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COMPACT DESIGN AND SIMULATION OF LOW PASS MICROWAVE FILTER ON MICROSTRIP TRANSMISSION LINE AT 2.4 GHZ

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Abstract (10pt)

This paper presents a frequency responsive 5 pole microstrip Low Pass filter at 2.4 GHz with Z_0 = 50 ohm and passband ripple L_{AR} = 0.04321dB. This presents a novel design of Chebyshev LPF 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 and shows cutoff at 2.4 GHz. In this filter with changing every high or low impedance characteristics such as length or width desired characteristics can be rich and the simulation and analysis of the low 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. Design with making by the micro strip technology, it becomes practical. This Filter has less complexity rather than other filters.

Keywords:
Microwave filter,
micro strip**,**
attenuation,
insertion loss,
stepped impedance.

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1. Introduction:

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. It consists of a conducting strip separated from a ground plane by dielectric layer known as the substrate. Lowpass filters are widely used component for microwave applications. 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. 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. Microstrip lines are also used in high-speed digital PCB designs, where signals need to be routed from one part of the assembly to another with minimal distortion, and avoiding high cross talk and radiation. The width of the strip, the thickness of the substrate and the relative permittivity of the substrate determine the characteristic impedance of the strip, which is a transmission line. Most communication systems require an RF front end, where RF filters and low noise amplifiers perform analog signal processing. Microstrip RF filters are commonly used in receivers and transmitters operating in 800 MHz to 30 GHz frequency range.

Stepped impedance lowpass filter are widely used in many RF/microwave applications. In general, the design of microstrip lowpass filters involves two main steps[1] .The first one is to select an appropriate lowpass 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 lowpass filters is to find an appropriate microstrip realization that approximates the lumped element filter[1]. In this paper, a design of prototype lowpass filter and its implementation to microstrip line is done and responses are analyzed.

2.Design Analysis :

The transfer function of a two-port filter network is a mathematical description of network response characteristics, namely, a mathematical expression of S_{21}.

An amplitude-squared transfer function for a lossless passive filter network is defined as[2]

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

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 low pass filter may be computed using equations. Low pass filter whose element value are normalised to make the source resistance equal to one i.e. g_0 = 1.So g_i for i = 1 to n represent either the inductance of a series inductor or the capacitance of a shunt capacitor, so n, is also the number of reactive element.

If g_1 is the shunt capacitor or series inductor than g_0 define as source resistance or source conductance and if g_1 is the shunt capacitor or series inductor, g_{n+1} is the load resistance or load conductance.

So g_i can be calculated for Chebyshev low pass prototype filter [4.6], using following formula:

$$g_0 = 1.0 \qquad 4$$

$$g_1 = (2 / \gamma) \sin(\pi / 2n) \qquad 5$$

γ is the complex propagation constant.

$$g_i = \frac{1}{g_{i-1}} 4 \sin \frac{\frac{(2i-1)\pi}{2n} . \sin\frac{(2i-3)\pi}{2n}}{\gamma^2 + \sin^2[\frac{(i-1)\pi}{n}]} \quad 6$$

for i = 2,3,4........n.

$$g_{n+1} = \begin{cases} 1 & for\ n\ odd \\ coth^2\left(\frac{\beta}{4}\right) & for\ n\ even \end{cases} \quad 7$$

Where $\beta = \ln [\coth \frac{LAR}{17.37}]$ 8

$\gamma = \text{Sinh } (\frac{\beta}{2n})$ 9

γ is the complex propagation constant and β is the phase constant. So by the table for prototype for L_{AR} = 0.04321dB [1] we get:

$g_1 = g_5 = 0.9714$

$g_2 = g_4 = 1.3721$

$g_3 = 1.8014$

$g_0 = g_6 = 1 = R$

2. <u>Simulation</u>

The microstrip line structure is shown in Figure 1. The Low 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. In the simulation, we used a FR4 substrate with a relative dielectric constant of 4.4 and a thickness of h = 1.6 mm. The simulated structure shows the microstrip structure of five-pole low-pass filter.

