Design of a Low pass filters with Chebyshev approximation using SERENADE and realization of the low pass filters in microstrip

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Abstract : In this paper, Chebyshev microstrip low pass filter of order 5 is designed on substrate, at frequency 5 GHz substrate GML 1000 (lossy) with dielectic constant 3.2 and tangent loss 0.002 was taken. The design and simulation of low pass filters were performed using SERENADE software. Further, filters were fabricated and tested in vector network analyzer.

Keywords: **SERENADE** ***software, Microstrip low pass filter,*** **Chebyshev approximation.**

I. Introduction

Electronic filters are circuits which perform signal processing functions, specifically to remove unwanted frequency components from the signal, to enhance wanted ones, or both. A passive filter consists of passive circuit elements, such as capacitors, inductors and resistors. There are four basic types of filters: Low pass, high pass filter, band pass and band stop filters. Low pass filters are designed to pass all frequencies below the cut off frequencies and reject all frequencies above the cut off. High pass filters are designed to pass all frequencies above the cut off frequencies and reject all frequencies below the cut off. Band pass filters passes all frequencies within a band of frequencies and rejects all other frequencies outside the band. Band stop filters rejects all frequencies within a band of frequencies and passes all frequencies outside the band.

In case of filter design, it is almost impossible to achieve the frequency response of an ideal filters and to overcome this problem, there are five different filter approximations which are used in filter design: Butterworth filter, chebyshev filter, inverse chebyshev filter, elliptical filter and bessel filters approximation. The Butterworth filter is a type of signal processing filter designed to have a frequency response as flat as possible in passband. It is also referred to as a maximally flat magnitude filter.

Chebyshev filters are analog or digital filters having a steeper roll off and more passband ripple (type I) or stopband ripple (type II) than Butterworth filters. Chebyshev filters have the property that they minimize the error between the idealized and the actual filter characteristic over the range of the filters, but with ripples in the passband. Because of the passband ripple inherent in Chebyshev filters, the ones that have a smoother response in the passband but a more irregular response in the stopband are preferred for some application.

An elliptic filter is a signal processing filter with equalized ripple(equi-ripple) behaviour in both the passband and the stopband. The amount of ripple in each band is independently adjustable, and no other filter of equal order can have a faster transition in gain between the passband and the stopband, for the given values of ripple (whether the ripple is equalized or not). Alternatively, one may give up the ability to adjust independently the passband and stopband ripple, and instead design a filter which is maximally insensitive to component variations. As the ripple in the stopband approaches zero, the filter becomes a type I Chebyshev filter. As the ripple in the passband approaches zero, the filter becomes a type II Chebyshev filter and finally, as both ripple values approach zero, the filter becomes a filter. In electronics and signal processing, a Bessel filter is a type of analog linear filter with a maximally flat group/phase delay (maximally linear phase response), which preserves the wave shape of filtered signals in the passband. Bessel filters are often used in audio crossover systems. Our main focus is on Chebyshev filters.

II. Design of Microstrip line low pass filters

Fifth order low pass filters are realized by Chebyshev approximation is assumed which exhibits the equal ripple pass-band and maximally flat stop-band.GML 1000 substrate with height 0.762 mm and dielectric constant 3.2 is taken for the designing of low pass filters. Following gives the element value for low pass Chebyshev filter prototypes with $L_a = 0.03\ dB$.

for given value, $L_a = 0.03\ dB$,we have

$$\beta = \ln\left[\coth\left(\frac{L_a}{17.37}\right)\right] \tag{1}$$

Substituting the value of L_a, $\beta = 6.365$ in eq 2,

$$\gamma = \sin h\ (\beta/2n) \tag{2}$$

Substituting, the value of β and putting n=5 (number of elements), $\gamma = 0.680$ in eq. 3,

$$a_k = \sin[(2k-1)\pi/2n] \tag{3}$$

Substituting for different values of k = 1,2,3,4 and 5.$a_1 = 0.309$,$a_2 = 0.809$,$a_3 = 1$,$a_4 = 0.809$ and $a_5 = 0.309$.For,

$$b_k = \gamma^2 + sin^2\ (k\pi/n) \tag{4}$$

Substituting for different values of k=1,2,3 and 4.$b_1 = 0.807$,$b_2 = 1.3669$,$b_3 = 1.3665$,$b_4 = 0.807$

