DESIGN OF QUASI-ELLIPTIC MICROWAVE FILTER

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
In Partial Fulfilment of the Requirements
For the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Department of Electrical & Electronic Engineering
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Approved:

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Dr. Wong Peng Wen
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Muthambi Christian

ABSTRACT

Microwave filters are components which provide frequency selectivity and usually designed to operate in megahertz to gigahertz range of frequencies. Basically the microwave filters discriminate between wanted signals which should pass through the filter and unwanted signals which will be blocked from being transmitted through the filter. The blocked signals are the interferences which we are not interested in them. These filters are used mainly in applications like broadcast radio, television, wireless communication and global system for mobile communications (GSM) [6, 7]. Almost all of the RF and microwave devices will include some kind of filtering. The challenge in designing the filter is to design a filter which is very small in size, with less weight and of minimum cost material, at the same time giving high frequency selectivity and low losses. This project is about to study and do literature review on the microwave filters which is used to design dual mode quasi-elliptic filter which is designed in Final Year Project II. The project introduction will cover background of study, problem statement, objectives, scope of study, relevancy and feasibility study. Literature review will cover aspects like, theory of transmission lines and two-port network, stepped impedance resonator, even-odd mode analysis, transmission zero, insertion loss, spurious resonance frequency, characteristics of different filters and the quasi-elliptic filter. The project methodology is also discussed in this project. Ideal state results together with microstrip results are presented in this report. All the literature view and research done on Final Year Project I is used to design the proposed design of the dual mode quasi-elliptic in Final Year Project II.

ACKNOWLEDGEMENTS

I would like to thank God for being with me throughout the progress of this project. I would also like to thank Dr. Wong Peng Wen for giving me the opportunity to do this project under his supervision. This project would not even have started if it was not because of him. I am also thankful to the lab technician Mr. Adz Jamros Bin Jamali for allowing me to use his lab and making it possible to have the Advanced Design System (ADS) software installed in the lab computer in a short notice of time. I am grateful to Mr. Cheab Sovuthy for helping me with the design of this project and the use of the ADS software.

Thanks to my family back home for all the endless phone calls, support and the encouragement they have shown. Lastly would like to thank all the people who also played a role in my life throughout this project. This Final Year Project would not have been completed without all of you people that I mentioned above.

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CHAPTER 1
INTRODUCTION

In this chapter we will cover the introduction of the microwave filter by starting with the background study and through problem statement, objective and scope of the study, relevancy and conclude with the feasibility of the project.

1.1 Background of the study

The microwave filter is a component which provides frequency selectivity in mobile and satellite communications, radar, electronic warfare, and remote sensing systems operating at microwave frequencies [1].

In general, the electrical performances of the filter are described in terms of insertion loss, return loss, frequency-selectivity which is attenuation at rejection band, group-delay variation in the pass band, and many more. The requirement of filters is to have a very small insertion loss but at the same time have large return loss for good impedance matching with interconnecting components, and for better selectivity to prevent interference. If the filter has a better selectivity, the guard band between each channel can be determined to be small which indicates that the frequency can be used efficiently.

And again, for small or minimum signal degradation, in the passband of the filter a small group-delay and amplitude variation are required [1].

In mechanical performance aspect, the minimum volume and weight of filters together with best temperature stability is required. Filters with High Temperature Superconductors compared to other filters achieve sensitivity and frequency selectivity of higher superiority over others. These filters with high temperature superconductors are preferable used in base stations of cellular communication systems and they are placed at the front of a receiver to make it protected or not being affected by other signals from other operators' signals and services [2].

When designing a microwave filter today, the components development that's should be used must be very economically affordable, very light in weight and the designing method for most design structure should be simple. Therefore microstrip is mostly used because is the one that possesses most of these requirements [3].

The microwave filter which acts like an elliptic has equalized ripple behavior in both the passband, that is where the signals are allowed to flow and stopband, that's is where the signals are not allowed to flow. The amount of ripple in each bands are independently adjustable. And this elliptic behavior gives the fastest transition between passband and stopband among the other kinds of filters ripples on the whole bandwidth. For the proposed project the quasi-elliptic filter is to be designed.

