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Design and Implementation of 0.5dB Chebyshev Low Pass Filter for L-Band Application

Shraddha Jadhav[1], Swati Misal[2], Abhilasha Mishra[3], Anita Murugkar[4]
[1]*M.Tech. Student, Dept. of Electronics &Telecommunication, Maharashtra Inst. of Tech., Aurangabad, India*
[2]*Ph.D. Student, Department of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India*
[3]*Associate Professor, Dept. of Electronics &Telecommunication, Maharashtra Inst. of Tech., Aurangabad, India*
[4]*Associate Professor, Dept. of Physics, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India*

***Abstract*: Life cannot be imagined without wireless communication. Almost all communication systems contain a RF front end which performs signal processing using filters. Microstrip filter play an important role in various L-Band applications. Stepped impedance lowpass prototype filter is the method used to design microstrip filter. For stepped impedance filter design, alternate low and high characteristic impedance lines are used. This paper describes the design of L-band low pass filter by using microstrip layout operating at 2 GHz for permittivity 2.2 with a substrate thickness 0.762 mm for order n=5. For simplicity and ease of fabrication of this filter microstrip technology is used. The design and simulation are performed using CST microwave studio software. The filter has a center frequency of 2GHz with covering the frequency range from 0 GHz to 2GHz. This filter is widely used today in radar, satellite and terrestrial communication applications.**

***Keywords*: Low pass Filter; Dielectric Constant; Butterworth low pass filter; Chebyshev low pass filter; Stepped Impedance Configuration; Microstrip filter.**

1. Introduction

Filters play an important role in most of the RF and microwave communication systems. Particularly Lowpass filters are used in many millimeter-wave and microwave systems to pass the desired low frequencies below cut off and reject the higher frequencies. Microstrip structured filters are popular due to compact size, low insertion loss, and ease of fabrication along with integration with other components [1]. These microstrip filters are simpler to design and offer better stop band characteristics [2].

The design of stepped impedance microstrip structure is based on the insertion loss method which allows high degree of control over the passband amplitude and phase characteristic. The goal is to achieve high accuracy in obtaining the desired cut-off frequency and return loss [3]. The sharper transition between the pass and stop band of a chebyshev filter produces smaller absolute errors and faster execution speed than a butterworth filter. Chebyshev filters are used where the frequency content of a signal is more important than having a constant amplitude. Hence, in this work we attempted to design one of the Chebyshev filter at 2GHz.

While choosing a substrate for filter design, important factors that are taken into account include dielectric loss, dispersion losses, moisture absorption, and electrical properties over broad frequency range, substrate thickness, loss tangent, anisotropy of the substrate, effects of temperature, humidity, Cost etc. Keeping all this factors in mind, we have chosen RT 5880 substrate for design of a low pass filter because its dielectric constant remains constant over a wide frequency range, it has the lowest electrical loss compared to any reinforced PTFE material. It is isotropic in nature and has low moisture absorption.

Fifth order stepped impedance chebyshev low pass microstrip filter has been designed, fabricated and analyzed at 2GHz frequency on RT Duroid substrate. An equivalent lumped L-C network is proposed and corresponding L-C parameters are extracted [4].

2. Design and Analysis of Microstrip Filter

In this section Chebyshev filter has been designed using a CST-Microwave studio simulation software. Design and Optimization of Low Pass Filter is carried out using Microstrip Lines. The design of lowpass filters involves two main steps. The first step is to specify an appropriate low pass prototype. The element values of the lowpass prototype filters, which are usually normalized to make a source impedance g0 = 1 and a cut-off frequency $\Omega_c = 1.0$, are then transformed to the L-C elements for the desired cut-off frequency and the desired source impedance, which is normally 50 ohms for microstrip filters. The second main step in the design of microstrip lowpass filters is to find an appropriate microstrip realization that approximates the lumped element filter. The element values for the lowpass prototype with Chebyshev are taken from normalized values gi i.e. g1, g2, g3, g4......, gn Our designed frequency is 2 GHz and the selected material is RT duroid 5880.

Design steps for the proposed filter are,
Cut off frequency =2GHz
Substrate thickness=0.762mm
Dielectric constant ε_r=2.2
Loss tangent=0.0009
Lowest line impedance Z_l=15Ω
Highest line impedance Z_h=105Ω
Characteristic impedance Z_0=50Ω

Width and length calculations are done using formula standard equations mentioned in D.M.Pozar [5] and are tabulated in table below.

Table 1
Dimensions of the Filter

Section	Z_i=Z_l or Z_h	$\beta_{l\ (in\ degrees)}$	$W_{i\ (mm)}$	$L_{i(mm)}$
1	15Ω	29.3354	10.9	8.55
2	105Ω	33.5650	0.6	10
3	15Ω	43.6952	10.9	12.68
4	105Ω	33.5650	0.6	10
5	15Ω	29.3354	10.9	8.55
6	105Ω	27.2975	2.3	8.31

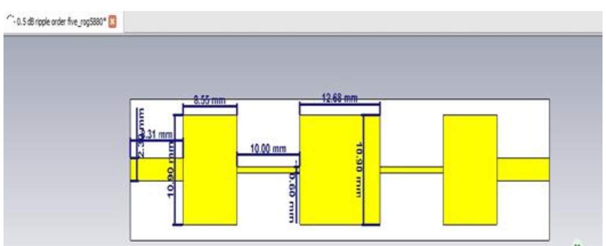

Fig. 1. Refers to the simulated structure of the proposed filter. The total size of the filter is 8.6cm×1.4cm

3. Results

The simulated and the fabricated filter response is shown in figure below. In the response graph gain (dB) is plotted on the Y-axis and frequency (GHz) on the X-axis. The low pass filter is capable of passing the frequency less than 2 GHz & rejects the frequency after 2 GHz. So this filter can be used for L-band applications. For the simulation purpose we have used CST microwave software.


Fig. 2. Refers to the Fabricated Filter structure with coaxial connectors

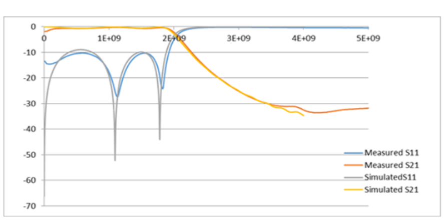

Fig. 3. comparison of measured and simulated frequency response of chebyshev filter

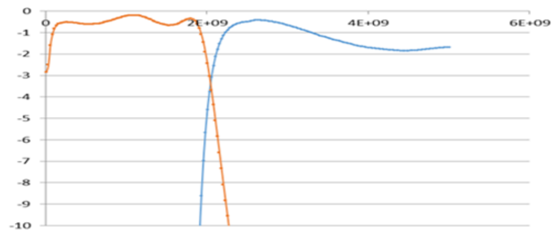
Fig. 4. Close view of cut-off frequency at 2GHz, for fabricated filter

4. Conclusion

As the simulated and measured results are in very good approximation. Our choice of the substrate has fulfilled all the requirements for a filter at L-band wireless application.

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