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COMPUTER BASED DESIGN AND SIMULATION MICROWAVE

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ABSTRACT: There are many component forms used to construct distributed element filters, but all have the common property of causing a discontinuity on the transmission line. These discontinuities present a reactive impedance to a wave front travelling down the line, and these reactance can be chosen by design to serve as approximations for lumped inductors, capacitors or resonators, as required by the filter.The distributed element model is more accurate but more complex than the lumped element model. The use of infinitesimals will often require the application of calculus whereas circuits analyzed by the lumped element model can be solved with linear algebra. The distributed model is consequently only usually applied when accuracy calls for its use Transmission lines are a common example of the use of the distributed model. Its use is dictated because the length of the line will usually be many wavelengths of the circuit's operating frequency. Even for the low frequencies used on power transmission lines, one tenth of a wavelength is still only about 500 kilometres at 60 Hz. Transmission lines are usually represented in terms of the primary line constants . From this model the behaviour of the circuit is described by the secondary line constants which can be calculated from the primary ones.Microwave filters represent a class of electronic filter, designed to operate on signals in the megahertz to gigahertz frequency ranges (medium frequency to extremely high frequency). This frequency range is the range used by most broadcast radio, television, wireless communication (cell phones, Wi-Fi, etc.), and thus most RF and microwave devices will include some kind of filtering on the signals transmitted or received. Such filters are commonly used as building blocks for duplexers and diplexers to combine or separate multiple frequency bands.In general, most RF and microwave filters are most often made up of one or more coupled resonators, and thus any technology that can be used to make resonators can also be used to make filters. The unloaded quality factor (Q) of the resonators being used will generally set the selectivity the filter can achieve. Ansoft corporation provides a good reference to the design and realization of RF and microwave filters.Ansoft designer of microwave components has advanced steadily over the past few decades with the improvement of computers. Many versatile Ansoft designer tools have been developed, and are being used to design all kinds of microwave components. The main purpose of Ansoft designer is to obtain the physical dimensions of a component with the prescribed specifications, and reduce or even avoid the experimental debugging and tuning period after the manufacture of the component. The final objective is, actually to shorten the development time and reduce the total cost.The goal of this thesis is to design and simulation of microwave filter which is worked as a passband filter for a specified value of two frequencies band over a range of many frequencies band.We propose a design of microwave filter for dual band frequency that is based on distributed elements. Microwave filters are among the most commonly used passive components in any microwave system. They are usually distributed networks that may consist of periodic structures in order to exhibit passband and stopband characteristics in various frequency bands. A design method must be able to determine the physical dimensions of a filter structure having the desired frequency characteristics.

Key words: OSTE Impedances (Zb),SSTE Impedances (Za) and TRLE Impedance.

I. INTRODUCTION

The distributed element model or transmission line model of electrical circuits assumes that the attributes of the circuit (resistance, capacitance and inductance) are distributed continuously throughout the material of the circuit. This is in contrast to the more common lumped element model, which assumes that these values are lumped into electrical components that are joined by perfectly conducting wires. In the distributed element model, each circuit element is infinitesimally small, and the wires connecting elements are not assumed to be perfect conductors; that is, they have impedance. Unlike the lumped element model, it assumes non-uniform current along each branch and non-uniform voltage along each node. The distributed model is used at high frequencies where the wavelength becomes comparable to the physical dimensions of the circuit, making the lumped model inaccurate.

A distributed element filter is an electronic filter in which capacitance, inductance and resistance (the elements of the circuit) are not localized in discrete capacitors, inductors and resistors as they are in conventional filters. Its purpose is to allow a range of signal frequencies to pass, but to block others. Conventional filters are constructed from inductors and capacitors, and the circuits so built are described by the lumped element model, which considers each element to be "lumped together" at one place. That model is conceptually simple, but it becomes increasingly unreliable as the frequency of the signal increases, or equivalently as the wavelength decreases. The distributed element model applies at all frequencies, and is used in transmission line theory; many distributed element components are made of short lengths of transmission line. In the distributed view of circuits, the elements are distributed along the length of conductors and are inextricably mixed together. The filter design is usually concerned only with inductance and capacitance, but because of this mixing of elements they cannot be treated as separate "lumped" capacitors and inductors. There is no precise frequency above which distributed element filters must be used but they are especially associated with the microwave band (wavelength less than one meter).

Problem Statement:

The goal of this thesis is to design and simulation of microwave filter which is worked as a passband filter for a specified value of two frequencies band over a range of many frequencies band.

