Interdigital Bandpass Filter for 2.5 GHz LTE Application: Design and Performance Analysis

Aparna.A.P, Loshni.T, K.Ramprakash

Abstract: ***Microwave filter is an indispensable component in all types of communication systems. The most desired features for filters thus designed are accuracy and satisfying degree of performance. The objective of this paper is to design an Interdigitalbandpass filter operating at a frequency of 2.5 GHz. This filter is therefore, suitable for LTE(Long Term Evolution) systems. The implementation of the filter is done using FR4 substrate and the simulation of the filter is done using Keysight ADS (Advanced Design System) software. Parameters such as insertion loss, returnloss and 3-dB bandwidth are measured for analyzing the performance of thefilter.***

Key Words: LTE, Keysight ADS, Interdigital, Microwave filter.

I. INTRODUCTION

Frequencies extending from Megahertz to Gigahertz range are considered as microwave frequencies. This range of frequencies is found to be highly suitable for communication applications like broadcasting of television, radio as well as wireless applications like Wi-Fi, Cellphones etc. In all these applications, it is necessary to remove unwanted signal frequencies so as to ensure the best performance. This is made possible by incorporating microwave filters in to the systems.

Microwave filters can be designed in a variety of configurations, out of which Interdigital filter configuration is given the prime focus in this paper. This configuration uses quarter wavelength lines which are alternately shorted. The opposite ends are alternately left open. Interdigital configuration is specifically considered in this paper because of it's ability to achieve miniaturization as well as desired insertion loss and return loss and hence is considered a good choice for designing microwave filters for communication applications.With the advancement of technology, one of the important attribute apart from having good performance parameters is miniaturization. Miniaturization makes the communication devices not only portable but also helps in reducing their cost.Miniaturization should be made possible in such a way that it does not compromise the device performance. This paper aims at analyzing the performance of a bandpass filter designed in the Interdigital configuration operating at 2.5 GHz, suitable for LTE applications. Long Term Evolution (LTE) makes use of GSM/EDGE (Global System for Mobile Communication/Enhanced Data Rate for Global Evolution) as well as UMTS/HSPSA (Universal Mobile Tele communication System / High Speed Packet Switched Access)technologies. Using LTE, mobile phones and other data terminals can achieve high speed communication in the wireless domain. LTE is also referred to as 4G LTE in the market and is incompatible with existing 2G and 3G technologies.

Nevertheless LTE is a promising technology for many years to come in future as far as communication field is concerned.

II. RELATED WORK

Ever since the concept of Interdigital structure has been introduced, several filter designs incorporating these configurations have become a vogue in the field of telecommunication. A filter with combline configuration by including inter resonator taps is discussed in [1]. This filter succeeded in achieving good size compaction as well as desired insertion and return loss. Another proof that Interdigital configuration is gaining more popularity is it's application in millimeter wave communication [2]. Again, the filter achieved the desired performance parameters. Since data rate is an important requirement in all modern telecommunication applications, short ended Interdigital coupled line unit can be used for this purpose, which obviously achieved good size compaction together with the desired data rate[4].

The concept of achieving improved selectivity, which is also an important quality of a good filter, is discussed in [9], by placing Interdigital capacitors between transmission line zeroes. Cascading Interdigital structure with hairpin configuration is a promising technique to improve quality factor , which again is an important performance parameter of afilter[11].

Stub loaded stepped impedance resonator with defected substrate structure [12]can be used to increase the accuracy of afilter.From all the above mentioned papers, it is clear that Interdigital filter configuration [16] is a promising choice for a compact microwave filter with desired performance parameters to be used in communicationapplications.

A. InterdigitalBandpass Filter

Interdigital filter configuration can be classified as a coupled line filter. It is made of several microstrip lines, each quarter wavelength long. The ends of these lines are alternately shorted and the opposite ends are alternately opened. This configuration is suitable for planar technologies and can easily interfaced to coaxial format lines. Mechanical arrangement of insulators eliminates the need for supporting insulatorsthereby removing dielectric losses. High fractional bandwidths as well as Q values low as 1.3 can be easily obtained.

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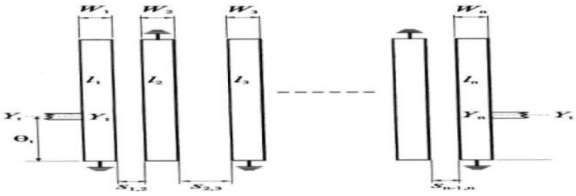

Fig. 1. Structure of InterdigitalBandpass Filter

Fig. 1. Structure of InterdigitalBandpass Filter

The following equations can be used for the design of the bandpass filter.