Now, $g_0 = 1$

$g_1 = 2_{a_1}/\gamma = 0.9088$

For , g_2, g_3, g_4 *and* g_5 ,calculate: $$g_k = 4_{ak-1}a_k/b_{k-1}g_{k-1} \quad (5)$$

$g_2 = 1.36$,$g_3 = 1.74$,$g_4 = 1.36$,$g_5 = 0.9110$ and $g_6 = 1$

Final Inductance and Capacitance calculations:

For Inductance: $$L_n = g_n Z_0/W_c \text{ nH} \quad (6)$$

Where,Z_0 is reference impedance i.e. 50 Ω and W_c is cut of frequency i.e. 5GHz. $W_c = 2\pi f_c = 2 * 3.14 * 5 * 10^9$.

Similarly, for Capacitance: $$C_n = g_n/W_c\, Z_0 \text{ pF} \quad (7)$$

So, by calculations

$L_1 = g_1 Z_0/W_c = 1.44$ nH

$C_1 = g_2/W_c\, Z_0 = 0.86$ pF

$L_2 = g_3 Z_0/W_c$ =2.77 nH

$C_2 = g_4/W_c\, Z_0$ =0.86 pF

$L_3 = g_4 Z_0/W_c$ = 1.44 nH

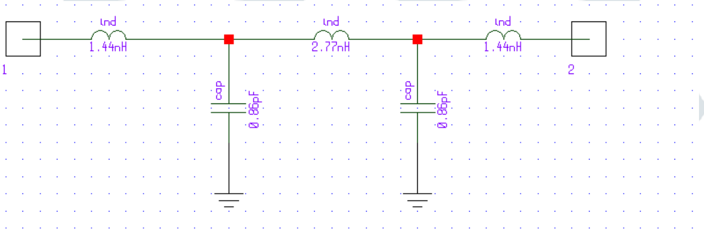

Figure 1:Circuit for low pass filter model (order 5)

III. Realization of the low pass filters with Microstrip lines

We can realize inductor with microstrip line, when the line is thin, it will act as an inductor at high impedance. Similarly, when we increase the width of the microstrip line, then it will act as a capacitor at low impedance. For input & output = 50 Ω line and $w_0 = 1.8\, mm$ (from SERENADE software).

For $Z_L = 120\,\Omega\,(L)$, $w_L = 0.29\, mm$ & $\varepsilon_{eff} = 2.31$ & For $Z_c = 20\,\Omega\,(C)$, $w_c = 6.3\, mm$ & $\varepsilon_{eff} = 2.80$

length for inductor line: $$l_L = \frac{\lambda_H}{2\pi} \sin^{-1}\left(\frac{WL}{Z_L}\right) \quad (8)$$

from eq.8, we get $l_1 = l_5 = 2.42\, mm$ and $l_3 = 5.09\, mm$

length for capacitive line: $$l_c = \frac{\lambda_L}{2\pi} \sin^{-1}(wcZ_c) \quad (9)$$

from eq. 9, we get,$l_2 = l_4 = 4.979\, mm$

IV. Results & discussion

Layout generation can be done in i-cad software for preparing the mask. Once the mask is printed on a transparent sheet, the low pass filters can be fabricated using conventional photolithography process.

