IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

FIVE POLE OPTIMUM DISTRIBUTED HIGH PASS MICROWAVE FILTER: DESIGN ANALYSIS AND SIMULATION ON MICROSTRIP AT 2.4 GHZ

Atul Makrariya*, P. K. Khare
Department of Postgraduate studies and Research in Physics & Electronics, Rani Durgawati University, Jabalpur, (M.P.), India

DOI: 10.5281/zenodo.60835

ABSTRACT

This paper presents a frequency responsive design of an optimum distributed high pass filter having a cutoff frequency fc = 2.4 GHz and a 0.1 dB ripple passband up to 10.4 GHz with Z0 = 50 ohm. This presents a novel design of Chebyshev HPF prototype with substrate thickness 1.6 mm, strip thickness 0.035 mm, FR4 substrate relative permittivity is 4.4 and dielectric loss tangent 0.02. The simulated results for the filter are in good concurrence. The analysis of the High pass planar filter is performed using the Ansoft's HFSS simulator. Snapshots of the simulation and the graphical results obtained are shown in the paper.

KEYWORDS: High pass filter, microstrip, attenuation, insertion loss, stepped impedance.

INTRODUCTION

High pass filters are widely used component for microwave applications. Filters are frequency selective elements. A network that is designed to attenuate certain frequencies but pass others without loss is called a "filter". Microstrip is a type of electrical transmission line, which can be fabricated using printed circuit board [PCB] technology, and is used to convey microwave-frequency signal. Stepped impedance consists of high and low impedance transmission lines in cascaded structure. The high-impedance lines act as series inductors and the low-impedance lines act as shunt capacitors. It consists of a conducting strip separated from a ground plane by dielectric layer known as the substrate. .The filtering behaviour results frequency dependent reactance providing by inductors and capacitors. Microstrip is much less expensive than traditional waveguide technology, as well as being far lighter and more compact. For lowest cost, microstrip devices may be built on an ordinary FR-4 (standard PCB) substrate using insertion loss method. The insertion loss method, however, allows a high degree of control over the passband and stopband amplitude and phase characteristics, with a systematic way to synthesize a desired response. The necessary design trade-offs can be evaluated to best meet the application requirements. a Chebyshev response would satisfy a requirement for the sharp cutoff and in all cases, the insertion loss method allows filter performance to be improved in a straightforward manner, at the expense of a higher order fllter. For the filter prototypes to be discussed below, the order of the filter is equal to the number of reactive elements.

Highpass filters constructed from quasilumped elements may be used in many applications, provided that these elements can achieve good approximation of desired lumped elements over the entire operating frequency band. Care should be taken when design this type of filter because as the size of any quasilumped element becomes comparable with the wavelength of an operating frequency, it no longer behaves as a lumped element. The simplest form of a highpass filter may just consist of a series capacitor, which is often found in applications for direct current or dc block. For more selective highpass filters, more elements are required. This type of highpass filter can be easily designed based on a lumped-element lowpass prototype.

Microstrip RF filters are commonly used in receivers and transmitters operating in 800 MHz to 30 GHz frequency range. In general, the design of microstrip lowpass filters involves two main steps [1] .The first one is to select an appropriate Highpass prototype. The choice of the type of response, including passband ripple and the number of reactive elements, will depend on the required specifications. The desired source impedance is normally 50 ohms for microstrip filters. Having obtained a suitable lumped-element filter design, the next main step in the design of microstrip Highpass filters is to find an appropriate microstrip realization that approximates the lumped element filter [1]. In this paper, a design of prototype Highpass filter and its implementation to microstrip line is done and frequency responses are analyzed.

Design Analysis: The transfer function of a two-port filter network is a mathematical expression of S_{21}. An amplitude-squared transfer function for a lossless passive filter network is defined as [2]

$$|S_{21}(j\Omega)|^2 = \frac{1}{1+\mathrm{F}_n^2(\Omega)\varepsilon^2} \qquad 1$$

Where ε is ripple constant. It is related to a given pass band ripple L_{AR} in dB by

$$\varepsilon = \sqrt{10^{LAR/10} - 1} \qquad 2$$

$T_n(\Omega)$[3], is a Chebyshev function of the first kind of order n , given as

$$T_n(\Omega) = \begin{cases} \cos(n\cos^{-1}\Omega) & \Omega \le 1 \\ \cosh(n\ \cos^{-1}\Omega) & \Omega \ge 1 \end{cases} \qquad 3$$

