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Design, Fabrication And Analysis of Parallel-Coupled Line Bandpass Microstrip Filter for C-Band Application

Anupam Bhattacharjee [*] ***and Nitesh Kumar Singh*** [**]
**Software Architecture Division, Sony India Software Centre Pvt. Ltd., Bangalore, India*
***Department of Electronics and Communication Engineering, Tezpur University, Assam, India*

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ABSTRACT*:* The use of planar circuit architecture has opened up new opportunities in terms of reduction in weight, volume, power consumption as well as extension of operating frequencies. This paper presents the design and simulation of a conventional parallel-coupled line band pass microstrip filter for C-Band communication. The band pass filter operates at a centre frequency of 6.93 GHz suitable for C-Band communication. A miniature 4th order filter is considered to obtain better selectivity and stop band rejection with a bandwidth of 693 MHz and a fractional bandwidth of 10 %. The filter is simulated using commercial software Serenade v8.5 (make: Ansoft Corp.) at a resonant frequency of 6.93 GHz and 0.5 dB equal-ripple response. The filter is fabricated using photolithography process and the simulated response is verified with network analyzer (make: Agilent) and a good agreement is found.

***Index Terms*—**Parallel-coupled line band pass microstrip filter, Selectivity, Stopband rejection, photolithography.

NOMENCLATURE

Centre frequency of the filter
J Characteristic admittance of J inverter **HU** Cover
Height of substrate
Characteristic Impedance
Even mode characteristic impedance
Fractional Bandwidth
Low pass prototype value
Odd-mode characteristic Impedance
Relative permittibilty of the substrate
$\mathbf{P_{LR}}$ Power loss ratio

I. INTRODUCTION

Band pass filters play a very significant role in wireless communication. Transmitted and received signals needs to be filtered at a certain frequency called the centre frequency with desired bandwidth. A band pass filter is an important component that is found in all transmitters and receivers for desired communication mainly wireless. It is a passive component that selectively passes few signal components comprising its pass band and rejects the other components specially those frequencies which interfere with the information in the signal comprises the stop band of the filter.

Microstrip line is one of the most popular types of planar transmission lines primarily because it can be fabricated by photolithographic process and is easily integrated with other passive and active microwave device. Parallel coupled line is a popular topology for printed circuit boards to design band pass filter. Narrowband pass filters can be designed with this technique as wider band pass filters require tighter coupling which is difficult to fabricate. The microstrip filter is designed with 5 sections to have better selectivity and stop band rejection. The filter is centred at a frequency of 6.93 GHz, mostly used in C-Band applications. The filter is simulated using commercially available software Serenade v8.5 (make: Agilent) and then fabricated using photolithographic process. The fabricated filter response is then obtained with network Analyzer (make: Agilent) and compared with the simulated response.

II. THEORY

Parallel-coupled line band pass filters makes use of a series of half wavelength long resonant conducting strips. The parallel coupled resonator filter is popularly used in band pass filter configuration in application requiring narrow to moderate bandwidth (up to about 20%). The adjacent resonators are parallel coupled along half of their length (Quarter wavelength).

A low pass to band pass transformation is required to realize band pass characteristics of the filter. In the transformation from low pass prototype, we find out the transformed impedances and using these values we calculate the admittance inverter values. The L component in the low pass prototype is converted to serial combination of L_1’ and C_1’ and the C component is converted to parallel combination of L_2’ and C_2’. Figure 1 shows a similar representation of the same.

The characteristic impedance Zo is generally considered as 50 Ω.

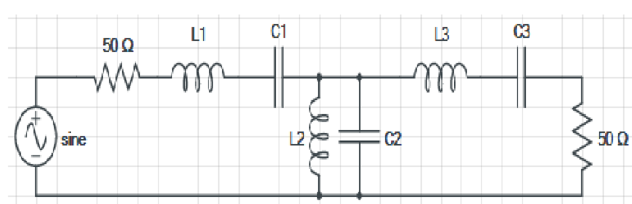

Fig. 1. Lumped circuit representation of a Bandpass filter.

III. DESIGN OF PATTERN-COUPLING MICROSTRIP BANDPASS FILTER

The design procedure involves conversion of low pass filter to band pass filter. First of all we transform the frequency of the low pass circuit and then transform its impedances.

Figure 2 shows flow of the overall design process:

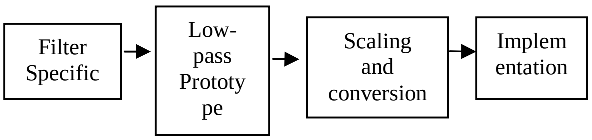

Fig. 2. Flow of steps required for design using insertion loss method.

