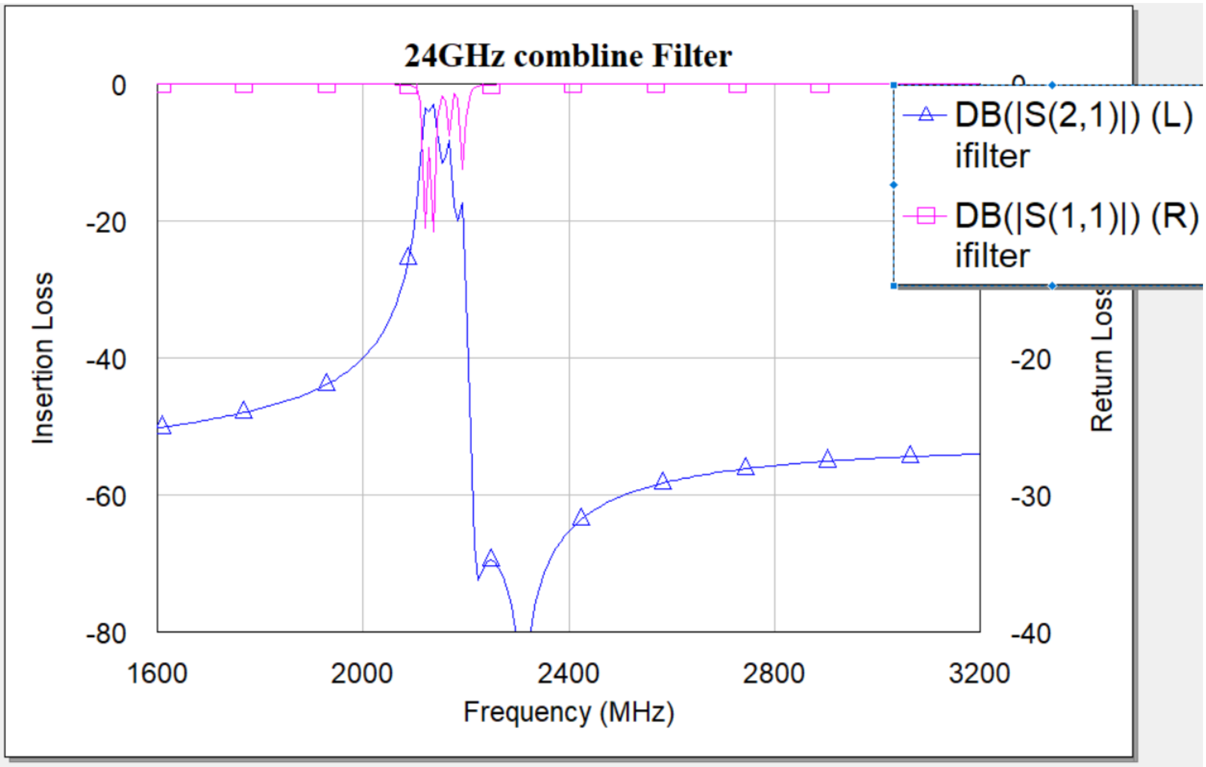
L = length of each line.

IMPLEMENTATION OF DESIGN USING AWR

Following is a schematic view of AWR design:



Following is the result of above Schematic:



CONCLUSION AND REFERENCES

Hence, a 2.4GHz Combline Filter of order-5 is designed. While going through this project, the concept of Combline filter design technique is learnt. From the above plots, it is clear that the results obtained are very close approximate to the ideal ones.

Following are the references used in this project:

1. *Microstrip Filters for RF/Microwave Applications by Jia-Sheng Hong and M.J. Lancaster*