Research Article | Impact Factor: 0.621 | ISSN: 2319-507X
Richa Arolkar, IJPRET, 2014; Volume 2 (9): 393-402 | IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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DESIGN OF MICROSTRIP BANDPASS FILTER USING PARALLEL COUPLED METHOD

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Accepted Date: 27/02/2014 ; Published Date: 01/05/2014

Abstract: Coupled filter design uses the basic knowledge of odd and even wave coupling of transmission lines, which results in odd and even characteristic line impedances. Cascading the parallel coupled-line sections gives rise to bandpass filter structures that are designed easily with the IE3D software. This paper shows the design and simulation of a 2300MHz and 700MHz parallel-coupled microstrip filter.

Keywords: Wave Coupling, Coupled-Line Section, Parallel Coupled Microstrip Filter

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How to Cite This Article:

Richa Arolkar, IJPRET, 2014; Volume 2 (9): 393-402

PAPER-QR CODE

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. These new applications offer certain features in telecommunication services, which in turn offer three important items to the customers. 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. LTE (Long Term Evolution) [1] which is believed as a key application for solving many actual problems today is an example.

A band pass filter is an important component must be found in the transmitter or receiver. Band pass filter is a passive component which is able to select signals inside a specific bandwidth at a certain centre frequency and reject signals in another frequency region, especially in frequency regions, which have the potential to interfere the information signals. In designing the band pass 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[2].

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 actual in satellite applications. The effort to fabricate waveguide filters prevents its application in huge amounts. As alternative, micro strip 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 band pass filter for the LTE application at the frequency 2.3 GHz and 0.7GHz with parallel-coupled micro strips.

The mobile communication industry and standardization organizations have therefore started to work on 4G access technologies such as LTE. Besides the peak data rate 1 Gbit/s that fully supports the 4G requirements as defined by the ITU-R, it also targets faster switching between power states. In the future even cheap mobile phones will come equipped with 4G-LTE connectivity for always on high speed internet access. The LTE standard can be used with many different frequency bands. In North America, 700 and 1700 MHz are planned to be used; 800, 1800, 2600 MHz in Europe; 1800 and 2300 MHz in India; and 1800 MHz in Australia.

Since we are designing filter at 2.3 GHz and 0.7GHz (which is included in the planned LTE bands), it might be useful in the equipments designed for LTE. The design is also completed on FR4 substrate which will be cost reducing factor..

II. COUPLING MICROSTRIP FILTER

Our works based on the odd and even wave coupling of transmission lines through a common ground plane, which results in odd and even characteristic line impedances. This sets the stage to an understanding of the coupling between two strip lines and their input/output impedances as part of a two-port chain matrix representation. Cascading these elements gives rise to bandpass filter structures that are most easily designed with the aid of RF circuit simulation packages. A simple modelling approach of coupled microstrip line interaction is established when considering the geometry depicted in Fig. 1.

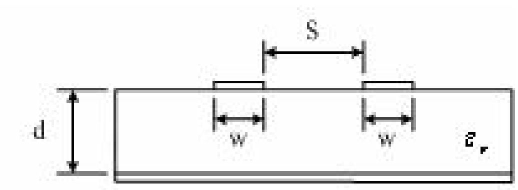

Fig. 1: A coupled microstrip line

A coupled microstrip line consists of two lines separated over a distance S and attached to a dielectric medium of thickness d and dielectric constant εr. The strip lines are wide, and the thickness is negligible compared with d.

The capacitive and inductive coupling phenomena between the lines and ground is given in Fig. 2.