1.2 Problem Statement

In this generation there is an increasing demand of miniaturized high performance microwave band pass filter for the next generation satellite and mobile communication. In order to reduce the filters size and cost, much research work has been conducted in the past [4].

The proposed project aims to design a dual mode quasi-elliptic microwave filter that gives elliptic response. This proposed quasi-elliptic filter should be smaller in size. The dual mode filters that have been introduced are still considerable large.

1.3 Objective and Scope of Study

The objectives of this project are:

1. To study and understand the characteristics and behavior of the different kinds of microwave filters.
2. To investigate, design and simulate the quasi elliptic microwave filter. Several calculations will have to be performed when designing this elliptic response filter. AWR and ADS software were used to design this filter.

1.4 Relevancy/significance

Microwave systems have an enormous impact on modern society. Applications are diverse, from entertainment via satellite television, to civil and military radar systems. The specifications on these devices are usually severe; often approaching the limit of what is theoretically achievable in terms of frequency selectivity [5]. It's yet a very challenging problem for most designers to come up with best microwave filter designs but is for us future engineers to conduct lot of research work so that we can be able to design microwave filters that will be able to meet these severe specifications.

1.5 Feasibility

The project was challenging but it was possible to finish the project within the Scope and Time frame and a lot of useful knowledge for future references was gained in this project. Below is the scope for the project.

Scope and task that are covered in the project

1. Literature reviews on microwave filter designs
2. Performing of mathematical and theoretical analysis (basic transmission lines and two port networks)
3. Design of ideal microwave filter simulation on AWR software.
4. Design of Microstrip simulation on ADS
5. Perform momentum simulation on ADS

CHAPTER 2

LITERATURE RIVIEW

2.1 Dual-Mode Resonator

Radio frequency and microwave filters are in a category of electronic filters, which are basically designed to operate on signals in the megahertz to gigahertz frequency ranges, that's medium frequency to extremely very high frequencies). Most of the radio frequency (RF) and microwave devices will include some kind of filtering on the signals received or transmitted and these filters will be filtering out or discriminating between wanted and unwanted signal frequencies. This frequency range is mostly used by most broadcast radio, television, wireless communications etc [6]-[7].

A signal processing filter with equalized ripple (equiripple) behavior on both the stop-band and the pass-band is called an elliptic filter and this is the filter that's proposed for this project. The amount of the ripple in either band whether pass-band or stop-band can be adjusted independently and is the only filter with faster transition gain between the pass-band and the stop-band [6].

Elliptic filter or the Zolotarev or Cauer filters as is also know, achieve the smallest filter order for the same specifications, or the narrowest transition width for the same filter order, as compared to other filter types. The negative side of the filters is having the most nonlinear phase response and this elliptic filter has that disadvantage as well. There is though other filters like the Bessel, Butterworth and Chebyshev. The table below will compare the basic characteristics of these filters with regard to filter order and phase response [8].

Smaller order or Narrow transition	↓	1. Bessel 2. Butterworth 3. Chebyshev 4. Elliptic	↑	More linear phase over the passband

Table 1: Filter characteristics

The elliptic filter can become a chebyshev or Butterworth filters as the ripple approaches zero in either the pass-band or stop-band or in both sides respectively. Look at the figure below further understanding.

