International Journal of Engineering and Advanced Research Technology (IJEART)
ISSN: 2454-9290, Volume-2, Issue-10, October 2016

Design & Analysis of Microstrip Bandpass Filter for High Frequency Applications

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Abstract— **Bandpass filters play a significant role in wireless communication systems. Transmitted and received signals have to be filtered at a certain center frequency with a specific bandwidth. In designing of microstrip filters, the first step is to carry out an approximated calculation based on using of concentrated components like inductors and capacitors. After getting the specifications required, we realized the filter structure with the Insertion loss technique or Image parameter technique. Experimental verification gives comparison, how close the theoretical results and measurements look like.**

Index Terms— **Bandpass filter, high frequency, microstrip, microwave.**

I. INTRODUCTION

The advances of telecommunication technology arising hand in hand with the market demands and governmental regulations push the invention and development of new applications in wireless communication [1]. These new applications offer certain features in telecommunication services that in turn offer three important items to the customers [2]. The first is the coverage, meaning each customer must be supported with a minimal signal level of electromagnetic waves, the second is capacity that means the customer must have sufficient data rate for uploading and downloading of data, and the last is the quality of services (QoS) which guarantee the quality of the transmission of data from the transmitter to the receiver with no error. In order to provide additional transmission capacity, a strategy would be to open certain frequency regions for new applications or systems. WiMAX (Worldwide interoperability Microwave Access) which is believed as a key application for solving many actual problems today is an example [3].

In realization of such a system like WiMAX we need a complete new transmitter and receiver. A band pass filter is an important component must be found in the transmitter or receiver. Bandpass filter is a passive component which is able to select signals inside a specific bandwidth at a certain center frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere the information signals. In designing the bandpass filter, we are faced the questions, what is the maximal loss inside the pass region, and the minimal attenuation in the reject/stop regions, and how the filter characteristics must look like in transition regions [4].

In the process to fulfill these requirements there are several strategies taken in realization of the filters, for example, the choice of waveguide technology for the filter is preferred in respect to the minimal transmission loss (insertion loss). This strategy is still used in satellite applications. The effort to fabricate waveguide filters prevents its application in huge amounts. As alternative, microstrip filter based on printed circuit board (PCB) offers the advantages easy and cheap in mass production with the disadvantages higher insertion losses and wider transition region. In this work we would like to give a way to conceive, design and fabricate bandpass filter for the WiMAX application at the frequency 1.0 GHz with parallel-coupled microstrips as opposed to the [5] which designed filter for wireless local area network 5.75 GHz, and [6] which used the composite resonators and stepped impedance resonators for filter realization.

II. BASICS OF FILTER

A. Transfer Function

In Radio Frequency (RF) applications, for defining transfer function we use the scattering parameter S_{21}. In many applications we use instead the magnitude of S_{21}, the quadrate of S_{21} is preferred. Here ε is the ripple constant, $F_n(\Omega)$ filter function and Ω is frequency variable. If the transfer function is given, the insertion loss response of the filter can calculated by

B. Butterworth Filter

Filters designed with Butterworth approach show the maximal flat characteristics in the pass region. Figure 1 shows the attenuation characteristics of lowpass Butterworth filter. In pass region, $f < f_c$, the attenuation of ideal lowpass filter is 0 dB, good approximation must have characteristics close to zero from the frequency zero Hertz to a certain so-called cut-off frequency f_c. For $f > f_c$, the ideal low pass filter attenuates the signal completely or $L_A \rightarrow \infty$. The Butterworth approach is expected to have the attenuation factor as high as possible.

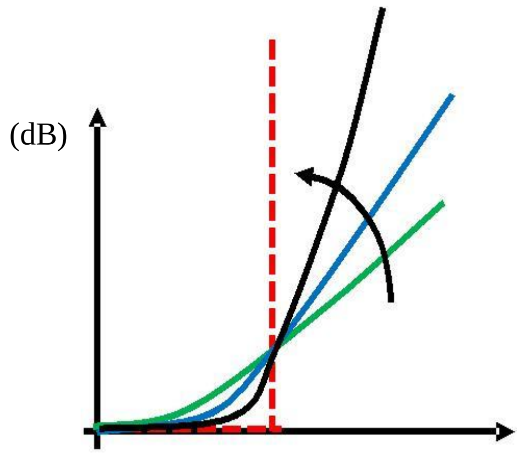

Fig.1 Frequency Response

Figure 1 gives the circuit implementation of the filter by means of concentrated components like inductors (L) and capacitors (C), for the even and odd filter degree (n). The Butterworth approach for designing filter uses the condition attenuation of 3 dB at the frequency $\Omega=\Omega_c=1$, so that the following equations can be used for collecting the values of L and C for the circuits for i=1 to n.