Proposed Work:

We propose a design of microwave filter for dual band frequency that is based on distributed elements. Microwave filters are among the most commonly used passive components in any microwave system. They are usually distributed networks that may consist of periodic structures in order to exhibit passband and stopband characteristics in various frequency bands. A design method must be able to determine the physical dimensions of a filter structure having the desired frequency characteristics. The method depends on combination of a simple synthesis and an accurate analysis based on advanced numerical methods. Basically, the filter designs proceed from the synthesis of the lumped-element band-pass prototypes. The physical dimensions/parameters of filter structures are then related to the corresponding parameters of the prototypes by numerical analysis. Optimization and tuning procedures are usually involved in microwave filter designs. For most of the filter designs, field-theory-based analysis is an integrated part of the design process. Such analysis methods allow filter responses to be predicted very accurately, so that experimental adjustments of the manufactured components can be reduced or eliminated. For some filter structures that can not be efficiently optimized by numerical methods due to the structure complexity or the lengthy simulation speed, experimental tuning is a necessary step in the design procedure. The tuning process can be guided by computer programs that enable parameter extractions.

II. METHODOLOGY

As the study done with previous research work and according to the set goal of designed microwave dual band filter consists of alternating sections of high-impedance and low-impedance lines which correspond to the series inductors and shunt capacitors in the lumped-element implementation. Microwave filter is a two port, reciprocal, passive, linear device which attenuates heavily the unwanted signal frequencies while permitting transmission of wanted frequency. In general, the electrical performance of the filter is described in terms of insertion loss, return loss, frequency selectivity (or attenuation at rejection band), group delay variation in the pass band and so on. Filters are required to have small insertion loss, large return loss for good impedance matching with interconnecting components and high frequency selectivity to prevent interference. If the filter has frequency selectivity, and guard band between channels can be determined to be small which indicates that the frequency can be used efficiently. Also, small group delay and amplitude variation of the filter in the pass band are required for minimum signal degradation. Layout of Stepped impedance Low Pass Filter using Advance Design System Simulator is shown in Fig 1.

There are two methods of filter design. One is image parameter method and second is insertion loss method. The image parameter theory filter is based on the properties of transmission lines. A simple network with lumped components is described in terms of this continuous structure. In insertion loss method, a filter response is defined by a transfer function which is ratio of output voltage to the input voltage of the filter. The ideal low pass transfer function is characterized by a magnitude function that is constant in pass band and zero in stop band. Since such a low pass network can be represented y a quotient of finite degree rational polynomials, it is necessary to approximate it. The four classical solutions to the approximation problems are the Butterworth (maximally flat), Chebyshev (equal ripples in pass band), inverse Chebyshev (equal ripples in stop band) and elliptical (equal ripples in stop and pass band).Today most microwave filter designs are done with insertion loss method.

Filter Design By Insertion Loss Method:

Characteristics of the Filter:

A perfect filter should have

- Zero insertion loss in the passband
- Infinite attenuation in the stopband
- Linear phase response in the passband (to avoid signal distortion)

However such filters don’t exist in practice

Power Loss ratio:

The filter response is defined by its insertion loss or power loss defined as

$$P_{LR} = \frac{\text{Power available from source}}{\text{Power delivered to the load}}$$

$$P_{LR} = P_{inc} = \frac{1}{P_{load}} = \frac{1}{1 - |\Gamma(\omega)|^2} \quad \text{----------------(4.4)}$$

If both source and load are matched

IL = 10 log P_{LR}

-----------------(4.5)

$$|\Gamma(\omega)|^2 = \frac{M(\omega^2)}{M(\omega^2) + N(\omega^2)} \quad \text{-----------------(4.6)}$$

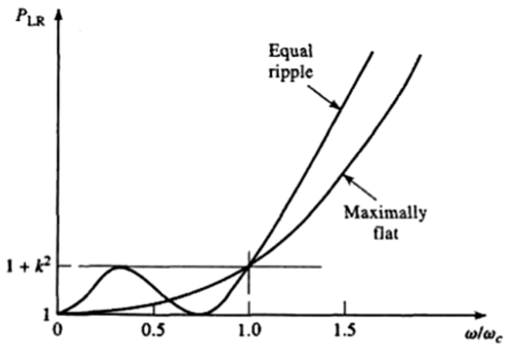
Where both M and N are polynomials in ω^2

From equation (4.3) and (4.4)

$$P_{LR} = 1 + M(\omega^2) = \frac{1}{N(\omega^2)} \quad \text{----------------(4.7)}$$

Maximally Flat: Also called “Binomial” or “Butterworth response” and is optimum in the sense that it’s provides the flattest possible passband response for given filter order. For a LPF