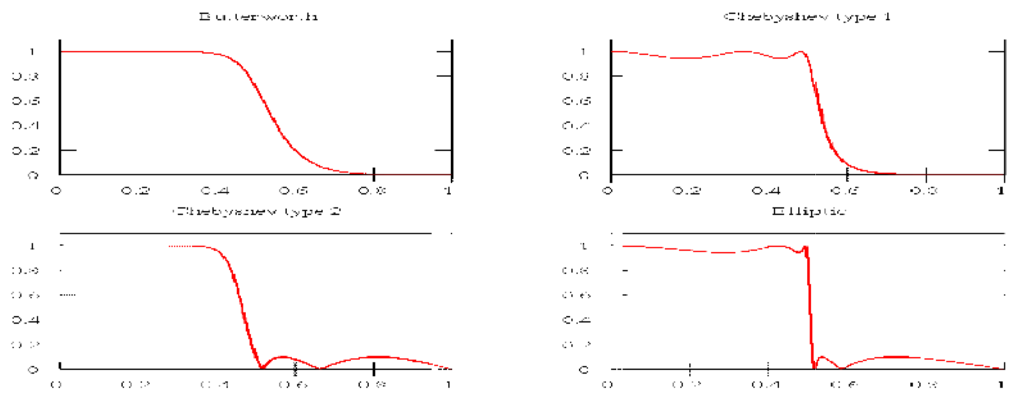


Figure 1: Filter characteristics

In this literature review I will also cover the theory of transmission lines and two port networks as they are the building blocks for any kind of a microwave filter as well as the basic design of filters.

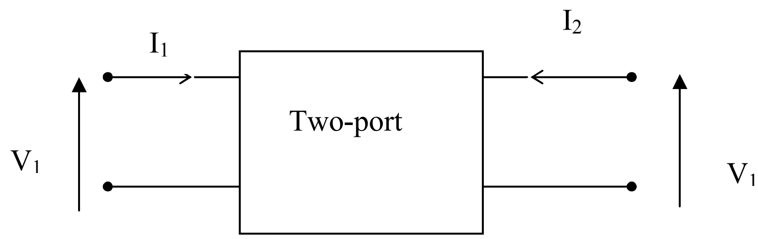
2.2 Theory of Transmission line

A transmission line to be used depends on the choice of the designer of the microwave filter. Transmission medium, generally called a transmission line is required for use of transmission of energy between a source and a load. The development of transmission lines springs largely from the familiar two-wire electrical power line. However, the demands of communication systems, with their far greater frequency requirements led to the development of other types of lines, e.g. Coaxial cables, microstrip lines, waveguides and optical fibers [5].

Transmission line theory in many ways links the gap between basic theory and filed analysis and is of very significant importance in microwave network analysis [9].

2.3 Two port Networks

The two-port is controlled by the four variables, V_1, I, V_2, I_2. Three parameters are used to model the network, Impedance, admittance and hybrid parameters [5].



Impedance parameters and matrix representation of z parameters

$$V_1 = z_{11} I_1 + z_{12} I_2$$
$$V_2 = z_{21} I_1 + z_{22} I_2$$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

Admittance parameters and matrix representation of z parameters

$$I_1 = y_{11} V_1 + y_{12} V_2$$
$$I_2 = y_{21} V_1 + y_{22} V_2$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

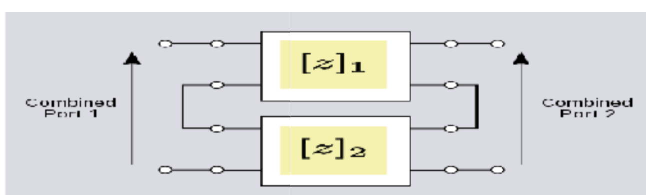
Hybrid parameters and matrix representation of z parameters

$$V_1 = h_{11} I_1 + h_{12} V_2$$
$$I_2 = h_{21} I_1 + h_{22} V_2$$

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

The two-port network can either be connected in series or parallel.

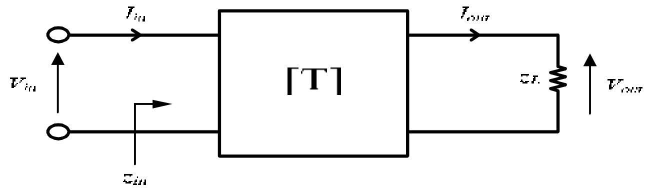
Series connection, we use z parameters.



Parallel connection, we use y parameters.

