Design of Stepped-Impedance Microstrip Line Low Pass Filter for Wireless Communication

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***Abstract*— Filters play an important role in microwave applications.Microwave systems have an enormous impact on modern society. Applications are diverse, from entertainment via satellite television, to civil and military radar system. In particular, the recent trend of multi-frequency bands and multi-function operations in wireless communication systems along with the explosion in wireless portable devices are imposing more stringent requirements such as size reduction tunability or reconfigurability enhancement and multiband operations for microwave circuits. This paper describes about the design of stepped-impedance microwave low pass filter by using Microstrip layout which works at 3.7 GHz for permittivity 4.4 value with a substrate thickness 1.6 mm for order n=3. The stepped-impedance low pass filter have a pass band ripple 0.1 dB. The development of the Microstrip filters are simulated by using IE3D simulator software.**

***Index Terms*— Low pass Filter, Dielectric Constant, Microstrip filter, Millimeter wave filter.**

I. INTRODUCTION

In a microstrip filters that we are trying to achieve are to have an exact center frequency, good bandwidth and low return loss level. There are no active devices to add uncertainty to the fabricated results. The filters are one of the primary and necessary components of a microwave system.

Microstrip line is a good candidate for filter design due to its advantages of low cost, compact size, light weight, planar structure and easy integration with other components on a single circuit board. Conventional filter structures like equal ripple and butterworth low pass filters are requirement of special fabrication methods. Conventional low frequency techniques for fabrication does not fit at these frequencies due to the very high losses associated. Although microstrip is not the highest performance filter technology, still it is the preferred choice in many thin-film on ceramic and printed circuit board applications. RF pre-selector filters, image rejection filters, local oscillator (LO) filters and intermediate frequency (IF) filters can all be realized in microstrip. The recent advance of novel materials and fabrication technologies, including monolithic microwave integrated circuit (MMIC), microelectromechanic system (MEMS), micromachining, high-temperature Superconductor (HTS), and low-temperature co fired ceramics (LTCC), has simulated the rapid development of new microstrip and other filters.

In this paper, filter is optimized for high performance and an efficient. Microstrip technology is used for simplicity and ease of fabrication. The design and simulation are performed using 3D full wave electromagnetic simulator IE3D. This filter is widely used today in radar, satellite and terrestrial communication applications.

II. MICROSTRIP FILTER DESIGN

The design of low pass filter involves two main steps. The first one is to select an appropriate low pass prototype. The choice of the type of response, including Pass band ripple and the number of reactive elements will depend on the required specifications. The element values of the low pass prototype filters, which are usually normalized to make a source impedance go = 1 and a normalized frequency Ωc = 1.0, are then transformed to the L-C elements for the desired cutoff frequency and the desired source impedance, which is normally 50 ohms for microstrip filters. The next main step in the design of microstrip low pass filters [3] is to find an appropriate micro strip realization that approximates the lumped element filter. The element values for the low pass prototype with Chebyshev response at pass band ripple factor L_{AR} = 0.1 dB, characteristic impedance source/load Zo = 50 ohms, are taken from normalized values g_i i.e. g_1, g_2, g_3, g_4......, g_n. The filter is assumed to be fabricated on a substrate of dielectric constant ε_r and of thickness h mm. for Angular

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(normalized) cutoff frequency Ω_c, using the element transformation[1].

The filter design steps are as follows:

1.Determine the number of sections from the specification characteristics for microstrip parameters.

Filter Specifications:

Relative Dielectric Constant, $\epsilon_r = 4.4$

Cut-off frequency, fc = 3.7 GHz

Height of substrate, h = 1.6 mm

The substrate used –

The loss tangent $\tan\delta = 0.02$

$Z_o = 50\,\Omega$

$\Omega_c = 1$

2. Determine the values of the prototype elements to realize the specifications. Also we have taken the element value for low pass from table 3.2[1] for n=3.

$L_i = (Z_o/g_o)\,(\Omega_c/2\pi f_c)\,g_i$ .... (1)

$C_i = (g_o/Z_o)\,(\Omega_c/2\pi f_c)\,g_i$ .... (2)

$l_L = \lambda_{gl}/2\pi \,\mathrm{Sin}^{-1}(\omega_c L_i / Z_{OL})$............... (3)

$l_C = \lambda_{gc}/2\pi \,\mathrm{Sin}^{-1}(\omega_c C_i\, Zoc)$.................... (4)

3.To calculate the width of capacitor and inductor we use the following formula

$W/h = 8\exp(A)/(\exp(2A)-2)$ .... (5)

Where $A = Zc/60\,\{(\varepsilon r+1)/2\}^{0.5} + (\varepsilon r+1)/(\varepsilon r-1)\{0.23+0.11/\varepsilon r\}$ .... (6)

Where $Zc = \eta / 2\pi\sqrt{\varepsilon re}\,[\ln(8h/w + 0.25\,w/h)]$ .... (7)

Where $\eta = 120\,\pi$ ohms is the wave impedance in free space.