$P_{LR} = 1 + K^2 (\omega/ \omega_c)^{2N}$ -----------------(4.8)
N = order of the filter
ω_c= cut of frequency
Passband $\omega = 0$ to $\omega = \omega_c$
At the band edge
$P_{LR} = 1 + K^2$
If it is -3dB point $\omega/\omega_c= 1$



Maximally flat equal ripple lowpass filter response (N=3)

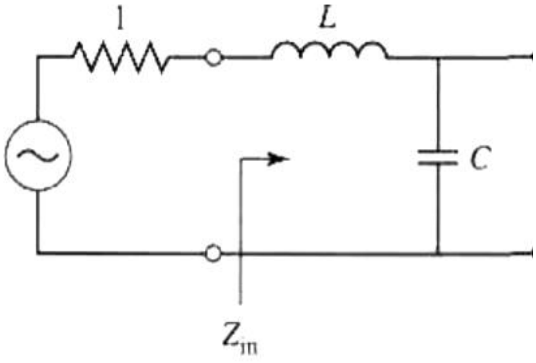
$P_{LR} = K2 (\omega/ \omega_c)^{2N}$ for $\omega > \omega_c$ ………………. (4.9)
Means it increases at the rate of 20N dB/decade
Equal Ripple: Chebyshev polynomial gives IL of an N^{th} order LPF as
$P_{LR} = 1 + K^2 T_N^{2N} (\omega/ \omega_c)$ …………… (4.10)
It has following characteristics

- Sharper cut off
- Ripple of amplitude $1+K^2$
- $T_N(x)$ oscillates between ±1 for $|x|^2$

For large x $T_N (x) \approx 0.5 (2x)^N$ for $\omega >> \omega_C$ .. (4.11)

$P_{LR} \cong \frac{K^2}{4} \{\frac{2\omega}{\omega_C}\}^{2N}$ .... (4.12)
IL increases 20N dB/decade
IL of Equal Ripple response is $(2^{2N})/4$
Times greater than that of maximally flat at $\omega >> \omega_C$

Maximally Flat Low Pass Filter Prototype:
Consider the two-element low-pass filter prototype shown in Figure below



Low-pass filter prototype, $N = 2$.

Fig.4.3 Low pass filter prototype

For
$R_O = 1\ \Omega$ and $\omega_C= 1$ rad / sec
Power loss ratio

$P_{LR} = 1 + K^2 (\omega/ \omega_c)^{2N}$

$P_{LR} = 1 + \omega^4$ ------------- (4.13)

The input impedance of the filter is

$$\text{Zin} = jwL + \frac{R(1-j\omega RC)}{1+\omega^2R^2C^2} \quad .... (4.14)$$

Since, $r = \frac{Z_{in}-1}{Z_{in}+1}$, ……… (4.15)

So, $PLR = \frac{1}{1-|r|^2} = \frac{1}{1-[\{Z_{in}-1\}]/\{Z_{in}+1\}][z\star_{in}-1\}/z\star_{in}+1]}$

$$= \frac{|Z_{in}+1|^2}{2\{Z_{in}+z\star_{in}\}}$$

$$Z_{in} + z\star_{in} = \frac{2R}{1+\omega^2R^2C^2}$$

$$|Z_{in}+1|^2 = \left(\frac{R}{1+\omega^2R^2C^2}+1\right)^2 + \left(\omega L - \frac{\omega C R^2}{1+\omega^2R^2C^2}\right)^2 \quad …….......... (4.16)$$

$$P_{LR} = \frac{1+\omega^2R^2C^2}{4R}\left\{\frac{R}{1+\omega^2R^2C^2}+1\right\}^2 + \left\{\omega L - \frac{\omega CR^2}{1+\omega^2R^2C^2}\right\}^2$$

$$= \frac{1}{4R}(R2+2R+1+R^2\omega^2C^2+\omega^2L^2+\omega^4L^2C^2R^2-2\omega^2LCR^2)$$

$$= 1 + \frac{1}{4R}[\{1-R\}^2 + \{R^2C^2+L^2-2LCR^2\}\omega^2 + L^2C^2R^2\omega^4] \quad ....(4.17)$$

This expression is a polynomial in ω^2
Comparing equation (4.16) and (4.17) we get R = 1 and coefficient of $\omega 2$ must be zero
$C^2 + L2 - 2LC = (C-L)^2 = 0$

So L = C
$\frac{1}{4} L^2C^2 = \frac{1}{4} L^4 = 1$

$L = C = \sqrt{2}$……..............(4.18)
By this procedure we can find the elemental values for a filter for an arbitrary no of Elements N, but this not practical method for large N. Filter prototypes for N =1 to 10.
This data is used with either of the ladder circuits of Figure 4.1.2 in the following way.