$\theta = \pi/2$ 1- FBW/2

Y= Y1/tanθ

$J_{i,i+1}=Y/\sqrt{G_i G_{i+1}}$; for i = 1 to (n-1) $Y_{i,i+1}=J_{i,i+1}$; for i = 1 to (n-1)

Inter digital filters are vertical in structure but basicmictrostrip line filters are horizontal in shape andstructure[15] θ is the electrical length of the filter and is usually measured in degrees. Ji,i+1 is the characteristic admittance of the filter where as Y1 is the characteristic admittance of the resonator.

Equations for calculating even mode and odd mode characteristic impedances for coupled line resonators is as follows

Zoe=1/ 1/Y1-Yn-1,n Z0o = 1/Y1+Yn-1,n

Spacing between adjacent resonators can be determined using the following equation.

K i,j+1 = (zoe)i,i+1-(z0o)I,i+1/(zoe)i,i+1+(z0o)I,i+1

III. DESIGN AND SIMULATION

A. Method Used

The most common method, that is, the insertion loss method is used here to design the filter. In the insertion loss method, a low pass filter prototype is generated first and subsequent transition to bandpass filter is done.

B. SimulatorUsed

These filters can also be used along with fractal antennas in the receivers[14]The simulator used for designing the filter is Keysight Advanced System Design. It is a highly suitable software for designing filters and analyzing their performances because of it's ability to design and verify in a single integrated platform. It is also highly successful and innovative and is a leading software in RF field.

C. Design Specifications

The designed InterdigitalBandpass filter is a Chebyshev filter with 0.5 dB ripple. The source and load impedances are selected to be of the standard value, that is, 50 ohms. The following table shows the filter coefficients for a third order low pass Chebyshev filter.

Table I. Normalized Filter Coefficients For Chebyshev Element Values For 0.5 Db Ripple

g1	g2	g3	g4	g5
1.000	1.5963	1.0967	1.5963	1.000

Filter Order	3
Filter type	Chebyshev
Passband Ripple	0.5 dB
Center Frequency	2.5 GHz
Fractional Bandwidth	10% or 0.1

Table II. Specification Of The Filter

J	( )	( )
0	53.316	47.0752
1	53.154	47.199
2	53.316	47.199
3	53.154	47.0752

TABLE III. Specifications Of Substrate

Name of the Substrate	FR4
Dielectric Constant	4.6
Thickness of Substrate	2.8mm
Metal Thickness	0.035mm
Tangent Loss	0.002

Table IV. Even and Odd Mode Impedances of the Filter

Based on the above mentioned specifications and also based on the equations previously discussed, the even and odd mode admittances as well as the physical dimensions of the Interdigital filter can be easilydetermined.

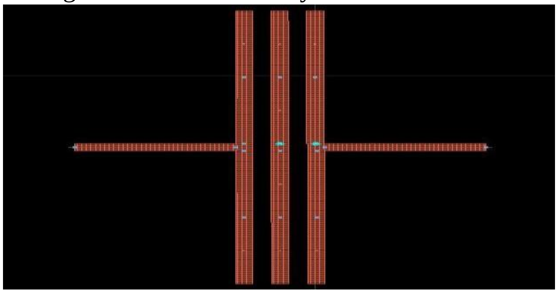

Fig . 2. Layout of InterdigitalBandpass Filter

IV. RESULT AND DISCUSSION

The analysis of the designed filter is done and the measured insertion loss and return loss are represented in the Fig. 3. The graph is plotted with Gain on the Y-axis in dB while frequency is represented on the X-axis in GHz. The S-parameter S21 is used for representing insertion loss whereas, S11 is for depicting return loss.

Order of the filter(n)	Center frequency(f0)	Insertion Loss(S21) in dB	Return loss(S11) in dB	3-dB Band width
3	2.5 GHz	-0.064	-29.339	370 MHz

TABLE V. Physical Dimensions of Interdigital Bandpass Filter

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Fig. 3. Return loss, Insertion Loss and 3-dB bandwidth of Interdigitalbandpass filter

S12 (mm)	S21 (mm)	L (mm)	W (mm)
2.1	2.1	17.4	0.88

TABLE V1. Measured Parameters of Interdigital Filter

Based on the specifications the filter is designed in ADS software and its schematic and layout are generated. The layout of the Interdigital filter structure is as follow

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