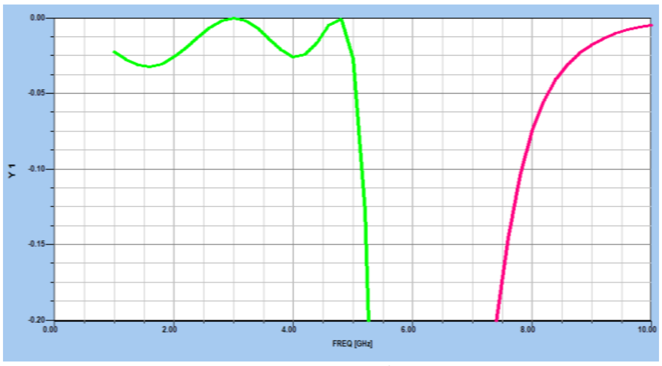

Figure 2: Simulated Microstrip low pass filter model with ripples

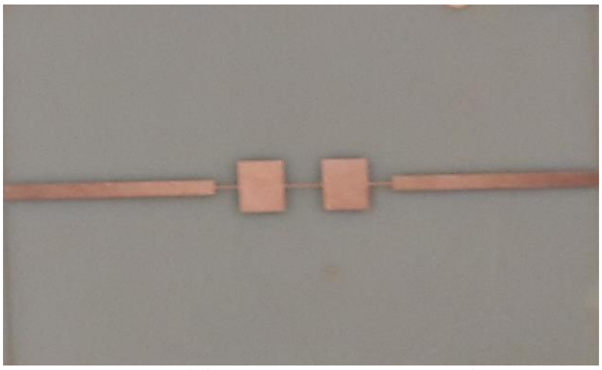

Figure 3: Image of fabricated Microstrip low pass filter model

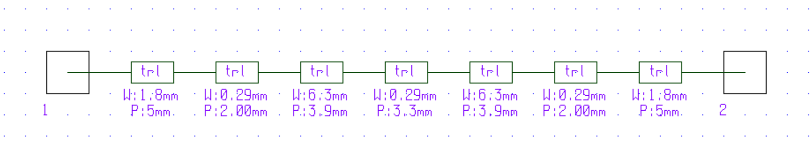

Figure 4: Microstrip low pass filter model designed on SERENADE

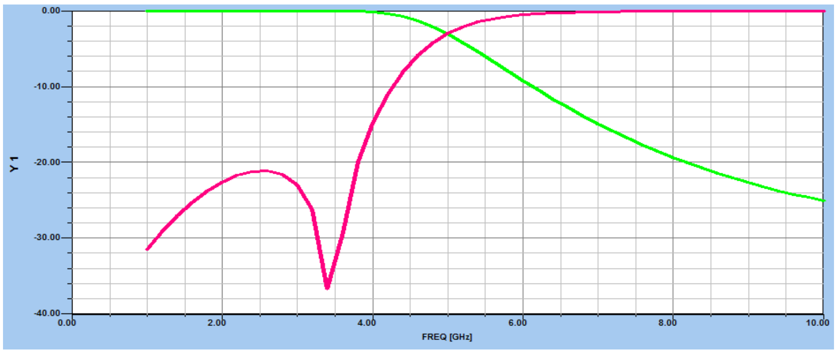

Figure 5: Overall simulated Microstrip low pass filter model (order 5)

The lumped-element low pass filter with above mentioned specifications has been designed using SERENADE software Figure 2 shows the magnified simulated result for microstrip low pass filter model with ripples, as the result shows less ripples in the filters. Figure 3 is the fabricated image of the microstrip low pass filter model and the layout of the model is designed on SERENADE in figure 4. Figure 5 shows the overall result of the microstrip low pass filters for order 5, the intersection shows clearly at 5 GHz frequency, So, the designed filters are working properly.