The element value of Chebyshev High pass filter may be computed using equations. For designing an optimum distributed 5 pole high pass filter having a cutoff frequency f_c = 2.4 GHz and a 0.1 dB ripple passband up to 10.4 GHz with Z_0 = 50 ohm, the the electrical lengthθ_c can be found from

$$\left(\frac{\pi}{\theta_c} - 1\right) f_c = 10.4\ GHz \qquad 4$$

So, $\theta_c = 33.75^0$

Here the number of poles are five so, n = 5 i.e. the filter is designed with five shorted-circuited stubs. we could choose the element values for n = 5 and $\theta_c = 33.75^0$ °, which will gives a wider passband, up to 10.4 GHz, because the smaller the electrical length at the cutoff frequency, the wider the passband. Alternatively, we can find the element values for $\theta_c = 33.75^0$ by interpolation from the element values presented in the table. As an illustration, for n = 5 and $\theta_c = 33.75^0$, the element value y_1 is calculated as follows:

$$y_5 = y_1 = 0.34252 + \left(\frac{0.46895-0.34252}{35^0 - 30^0}\right) X\ (33.75^0 - 30^0)$$

So,

$$y_5 = y_1 = 0.43734$$

$$y_{1,2} = y_{4,5} = 1.07119 + \left(\frac{1.02790-1.07119}{35^0 - 30^0}\right) X\ (3.7^0)$$

$$y_{1,2} = y_{4,5} = 1.03872$$

Similarly,

$$y_2 = y_4 = 0.60563$$

$y_{2,3} = y_{3,4} = 1.01187$

$y_3 = 0.66389$

These interpolated element values are well within one percent of directly synthesized element values.

The filter is supposed to be doubly terminated by Z_0 = 50 ohms. The characteristic impedances for the line elements are:

$Z_i = \frac{Z_0}{y_i}$ 5

$Z_{i,i+1} = \frac{Z_0}{y_{i,i+1}}$ 6

$Z_1 = Z_5 = 114.33\ \Omega$

$Z_2 = Z_4 = 82.56\ \Omega$

$Z_3 = 75.31\ \Omega$

$Z_{1,2} = Z_{4,5} = 48.14\ \Omega$

$Z_{2,3} = Z_{3.4} = 49.42\ \Omega$

Electrical length $\theta_c = 33.75^0$.

Physical Length of stub $= (\frac{\theta_c}{360^0})$ x λg 7

$= (\frac{33.75}{360^0})$ x (3 x 10^8 / 2.4 x 10^9 x 4.4 $^{1/2}$)

= 5.59 mm

Electrical length of connecting line = 2 θ_c 8

$= 67.5^0$

Physical length of connecting lines

$= (\frac{\theta_c}{360^0})$ x λg 9

= 11.17 mm

Simulation: The microstrip line structure is shown in Figure 1. The High Pass Filter structure has 5 poles, which are connected to each other. The microstrip line computed for a characteristic impedance Z_0 = 50 ohm, is on the top. The filter is realized in microstrip on a substrate with a relative dielectric constant of 4.4 and a thickness of 1.6 mm. The initial dimensions of the filter can be easily estimated by using the microstrip design equations [9], for realizing these characteristic impedances and the required electrical lengths at the cutoff frequency, namely, $\theta_c = 33.75^0$ for all the stubs and $2\theta_c$ = 67.5° for all the connecting lines. The final filter design with all the determined dimensions is shown in Figure 1,