A perfect filter would have zero insertion loss at the pass band and infinite attenuation in the stop band but practically these characteristics are not feasible. The insertion loss method is used to design realizable filters with various desired qualities using different polynomials. The insertion loss method allows a high degree of control over the passband and stopband amplitude and phase characteristics, with a systematic way to synthesize a desired response. A minimum insertion loss is obtained on the expense of a higher order filter.

In our study we have considered Chebyshev response to satisfy a sharper cut-off frequency. Though the passband has ripples unlike maximally flat response. The following figure 3 distinguishes the responses between them.

For an equal ripple response, Chebyshev polynomial is used to specify the insertion loss (P_{LR}) in dB for an N-order low pass filter,

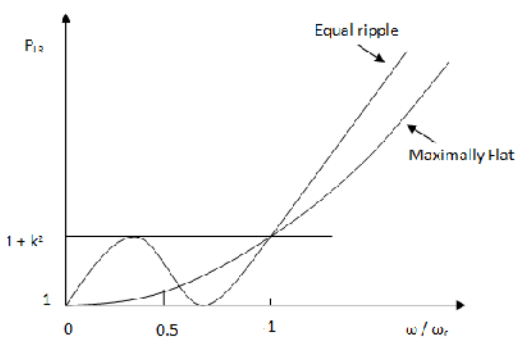

Fig. 3. Maximally Flat response and equal ripple response for a low pass filter for a finite order filter.

Using the values of G_N from standard for 0.5 dB equal-ripple response, we find out the transformed impedances and using it we can find out the values of the admittance inverters.

Using the table for 0.5 dB equal-ripple response, we get the low-pass prototypes for 5 sections as,

$G_1 = 1.6703$, $G_2 = 1.1926$, $G_3 = 2.3661$, $G_4 = 0.8419$, $G_5 = 1.9841$

Now, calculating the admittance inverters for converting a series reactance into shunt reactance.

Fractional Bandwidth (Δ) =

=

= 0.1 = 10 % (1)

Thus, calculating the admittance inverters for all the sections:

For N=1

$$Z_0 J_1 = \sqrt{\frac{\pi.\Delta}{2.G_1}} = 0.3066$$

Hence, for this value of admittance inverter, let us calculate,

(even impedance) = $Z_0.(1+J$

= 70.03 Ω (2)

And,

(odd impedance) = $Z_0.(1-J$

= 39.37 Ω (3)

For N=2

$$Z_0 J_2 = \frac{\pi.\Delta}{2.\sqrt{G_1.G_2}} = 0.1112$$

Hence, for this value of admittance inverter, let us calculate,

(even impedance) = $Z_0.(1+J_2$

= 56.18 Ω (4)

And,

(odd impedance) = $Z_0.(1-J_2$

= 45.06 Ω (5)

For N=3

$$Z_0 J_3 = \frac{\pi.\Delta}{2.\sqrt{G_2.G_3}} = 0.0934$$

Hence, for this value of admittance inverter, let us calculate,

(even impedance) = $Z_0.(1+J_3$

= 55.11 Ω (6)

And,

(odd impedance) = $Z_0.(1-J_3$

= 45.77 Ω (7)

For N=4

$$Z_0 J_4 = \frac{\pi.\Delta}{2.\sqrt{G_3.G_4}} = 0.1112$$

Hence, for this value of admittance inverter, let us calculate,

(even impedance) = $Z_0.(1+J_4$

= 56.18 Ω (8)

And,

(odd impedance) = $Z_0.(1-J_4$

= 45.06 Ω (9)

For N=5

$$Z_0 J_5 = \frac{\pi.\Delta}{2.\sqrt{G_4.G_5}} = 0.3066$$

Hence, for this value of admittance inverter, let us calculate,

(even impedance) = $Z_0 \cdot (1 + J_5$

= 70.03 Ω (10)

And,

(odd impedance) = $Z_0 \cdot (1 - J_5$

= 39.37 Ω (11)

The above (even mode impedances) and (odd mode impedances) are used to calculate the dimension of the practical filter using the simulation software Serenade.

IV. PRACTICAL LAYOUT DESIGN IMPLEMENTATION

The practical design layout can be obtained using the above data. The values of even mode impedance and odd mode impedance is fed to the report editor of the simulation software to obtain W (width) of each parallel lines, L (Length) of each parallel line and S (Spacing) between them. The below figure 4 shows a prototype for a single section coupled line bandpass filter specifying the dimensions:

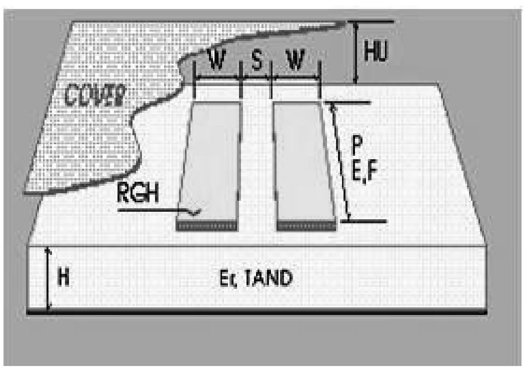

Fig. 4. A prototype for N=1 parallel-coupled line bandpass filter.