V. CONCLUSION:

The main aim of this paper is to design and test microstrip low pass filter (printed circuit board of type GML 1000 with dielectric constant 3.2 and thickness of 0.762 mm of double clad coper). The microstrip antenna is designed by SERENADE software on size 50 x 50 (length and width) and 1.7μm (0.017 mm) height. The thin film was obtained with i-cad software followed by the fabrication steps. After fabrication the filters has been tested for S11, S12 and S22 measurement by using a vector network analyser. The test has been conducted for S parameters and comparison is shown between the measured and simulated values.

REFERENCES

[1] Ian C. Hunter, L. Billonet, B. Jarry, and P. Guillon,"Microwave filters application and technology",IEEE transaction on vol.50, issue 3,march 2002.
[2] T. J. Ellis and G. M. Rebeiz, "MM-wave tapered slot antennas on micromachined photonic bandgap dielectrics," in IEEE MTT-S Int. Microwave Symp. Dig., June 1996, pp. 1157–1160.
[3] M. M. Sigalas, R. Biswas, and K. M. Ho, "Theoretical study of dipole antennas on photonic–crystal substrate," Microwave Opt. Technol. Lett., vol. 13, pp. 205–209, Nov. 1996.
[4] M. P. Kesler, J. G. Maloney, and B. L. Shirley, "Antenna design with the use of photonic bandgap material as all dielectric planar reflectors," Microwave Opt. Technol. Lett., vol. 11, no. 4, pp. 169–174, Mar. 1996.
[5] V. Radisic, Y. Qian, R. Coccioli, and T. Itoh, "Novel 2-D photonic bandgap structure for microstrip lines," IEEE Microwave Guide Wave Lett., vol. 8, pp. 69–71, Feb. 1998.
[6] Yablonovitch, "Photonic band-gap structures," J. Opt. Soc. Amer. B, Opt. Phys., vol. 10, pp. 283–295, Feb. 1993.
[7] Y. Qian, F. R. Yang, and T. Itoh, "Characteristics of microstrip lines on a uniplanar compact PBG ground plane," in Asia–Pacific Microwave Conf. Dig., Dec. 1998, pp. 589–592.
[8] Y. Qian and T. Itoh, "Planar periodic structures for microwave and millimeter wave circuit applications," in IEEE MTT-S Int. Microwave Symp. Dig., June 1999, pp. 1533–1536.
[9] Y. Qian, V. Radisic, and T. Itoh, "Simulation and experiment of photonic bandgap structures for microstrip circuits," in Proc. APMC'97, pp. 585–588.
[10] V. Radisic, Y. Qian, and T. Itoh, "Broadband power amplifier using dielectric photonic bandgap structure," IEEE Microwave Guide Wave Lett., vol. 8, pp. 13–14, Jan. 1998.
[11] F. R. Yang, Y. Qian, R. Coccioli, and T. Itoh, "A novel low loss slow-wave microstrip structure," IEEE Microwave Guide Wave Lett., vol. 8, pp. 372–374, Nov. 1998.
[12] K. P. Ma, K. Hirose, F. R. Yang, Y. Qian, and T. Itoh, "Realization of magnetic conducting surface using novel photonic bandgap structure," Electron. Lett., vol. 34, pp. 2041–2042, Nov. 1998.
[13] F. R. Yang, K. P. Ma, Y. Qian, and T. Itoh, "A novel TEM waveguide using uniplanar compact photonic-bandgap (UC-PBG) structure," IEEE Trans. Microwave Theory Tech., vol. 47, pp. 2092–2098, Nov. 1999.
[14] G. L. Matthaei, L. Young, and E. M. T. Jones, Microwave Filters, Impedance Matching Networks and Coupling Structures. Norwood, MA: Artech House, 1980, pp. 217–228.
[15] D. M. Pozar, Microwave Engineering. Reading, MA: Addison-Wesley, 1990, pp. 486–517.
[16] J. I. Park, C. S. Kim, J. Kim, J. S. Park, Y. Qian, D. Ahn, and T. Itoh, "Modeling of a photonic bandgap and its application for the low-pass filter design," in APMC'99 Dig., pp. 331–334.