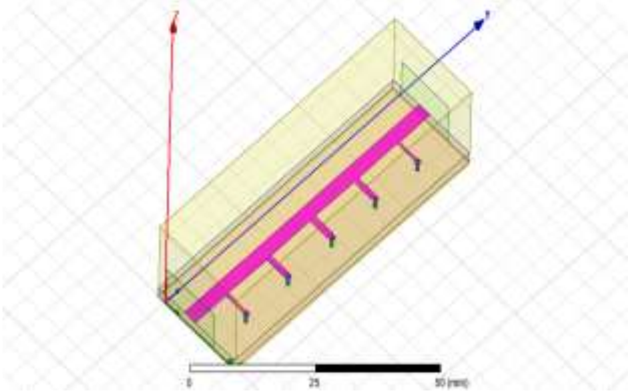

Fig. 1 Layout of a 5 pole stepped impedance Microstrip High pass filter

RESULT AND DISCUSSION

The optimized HPF was fabricated on a substrate with a relative dielectric constant ε_r of 4.4 and thicknesses 1.6 mm. Measurements were carried out on an HFSS simulator[7]. The filter components have been drawn using copper conductor on a double side printed FR4 substrate (22.00 mm x 66.768mm) of thickness 1.6 mm and permittivity 4.4. The ground plane has been laid at the bottom of the substrate. The filter has been set up for a sweep frequency of 2 GHz in a sweep range of 1GHz - 10 GHz with lumped port input fed to two ports and simulated. The simulated HPF has a 3dB cutoff frequency at 2.4 GHz.

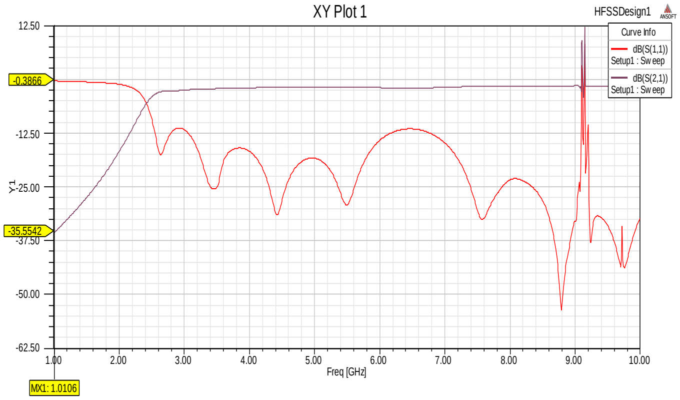

Fig. 2 Curve $S_{1,1}$ & $S_{2,1}$ Vs Frquency

The simulated S parameters of the conventional HPF as a function of frequency are shown in Figure 2. The reflection loss value lies well below -10 dB with a deep upto -50 dB at 2.4 GHz indicating a good matching at the port. From the transmission properties it can be found that a roll-off takes place after cut-off frequency (2.4 GHz). Figure 2 shows the return loss S_{11} and insertion loss S_{21} behaviour of LPF at 2.4 GHz and it is clear that it gives a sharp cutoff at 2.4 GHz.

CONCLUSION

This paper describes design and simulation for a HPF structure. Method of moment is applied to simulate the fields and currents distribution of the design. The results of full wave electromagnetic analyses are in good agreement and an optimal structure of the HPF plane structure is determined. Better transmission and reflection characteristics have been obtained without compromising the size. Good reflection and transmission loss in the pass and stop bands are the advantages in this filter.

REFERENCES

[1] Hong, Jia-Sheng and Lanchester, M.J. (2001). "Microstrip Filters for RF / Microwave Applications" USA: John Wiley & Sons, Inc.
[2] J. D. Rhodes, Theory of Electrical Filters, Wiley, New York, 1976.
[3] J. Helszajn, Synthesis of Lumped Element, Distributed and Planar Filters, McGraw- Hill, London, 1990.
[4] S. Darlington, "Synthesis of reactance-four-poles which produce prescribed insertion loss characteristics," J. Math. Phys., 30, 257–353, Sept. 1939.
[5] R. Saal and E. Ulbrich, "On the design of filters by synthesis," IRE Trans., CT-5,284–327, Dec. 1958.
[6] G. Mattaei, L. Young, and E. M. T. Jones, Microwave Filters, Impedance-Matching Networks, and Coupling Structures, Artech House, Norwood, MA, 1980.
[7] Maksim Berezin, HFSS Training (overview) Course "Antennas and Radiation". Ben- Gurion University, 2007.
[8] J. S. Wong, Microstrip tapped-line filter design, IEEE Trans., MTT-27, 1, 1979, 44–50.
[9] E. O. Hammerstard, Equations for microstrip circuit design, 1975, Proceedings of the European Microwave Conference, Hamburg, Germany, pp. 268–272.
[10] I. J. Bahl and R. Garg, Simple and accurate formulas for Microstrip with finite strip thickness, 1977, proceeding of IEEE, 65, 1611–1612.
[11] R. Levy, "A new class of distributed prototype filters with applications to mixed lumped/distributed component design," *IEEE Trans., MTT-18,* December 1970, 1064 – 1071.