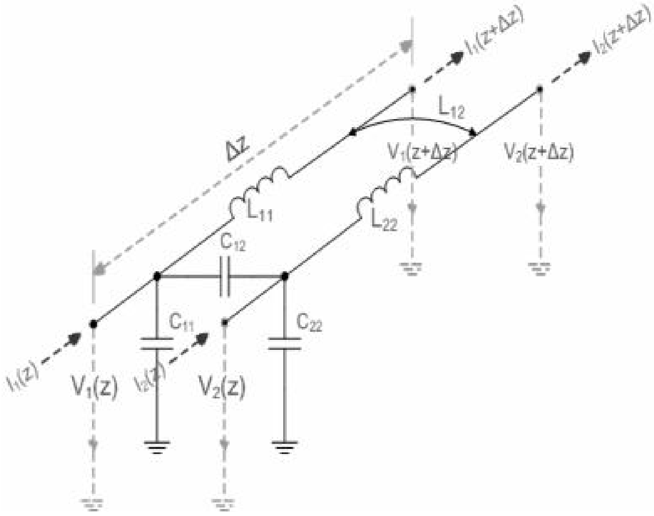

Fig. 2: Equivalent circuit diagram and appropriate

voltage and current definitions for a system of two lossless coupled transmission lines

The even mode voltage Ve, and an odd mode voltage Vo in terms of the total voltage at terminals 1 and 2 [3] and [4].

Ve =0.5 (V1 +V 2) (1)

Vo =0.5 (V1−V 2) (2)

The circuit in Fig. 2 can be further described by the characteristic line impedances Zoe and Zoo for the even and odd modes which can be defined in terms of even and odd mode capacitances Ce, Co, and the respective phase velocities, vp as follows:

$$Z_{oe} = \frac{1}{v_{pe}c_e} \quad (3)$$

$$Z_{oo} = \frac{1}{v_{po}c_o} \quad Z_{oo} = \frac{1}{v_{po}c_o} \quad (4)$$

For the bandpass filter section, the geometric arrangement with input and output ports and open-circuit conditions and the corresponding transmission line representation are shown in Fig.3.

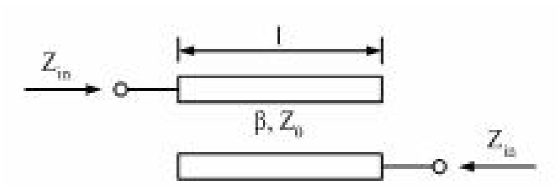

Fig. 3: Bandpass filter element

The input impedance, Zin responses as a function of the electric length in the range, $0 \le (\beta l) \le 2\pi$

$$z_{in} = \frac{1}{2\sin(\beta l)} \sqrt{(z_{oe} - z_{oo})^2 - (z_{oe} + z_{oo})^2 \cos^2 \beta l} \qquad (5)$$

The characteristic bandpass filter performance is obtained when the length is selected to be λ/2 or $\beta l = \pi/2$.

III. DESIGN OF PARALLEL-COUPLED MICROSTRIP FILTER

A single bandpass element as discussed before does not result in a good filter performance with start passband to stopband transitions. However, it is the ability to cascade these bandpass element that results in high-performance filters. Fig. 4 shows a cascaded parallel-coupled or multi-element design. To design a structure that meets a particular bandpass filter specification, computations have to be performed.

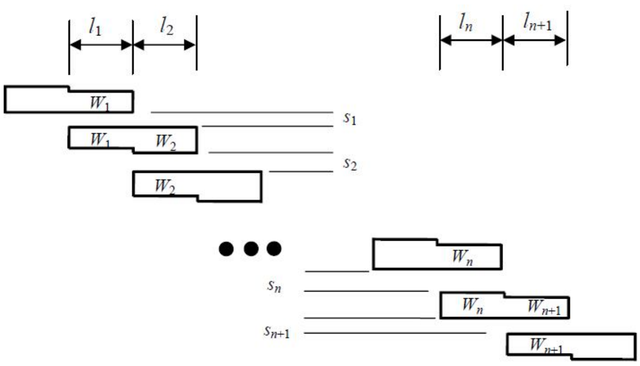

Fig.4: Parallel Coupled Band pass Filter

We use the following equations for designing the parallel-coupled filter

$$\frac{J_{01}}{Y_0} = \sqrt{\frac{\pi FBW}{2 g_0 g_1}} \qquad (6)$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2} \frac{1}{\sqrt{g_j g_{j+1}}}$$

$$\frac{J_{j,j+1}}{Y_0} = \frac{\pi FBW}{2}\frac{1}{\sqrt{g_j g_{j+1}}} \qquad (7)$$

For j=1 to n-1

$$\frac{J_{n,n+1}}{Y_0} = \sqrt{\frac{\pi FBW}{2 g_n g_{n+1}}} \qquad (8)$$

FBW is the relative bandwidth , Jj,j+1 is the characteristic admittance of J inverter and Y0 is the characteristic admittance of the connecting transmission line.

