Design and testing of Chebyshev micro strip low pass filters at mm wave frequency

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Abstract : In this paper we have designed chebyshev microstrip low pass filter at the millimetre wave frequency (5 GHz) with GML 1000 (lossy) substrate. The dielectric constant 3.2 and tangent loss 0.002 was taken to design and simulated using CST MW studio software. Further, low pass filters were fabricated and tested with measurement results were compared and represented in terms of S11, S21 and S22 parameters.

IndexTerms - CST MW studio software, Microstrip low pass filter, **Chebyshev approximation.**

I. Introduction

Filters circuits usually performs signal processing functions, categorically to get rid of unwanted frequency components from the signal, to strengthen wanted ones, or both. Passive filters subsist of passive circuit elements, like resistors, capacitors and inductors. Low pass, high pass filter, band pass and band stop filters are four basic types of filter,where,low pass filters are intended to pass by all frequencies under the cut off frequencies and turn down all frequencies beyond the cut off, high pass filters are simply designed to pass frequencies above the cut off and reject all frequencies below the cut off, band pass filters allows all frequencies inside a band of frequencies and exclude all other frequencies outside the band,whereas,band stop filters rejects all frequencies inside a band of frequencies and allows 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. Butterworth filters are signal processing filters which is constructed to have a frequency response as flat in passband. It is also attributed as to a maximally flat magnitude filter.

Chebyshev filters have steeper roll off and more passband or stopband ripple than Butterworth filters, it has property to minimize the fault among the idealized and actual filter characteristic over the range of filters, with ripples in the passband. Because of the passband ripple built-in in Chebyshev filters, offers easy response in the passband and random response in the stopband .

An elliptic filter is a signal processing filter with equi-ripple behaviour in passband as well as stopband. Whether the ripple is even up or not, or whatever be the value of ripple, it gets individually adapted, and no other filters of same order can have speed transition in gain both for passband and stopband. Preferably, in place of constructing a filter with maximally insensitive to component variations one may has ability to adjust independently stopband and passband ripples .Ripples in stopband approaching towards zero, the filter is type I Chebyshev filter and when passband towards zero then it is type II Chebyshev filter.

II. Layout of Microstrip line low pass filters

Low pass filters of order 5 are executed by Chebyshev approximation that shows 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 $L_a = 0.03\ dB$.

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

$$\gamma = \sin h\left(\frac{\beta}{2n}\right) \quad (2)$$

For $L_a = 0.03\ dB$,value of β and γ is 6.365 and 0.680,respectively calculated from equation 1 & 2.

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

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

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

Substituting values of k=1,2,3 and 4, $b_1 = b_4 = 0.807$ and $b_2 = b_3 = 1.3669$.To calculate the elements, we have

$$g_0 = 1 \quad (5)$$

$$g_1 = 2_{a_1}/\gamma \quad (6)$$

For , g_2, g_3, g_4 *and* g_5 ,

$$g_k = 4_{ak-1}a_k/b_{k-1}g_{k-1} \quad (7)$$

From equation 5,6 and 7, we get

g_0	g_1	g_2	g_3	g_4	g_5	g_6
1	0.9088	1.36	1.74	1.36	0.9110	1

Final Inductance and Capacitance calculations represented in eq 8 and 9, where, Z_0 is reference impedance i.e. 50 Ω and W_c is cut of frequency i.e. 5GHz. $W_c = 2\pi f_c = 2 * 3.14 * 5 * 10^9$.

$$L_n = g_n Z_0 / W_c \text{ nH} \tag{8}$$

$$C_n = g_n / W_c Z_0 \text{ pF} \tag{9}$$

So, depending upon the elements value of inductor and capacitor are calculated as,

Inductor and capacitor	Related formula	Values
L_1	$g_1 Z_0/W_c$	1.44 nH
C_1	$g_2/W_c Z_0$	1.22 pF
L_2	$g_3 Z_0/W_c$	2.77 nH
C_2	$g_4/W_c Z_0$	1.22 Pf
L_3	$g_4 Z_0/W_c$	1.44 nH

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 a 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 CST 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 is given as:

$$l_L = \frac{\lambda_H}{2\pi} \sin^{-1}\left(\frac{WL}{Z_L}\right) \tag{10}$$

From eq. 10, $l_1 = l_5 = 2\ mm$ and $l_3 = 2.5\ mm$.
Length for capacitive line is given as:

$$l_c = \frac{\lambda_L}{2\pi} \sin^{-1}(wcZ_c) \tag{11}$$

From eq. 11, $l_2 = l_4 = 3.8\ mm$. 1.85 0.29 6.3

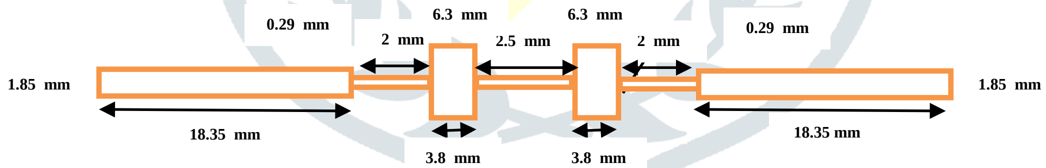

Figure 1:Mictrostrip low pass filter model

IV. Mask making and filter fabrication

Mask can be prepared on i-cad software and printed on a transparent sheet, the patch can be fabricated using photolithography process. The fabrication process are as follows:

Step 1: Thoroughly clean the petri dishes and beakers.
Step 2: Clean the substrate (50.8 x 50.8) mm with detergent using cotton.
Step 3: Apply the photoresist and spin it for 1 min. in controlled speed.
Step 4: Bake the substrate in oven at 100 deg. Celsius for 5-10 min.
Step 5: Allow the substrate to cool.
Step 6: Align the mask with coated substrate.
Step 7: Exposure under UV light for 1-2 minutes
Step 8: Develop the pattern for 45-60 sec in ferric chloride and acetone.
Step 9: Apply the dye and wash the excess die under running water.
Step 10: Put the substrate in oven for post baking.
Step 11: Proceed for chemical etching.

V. Results and Discussion

The lumped-element low pass filter with above mentioned specifications has been designed using CST software Figure 3,4 and 5 shows result for comparison of S11,S21 and S22 for microstrip low pass filter in CST software values and fabricated values at

5GHz.For practical measurement of return loss of the designed microstrip low pass filters was connected to vector network analyser through co-axial cable. From the result on VNA, it is clear that at 5GHz frequency the return losses are below -35 dB i.e. very close to the simulated values. So, the designed filters is working properly.

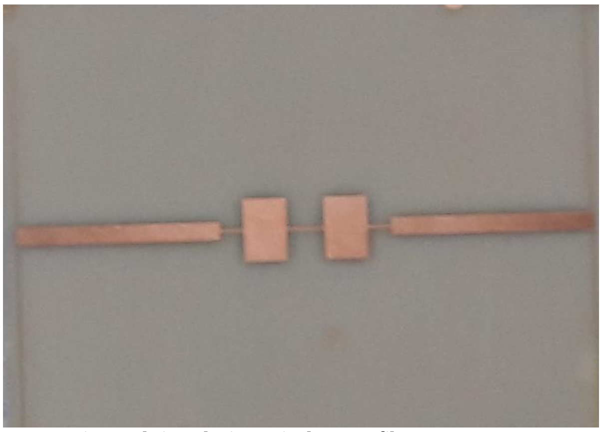

Fig 2: Fabricated microstrip low pass filter

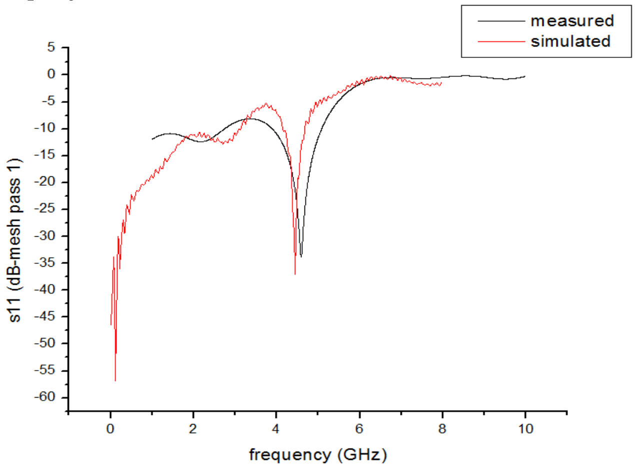

Fig 3: Comparison of S11 for measured and simulated values at 5 GHz

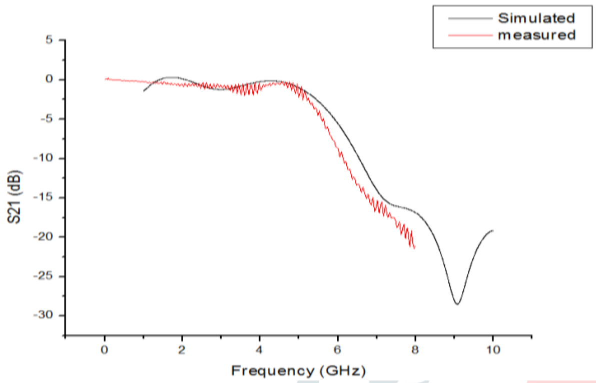

Fig 4: Measured and simulated values of S21 at 5 GHz

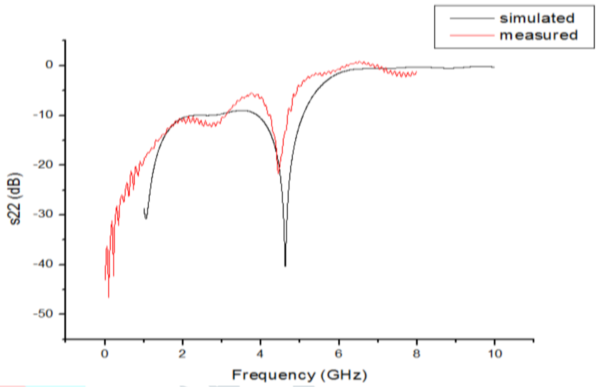

Fig 5: Measured and simulated values of S22 at 5 GHz

VI. CONCLUSION:

In this paper we have designed and tested microstrip low pass filter with dielectric constant 3.2 and thickness of 0.762 mm of double clad coper. The layout is designed by CST 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 VNA. The test has been conducted for S parameters and comparison is shown between the measured and simulated values in the result section.

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