ABCD matrix [ABCD] or Transfer function equations are follows:

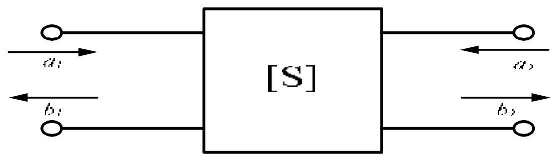
$$\begin{bmatrix} V_{in} \\ I_{in} \end{bmatrix} = [T] \begin{bmatrix} V_{out} \\ I_{out} \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_{out} \\ I_{out} \end{bmatrix}$$



And the scattering or S parameter [S] is as follows

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

$$[b] = [S][a]$$



2.4 Stepped impedance Resonator

In a stepped impedance dual mode resonator, lump coupling element is loaded to the resonators. A lump inductor will be shunted at the midpoint of the transmission line where the transmission line has two line sections with different characteristic impedance [4].

The design parameters that must be usually taken into consideration for a microwave filter design are number of resonators, selectivity, insertion loss and bandwidth. Insertion loss is proportional to the number of resonators, as the number of resonators increase the insertion loss increases as well for a given bandwidth. And the narrower the bandwidth gets for a given filter design, the insertion loss of the filter also increases.

2.5 Even-odd mode analysis

For the proposed design with a structure of the symmetrical circuit (fig. 2 below) the even-odd mode networks are used to analyze the design of the filter.

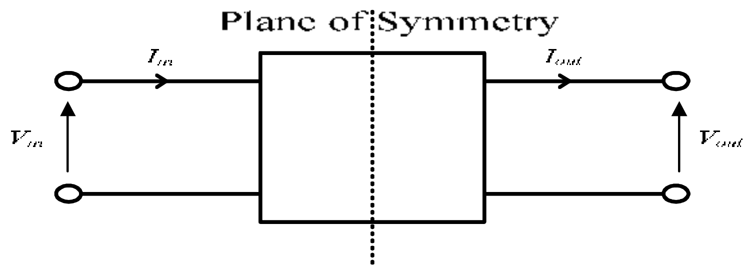


Figure 2: Symmetrical two-port network

In even-mode same and equal potential are supplied to both ends, V_{in} and V_{out} respectively and there is an open circuit in the plane of symmetry. Equal potentials at both ends means V_{in}=V_{out} and I_{out}= -I_{in} [5]. The even-mode admittance after rearing the ABCD matrix is given by, $=$ —

In odd-mode opposite potentials are supplied to both ends, V_{out}= -V_{in} and I_{out}=I_{in} [5]. The odd-mode admittance is give by, $=$ —

After all the mathematics are computed we end up with the transfer matrix of the a symmetrical network as results of even-mode and odd-mode admittances given by:

[T] =

And finally after some mathematical computation we end up with the expressions for S parameters in terms of Y_{even} and Y_{odd} [5].

$$S_{11} = S_{22} = \frac{1 - Y_{odd} Y_{even}}{(1 + Y_{even})(1 + Y_{odd})}$$

$$S_{12} = S_{21} = \frac{Y_{even} - Y_{odd}}{(1 + Y_{even})(1 + Y_{odd})}$$

2.6 Transmission Zero (TZ)

The value of frequency or critical frequencies where the transmission of signal to the load from the source is stopped is called transmission zero. There is zero signal power to the load, so the signal is not being able to pass through in the network [12]. To form the transfer function between the output and the input of a microwave filter, the filter uses this transmission zero frequencies altogether with pass band edge frequencies plus passband ripple. There are three types of transmission zero available in microwave filters which are Transmission Zero at DC, Transmission Zero at Infinity and Transmission Zero at Finite Frequency [12].

Transmission Zeros at DC (f=0) are of importance in highpass and bandpass filters. The quantity of transmission zeros at DC determines the selectivity or slope of the filter in the side of the lower stopband.

Transmission Zeros at Infinity ($f = \infty$) are of importance in the lowpass and bandpass filters. The quantity of these transmission zeros at infinity determines the selectivity in the upper stopband [13].