Depending on whether a Butterworth or Chebyshev design, the standard low-pass filter coefficients (g0, g1,..., gN, gN+1) are used.

The design of band pass filter will be done at the centre frequency of 2.3 GHz with the Bandwidth of 0.1GHz,or FBW=0.1/2.3. In designing the filter, equal ripple low pass prototype (3.0dB) with the filter order of n=3 is used. Therefore we get g0=g4=1; g1=g3= 3.3487; g2= 0.7117.

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 micro strip transmission line, as follows [5,6]

$$(Z_{0e})_{j,j+1} = \frac{1}{Y_0}\left[1 + \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \qquad (9)$$

$$(Z_{0o})_{j,j+1} = \frac{1}{Y_0}\left[1 - \frac{J_{j,j+1}}{Y_0} + \left(\frac{J_{j,j+1}}{Y_0}\right)^2\right] \qquad (10)$$

With the procedure explained in [7, 8, 9, 10], we can determine the width of parallel-coupled micro strip lines W and the distance between them s. A pair of parallel-coupled micro strip lines with certain width and separation distance will deliver a pair of characteristic impedances, the even mode and the odd mode ones. W1 and s1 are determined such that the resultant even- and odd mode impedances match to (Z0e)0,1 and (Z0o)0,1. Assume that the micro strip filter is constructed on a substrate with a relative dielectric constant of 4.4 and thickness of 1.6 mm.

Using the design equations the effective dielectric constants of even mode and odd mode can be determined [11].

The actual lengths of each coupled line section are then determined by

$$\lambda \qquad l_j = \frac{0}{4\left(\sqrt{\varepsilon_{re}\varepsilon_{ro}}\right)^{\frac{1}{2}}} - \Delta l_j$$

lj is the equivalent length of micro strip open end[5]

TABLE I. MICROSTRIP DESIGN PARAMETERS OF THE THREE-POLE, PARALLEL-COUPLED HALF-WAVELENGTH RESONATOR FILTER AT 2.3GHZ

J	Wi(mm)	Si(mm)	re	ε_{ro}	Lj
1 and 4	2.9	1.37	3.55	2.99	18.05
2 and 3	3.04	3.88	3.5	3.14	17.91

For 2300MHz, final filter layout is illustrated in Figure5a and The EM simulated frequency responses of the filter are plotted in Figure 5b.