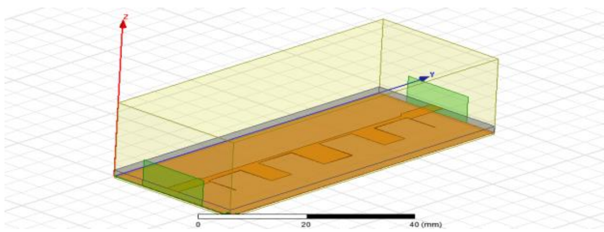

Fig. 1 Layout of a 5 pole stepped impedance Microstrip Low pass filter

3. Result and Discussion:

The optimized LPF was fabricated on a substrate with a relative dielectric constant ϵr 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 (30.00 mm x 71.288mm) 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 1 - 5 GHz with lumped port input fed to two ports and simulated. The simulated LPF has a 3dB cutoff frequency at 2.4 GHz .

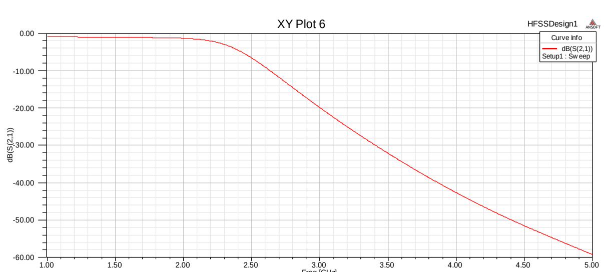

Fig. 2 Curve $S_{2,1}$ Vs Frequency

The simulated S parameters of the conventional LPF 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 the passband ripple varying between -1 and -4 and a roll-off takes place after cut-off frequency (2.4 GHz). Figure 3 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.

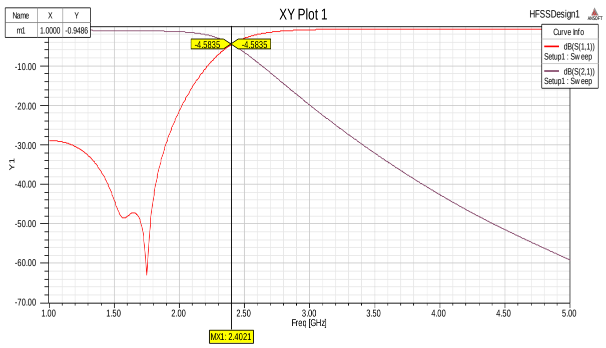

Fig. 3 Full-wave EM simulated Frequency response of LPF at 2.4 GHz

One another important filter parameter is group delay figure 4 shown below. The group delay is the measure of the time delay of the frequency spectrum of a signal and given as $\tau_g = \frac{\Delta\Psi}{\Delta\omega}$. The group delay can also be defined as the rate of change of transmission phase angle with respect to frequency. Mathematically group delay can be expressed as where, Δφ is change in phase angle of |S21| in radians and Δω, is the change in frequency. It is always desirable to have a minimum and uniform group delay so as to achieve minimum signal distortion. We observe a fine group delay up to 2.4 GHz

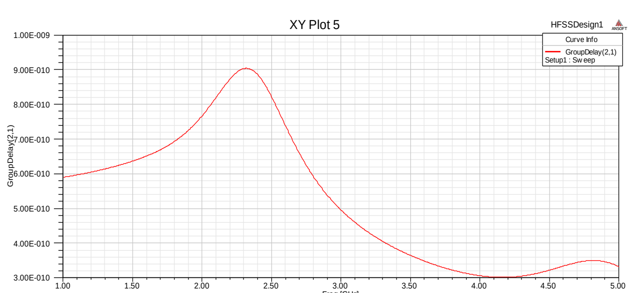

Figure 4. Group delay

5.Conclusion:

This paper describes design and simulation for a LPF structure. The structure with stop-band Characteristic for broadband harmonic rejection tuning has been shown. 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 LPF 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.

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