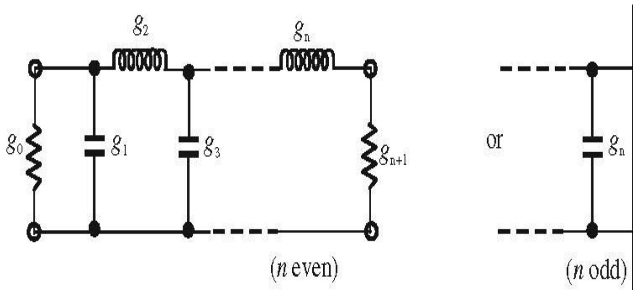

Fig.2 Realization of filter using LC components

The value of n can be determined if an additional constraint is given, for example, the filter must have minimal attenuation factor at a certain frequency.

C. Chebyshev Filter

In practical implementation, the specification for losses in pass region can normally be higher than zero. Chebyshev approach exploits this not so strictly given specification values. It can be 0.01 dB, or 0.1 dB, or even higher values. The Chebyshev approach thereby shows certain ripples in the pass region, this can lead to better (higher) slope in the stop region. Figure 3 shows the attenuation characteristics for lowpass filter based on Chebyshev approach. The quadrate of the magnitude of the transfer function with Chebyshev approach is given by $T_n(\Omega)$ is Chebyshev function type 1 with order n.

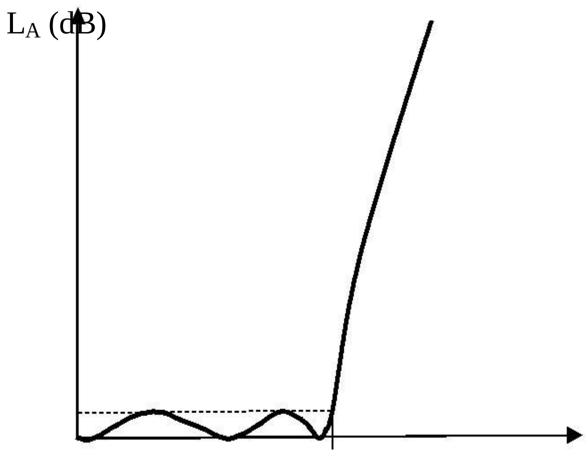

Fig.3 Attenuation characteristics for Chebyshev approach

D. Transformation to Bandpass Filter

The previous observation was done for lowpass implementation. A transformation to bandpass is needed for getting bandpass characteristics. In the transformation, the component L will be converted to serial combinations of L_s and C_s, whereas the component C becomes parallel combination of L_p and C_p. With the cut-off frequencies ω_1 and ω_2 as lower and upper boundary, we can calculate the center frequency and the relative frequency bandwidth as follows. For the serial combination, and for the parallel combination Z_o is the value of the load impedance, normally set to 50 Ω.

III. FILTER REALIZATION WITH MICROSTRIP TECHNOLOGY

A. Microstrip Transmission Line

Microstrip transmission line is the most used planar transmission line in Radio frequency (RF) applications [7]. The planar configuration can be achieved by several ways, for example with the photolithography process or thin-film and thick film technology. As other transmission line in RF applications, microstrip can also be exploited for designing certain components, like filter, coupler, transformer or power divider.

If a microstrip transmission line, as depicted in Fig, 4, is used for transport of wave with relative low frequency, the wave type propagating in this transmission line is a quasi-TEM wave. This is the fundamental mode in the microstrip transmission line. The width of the strip W together with the dielectric constant and the thickness of the substrate determine the characteristic impedance Z_o of the line [8].

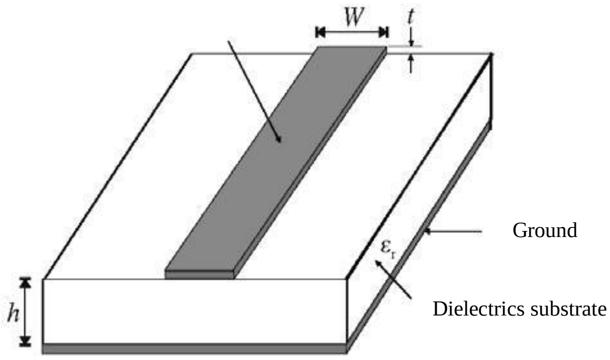

Fig.4 Microstrip Transmission line.