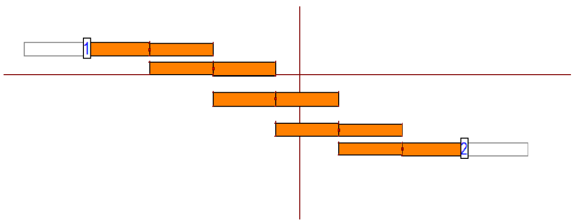

Figure 5a Final Filter Layout

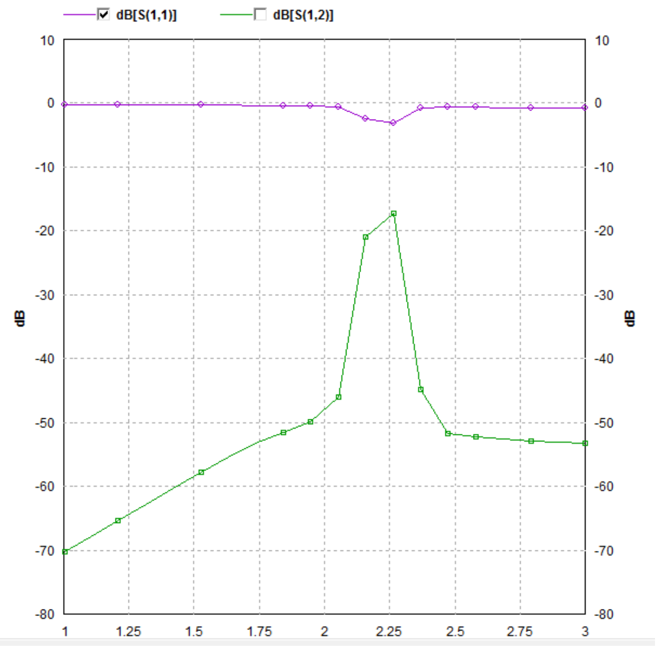

Figure 5b EM simulated frequency responses of the filter

TABLE II. MICROSTRIP DESIGN PARAMETERS OF THE THREE-POLE, PARALLEL-COUPLED HALF-WAVELENGTH RESONATOR FILTER AT 0.7GHZ

J	Wi(mm)	Si(mm)	re	ε_{ro}	Lj
1 and 4	2.02	0.35	3.4340	2.8667	59.54
2 and 3	2.20	1.526	3.4681	3.020	58.32

For 700MHz, final filter layout is illustrated in Figure6a and The EM simulated frequency responses of the filter are plotted in Figure 6b.

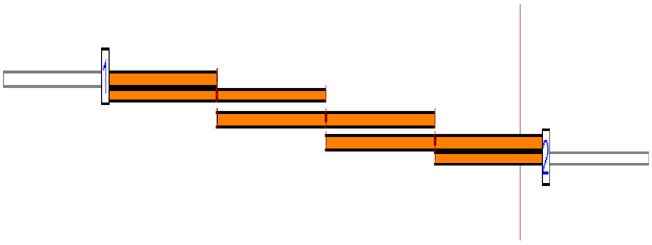

Figure 6a Final Filter Layout

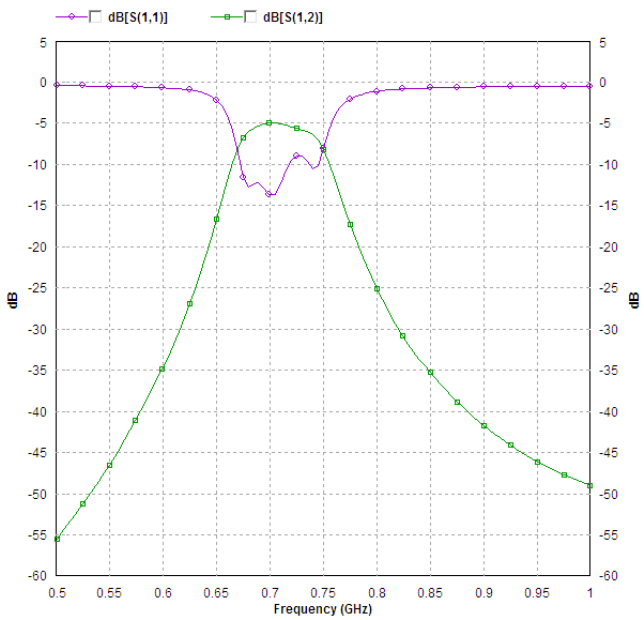

Figure 6b EM simulated frequency responses of the filter

We built a band pass filter with the data given in table 1, and showed the characteristics of the filter in Figure 4 and 5. We see at 2.3 GHz, reflection factors smaller than -5dB and the insertion loss occurring in S21, of about -15dB, primarily due to the tangent loss of the substrate. At 0.7 GHz, reflection factors smaller than -12dB and the insertion loss occurring in S21, of about -5 dB.

IV. CONCLUSION

A bandpass filter designed at 2.3GHz has been presented. Designing of band pass filter with Equal ripple approach in combination with concentrated components, i.e. inductors and capacitors and its computational verification in form of parallel coupled micro strip lines with the IE3D give very good filter characteristics at the centre frequency 2.3 GHz and 0.7GHz.

ACKNOWLEDGEMENT

I would like to express my gratitude to Principal, Dr. V. N. Shet, Goa College of Engineering for constant support and motivation.

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