4. The effective dielectric constant can be found by the following formula

$\varepsilon_{re} = (\varepsilon_r+1)/2 + (\varepsilon_r-1)/2\,[(1+12h/W)^{-0.5}]$...... (8)

5. Effective wavelength is also found as

$\lambda_{ge} = 300/(6\sqrt{\varepsilon_{ree}})$ .... (9)

TABLE I

DIMENSIONS FOR A STEPPED-IMPEDANCE LOW PASS FILTERS (FOR N=3)

S.No.	Dimension	Value
1.	Microstrip line width in mm	W_C=7.027,W_O=3.059, W_L= 1.707
2.	Characteristic impedance in ohm	Z_{OC} = 20,Z_O = 50, Z_{OL} = 60
3.	Effective dielectric constant	$(\varepsilon re)_C$ = 3.5799, $(\varepsilon re)_O$ = 3. 381, $(\varepsilon re)_L$ = 2.9846

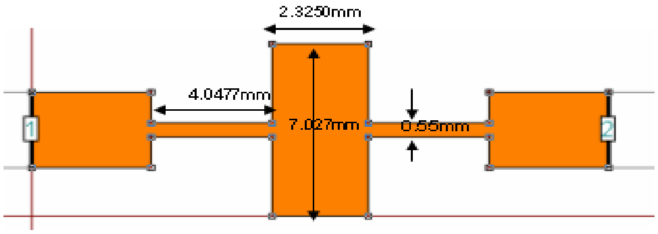

Fig.1. Layout of a 3-pole, stepped- impedance Microstrip low pass filter on a substrate with εr= 4.4and h = 1.6 mm at 3.7 GHz frequency.

III.SIMULATION RESULTS

In order to verify the validity of the above expressions in millimeter wave regime, a simulation study was performed using IE3D. To get the exact response for our purpose, an optimization was performed using software. The design of the filter is completed, the layout of the filter is given in figure 1 with all the determined dimensions. Figure 2 shows the EM simulated performance of the filter.

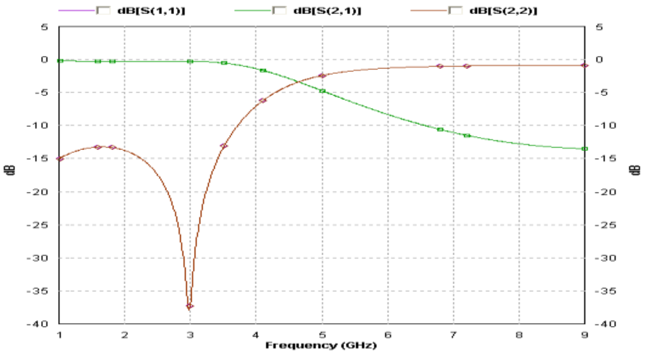

Fig.2. Full-wave EM simulated performance of the stepped-impedance low pass filter for n = 3 at 3.7 GHz.

IV. RESULTS & ANALYSIS

The Simulated filter as shown in Figure 1 and 2 shows the geometry & response of low pass filters for n=3.The graph is plotted by taking gain (dB) on the Y-axis and frequency in GHz on the X-axis. From the graph it is clear that the cut-off frequency is found to be 2.3 GHz for stepped-impedance low pass filter. Hence the stepped-impedance low pass filter is capable of passing the frequency less than 3.7 GHz & rejects the frequency after 3.7GHz for the thickness of the substrate 1.6mm and also has the return loss performance up to -38 dB.

V. CONCLUSION

The filters are one of the primary and necessary components of a microwave system and they are the very essential part of the microwave system, not only in microwave are they very important in communication field. Any communication system cannot be design without filters. Low pass filter must be included at the transmitting end and the receiving end of the system to get desired spectrum. In conclusion, the authors believe that the design can be archived compact filter design. The measured characteristics of the filter agree with the theoretical simulations. The conventional geometry of the stepped-impedance low pass filter, shown in figure 1 and the simulated response of the conventional geometry shown in figure 2.The symmetrical approach tends to produce a more compact filter with less coupling effect in its realization. Its compact nature minimizes required space for realization and is suitable for integration within Wireless system. The most efficient way in order to obtain a filter with maximum size reduction is by using the microstrip technique in which each filter's lumped component is realized as microstrip transmission line.

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