B. Designing Bandpass Filter

Figure 5 shows the filter structure observed in this work. This filter type is known as parallel-coupled filter. The strips are arranged parallel close to each other, so that they are coupled with certain coupling factors. We use the following equations for designing the parallel-coupled filter g_0, g_1, .., g_n can be taken from table, FBW is the relative bandwidth as explained before, $J_{j,j+1}$ is the characteristic admittance of J inverter and Y_o is the characteristic admittance of the connecting transmission line. With the data of characteristic admittance of the inverter, we can calculate the characteristic impedances of even-mode and odd-mode of the parallel-coupled microstrip transmission line, as follows [9, 10]

IV. FILTER CALCULATIONS WITH IE3D AND HFSS SOFTWARE AND MEASUREMENTS

For filter fabrication we use a PCB of type RO TMM10 provided by the Rogers Corp with the thickness 1.6 mm. The substrate of type RO TMM10 has the relative permittivity of 4.4 and tangent loss of 0.001.

In order to have the wave impedance of 50 ohms, the microstrip line designed in this PCB must have the strip width of 0.7 mm or 0.8 mm. Figure 6 shows the microstrip transmission line expected to have the wave impedance of 50 ohms as the external connector for connecting to other components. Figure 5 visualizes the reflection factor gained by computer simulation with IE3D and HFSS for strip width of 0.7 mm and 0.8 mm. We see the strip width of 0.8 mm gives much better results compared to strip width of 0.7 mm.

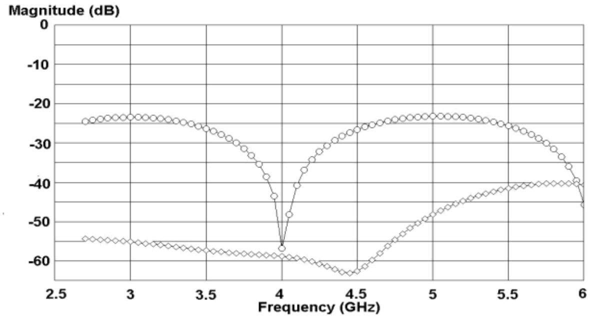

Fig.5 Reflection factor (o) 0.7 mm and (◊) 0.8mm.

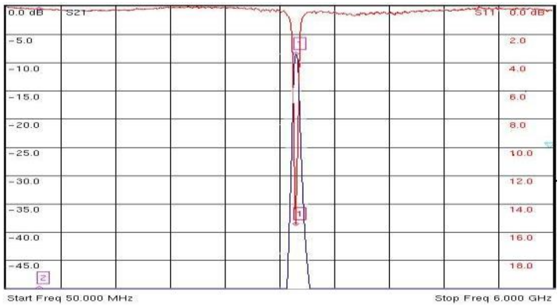

Fig.6 Measured reflection and transmission factor 50 MHz to 6 GHz.

IE3D is commercial software which is used for designing of microwave filters and antennas. It is introduced by Zeland Corporation and there are many version of this software. Here we use IE3D version-14. HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. The acronym originally stood for high frequency structural simulator. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines, and packaging. It was originally developed by Professor Zoltan Cendes and his students at Carnegie Mellon University. Prof. Cendes and his brother Nicholas Csendes founded Ansoft and sold HFSS stand-alone under a 1989 marketing relationship with Hewlett-Packard, and bundled into Ansoft products.

V. CONCLUSION

Designing of band pass filter with Butterworth approach in combination with concentrated components, i.e. inductors and capacitors and its computational verification in form of parallel-coupled microstrip lines with the program Sonnet give very good filter characteristics at the center frequency 1 GHz with frequency bandwidth of about 100 MHz as required at the specification stage. At the center frequency the insertion loss and reflection factor has the values about -2 dB and better than -15 dB, respectively. The measurement gives also very good filter characteristics at the frequency 1 GHz, however with larger insertion loss of about -7.5 dB and smaller bandwidth of about 50 MHz. This larger loss originates likely from losses of the coaxial connectors and their poor contacts to the microstrip line.

ACKNOWLEGMENT

The authors thankfully acknowledge the support and encouragement provided by authorities of IMS Engineering College, Ghaziabad.

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