The practical layout dimensions obtained using the calculated data are listed below in Table 1.

Table1: Practical dimensions of the filter.

N	ZoJ_N	Zoe (ohm)	Zoo (ohm)	W (mm)	L (mm)	S (mm)
1	0.3066	70.03	39.37	1.47	6.85	0.18
2	0.1112	56.18	45.06	1.78	6.738	0.87
3	0.0934	55.11	45.77	1.8	6.730	1.05
4	0.1112	56.18	45.06	1.78	6.738	0.87
5	0.3066	70.03	39.37	1.47	6.85	0.18

These dimensions are fed into the report editor of the simulation software Serenade to obtain the practical design of the filter in the design editor along with the practical layout dimension. The following figure 5 is the snapshot of the layout design in the design editor along with different physical dimension of the filter:

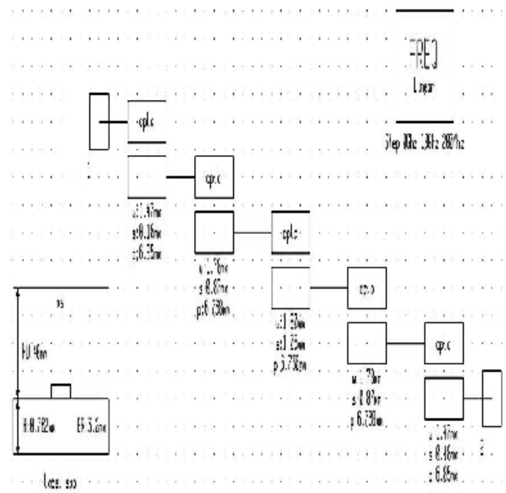

Fig. 5. Layout design of parallel-coupled line bandpass filter with N=5 in design editor of Serenade.

V. FABRICATION OF FILTER

For filter fabrication, double sided coated PCB is used with thickness (h) = 0.762 mm and relative permittivity 3.2. The cover height (HU) of the substrate is 40 mm. The strip width of the micro strip at the input and output terminal is considered to be 0.8 mm in order to have characteristic wave impedance of 50 Ω.

The filter is fabricated utilizing the above simulated data by photolithographic process.

VI. MEASUREMENT RESULTS

Using the above calculated value we designed a parallel-coupled line bandpass filter at 6.93 GHz. The following figure 6 shows the simulated response of the filter by Serenade software.

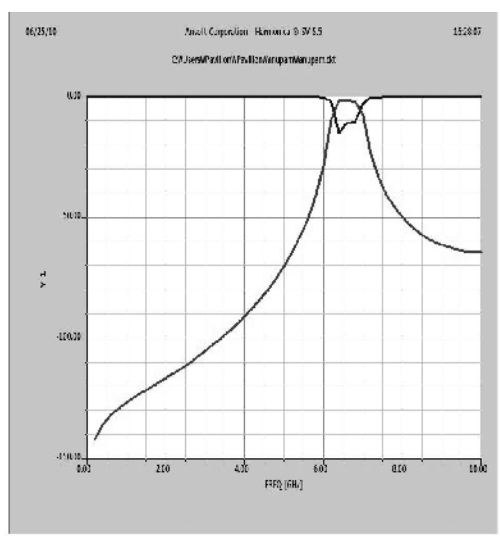

Fig. 6. Simulated response of the parallel-coupled line band pass filter.

From the above response it is evident that the resonant frequency is obtained at the desired frequency 6.93 GHz.

VII. CONCLUSION

On analysis of the simulated result obtained by Serenade it is found that with the above calculated parameters the resonance occurs at the desired frequency 6.93 GHz with reflection losses smaller than –10 dB. The obtained 3 dB bandwidth is approximately equal to 693 MHz which is 10 % of the centre frequency. The insertion loss is approximately -3 dB which can be attributed to tangent loss of the substrate.

When the fabricated filter with the above simulated data is tested with network analyzer, it is found that the 3 dB bandwidth decreases and insertion loss increases which can be attributed to poor feeding of the microstrip filter and co-axial cable losses. The designed filter can be used in C-Band applications.

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