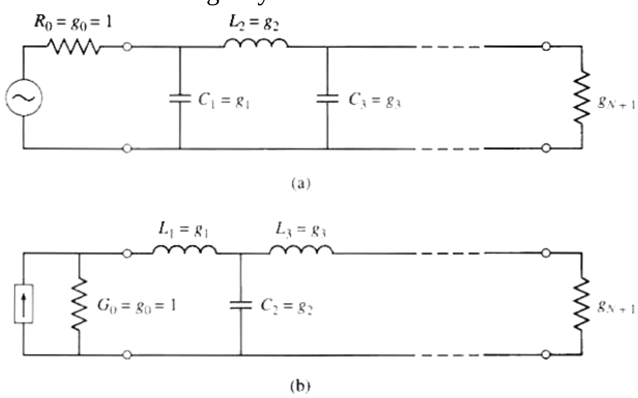


Figure 4.4 Ladder circuit for low pass filter prototypes and their elements definition (a) Prototype beginning with a shunt element. (b) Prototype beginning with a series element.
The element values are defined as

g_0 = [generator resistance (network of Figure 8.25a)
Generator conductance (network of Figure 8.25b)

g_k = (k = l to N) { inductance for series inductors
capacitance for shunt capacitors

g_{n+1} = { load resistance if gn is a shunt capacitor
Load conductance if gn is a series inductor

Equal Ripple Low Pass Prototype:
For ω_C= 1 rad /sec the power loss ratio

$P_{LR} = 1 + K^2 T^2_N(\omega)$ …............(4.19)

Where $1+k^2$ is the ripple level in the passband. Since the Chebyshev Polynomials have the property that

$T_N(0)$ = 0 for N odd,
1 for N even… (4.20)

So P_{LR}= 1 at ω = 0 for N odd and
$P_{LR} = 1+k^2$ at ω = 0 for N even

For the two element filter of the figure 1 the power loss ratio is given by equation (1.8)
And Chebyshev Polynomial for N=2 is given by

$T_2(x) = 2x^2 - 1$ ----------(4.21)

Comparing equation (4.20) and (4.21)

$1 + k^2(4\omega^4 - 4\omega^2 + 1) = 1 + \frac{1}{4R}[(1-R)^2 + (R^2C^2+L^2 + L^2 - 2LCR^2)\omega^2 + L^2C^2R^2\omega^4]$, ……..........(4.22)

Solving above equation for values of R, L, C if the ripple level is known so at ω = 0

$K2 = \frac{(1-R)^2}{4R}$

$R = 1+ 2K^2 + 2K\sqrt{1+K^2}$ (for N even)……...........(4.23)

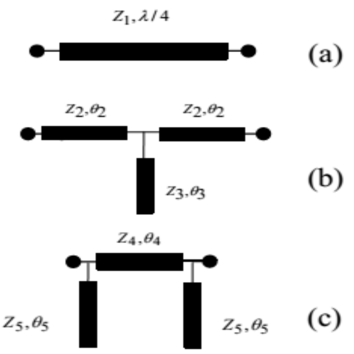
Equating coefficients of ω^2 and ω^4

$4k2 = \frac{1}{4R} L^2 C^2 R^2$,

$- 4k2 = \frac{1}{4R}(R^2C^2 + L^2 - 2LCR^2)$ …............(4.24)

There is impedance mismatch if the load has unity impedance. By using an additional filter element makes it odd N so the R = 1.

Implementation Of Dual Band Filters:



λ/4 transmission line and its equivalents .
λ/4 section
λT-shape equivalent
π- shape equivalent… [5]

The λ/4 transmission line is transformed into its equivalent T shape by using the condition that

$Z_2 = Z_1 / \tan\theta_2 f_1$…….............. (4.49)

$Z_3 = 0.5\, Z_2 \tan^2(2\theta_2 f_1)$ ……............. (4.50)

Where f_1 is first resonance frequency
Similarly the QWTL is transformed into its π equivalent by using condition that

$Z_4 = \frac{Z_1}{\sin(\theta_4 f_1)}$ ……............(4.51)

$Z_5 = Z_4 \tan(\theta_5 f_1).\tan(\theta_4 f_1)$ ……...........(4.52)

$f_2 / f_1 = R$ frequency ratio (resonant frequencies)
$\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta = \pi / (R+1)$ for equal electrical length of line.
The following is the simulation of 3rd order dual band filter using stub resonators
$Z_0 = 50\ \Omega$, $\theta = \pi/(R+1)$ here $R = f_2 / f_1$.

RESULTS :

As per literature review, objective of the proposed work has been set and based on problem identification, methodology is opted to achieve set goal. To test whether we achieve our goal or not. I have made a MATLAB coding and using that we get a resultant impedance values.

5.1 Design a Circuit for Microwave Dual Band Filter :

The values of impedances we got from MATLAB coding and using that we design a circuit for dual band. For Impedance matching Zin (Input impedance) = Zo (Output impedance) = 50 Ω so that design is reach on fully power transformation. Here port 1 is input port and port 2 is output port. We take a following examples to find out the result-

5.1.1 Dual Band for f1= 1 GHz and f 2= 2 GHz

The two frequencies we want to pass from that is f1= 1 GHz first resonant frequency and f 2= 2 GHz second resonant frequency, using MATLAB we get a impedances are-
For OTLE Impedances (Zb) and STLE Impedances (Za)

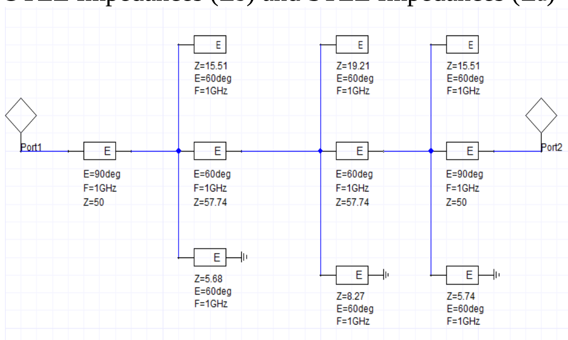


Fig. 5.1 Implementation of circuit dual band filter for f1= 1 GHz and f 2= 2 GHz .

Here input and output impedance of circuit is their electrical length is 90 degree

Resultant graph for Transfer coefficient and Reflection coefficient

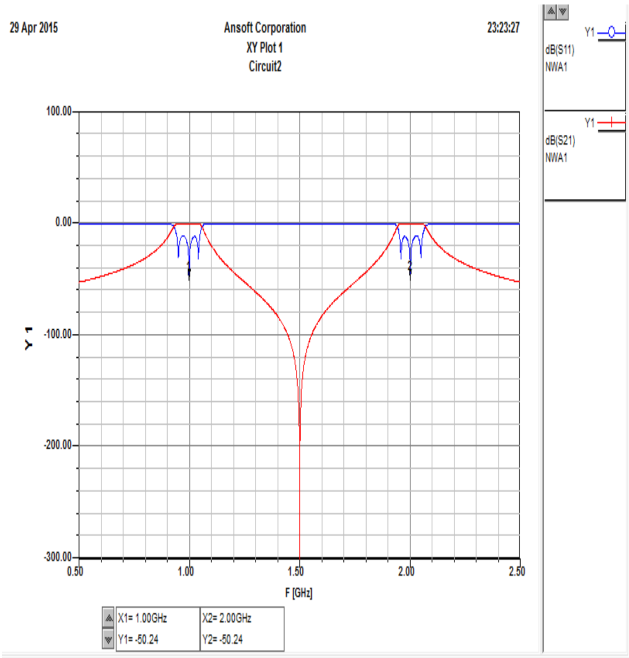


Fig. 5.2 Resultant graph for Transfer coefficient and Reflection coefficient

Here reflection coefficient S11 is minimum on f1= 1 GHz and f 2= 2 GHz on graph and its value is -50.24 . so that on this value maximum transfer of signal this frequency signal. so that frequencies f1= 1 GHz and f 2= 2 GHz is pass on filter and other frequencies are stop by filter because their reflection coefficient is maximum that's way they are reflected and stop by filter.

III. CONCLUSION

In this thesis work we have proposed a design and simulation of microwave filter which is worked as a passband filter for a specified value of two frequencies band over a range of many frequencies band based on combination of a simple synthesis and an accurate analysis based on advanced numerical methods. It also depend upon Ansoft designer and Ansoft corporation provides a good reference to the design and realization of RF and microwave filters. Generalized filter theory operates with resonant frequencies and coupling coefficients of coupled resonators in a microwave filter. This method is able to determine the physical dimensions of a filter structure having the desired frequency characteristics. This design give a schematic circuit of microwave dual band filter for proposed work to reduce a complexity of filter. It method give compact size of filters for various needs. This design give sharp Cutoffs and less reflected power. This design of filter must have good resonance property. In this methodology of design we must have choice of good and cheap material so that technology can be cheaper.