Basically the transmission zeros can be used to determine or to shape the response of the filter to get the desired design by enhancing the selectivity of the filter.

2.7 Insertion Loss

Insertion loss is the measure of the amount of power that is lost through a loaded two-port network is loaded, this power loss maybe through dissipation or reflection. Insertion loss can also be defined well by the power loss ratio, P_{LR} [9].

$$P_{LR} = \frac{\quad}{\quad} = \frac{\quad}{\quad} = \frac{\quad}{|(\quad)|}$$

The filter must be able to pass the signal of interest within the passband with no losses or with minimum losses as possible, and it should be able to select out or to get rid of undesired signals.

Unfortunately we do live in an imperfect word and we are forced to abide to the physics laws. So in this imperfect world we are living in, the radio transmitters do transmit both desired and undesired signals. Since bandpass filters are used to pass the desired centre frequencies, insertion loss do affect this desired signal that is supposed to pass through the passband [17].

To have a narrower bandwidth of the signal of interest to pass through the filter, the insertion loss setting must be higher. The lower insertion loss setting will give us a wider bandwidth. However insertion loss is not the only factor that has an effect on the signal of interest to be passed in the filter, the length of the cable also do affect the bandwidth of the cable [17]. For example look at the fig.3 below, the curves in this figure have different insertion loss settings. The curve of the top signal at the centre frequency has the lower insertion loss compared to other signals and the bottom signal curve has the highest. So from this signal curves we can see that when the insertion loss in lower there is poor filtering of the signal.

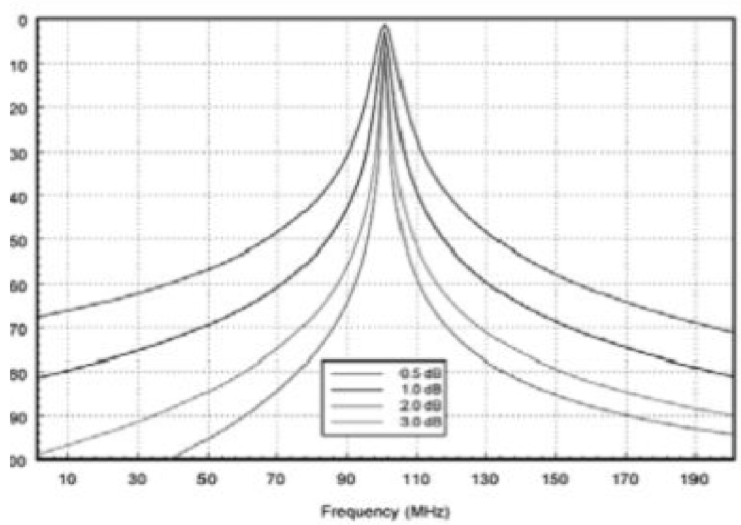


Figure 3: Shows insertion loss characteristics

The insertion loss in the filter's bandpass can be estimated using the equation:

$$(\quad) = \frac{4.343 * \quad 0}{\Delta \quad *} * \sum$$

2.8 Spurious Resonance Frequency

Spurious resonances of the designed filter at frequencies not of the desired centre frequency are just the repetition of the bandpass characteristics. Naturally bandpass filters which are designed with half-wavelength resonators do have spurious passband at $2f_o$ [18]. To control the spurious bandpass response, defected ground structure, stepped impedance resonators, over-coupled end stages, slow-wave resonator can be used to the spurious resonance frequency [18].

2.9 Microwave filters

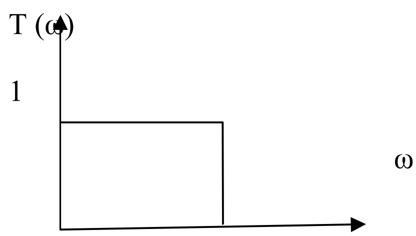
Power transmission coefficient T(ω) or its power reflection coefficient Γ(ω) can be used to describe a lossless filter, as the two values are completely dependent [10]:

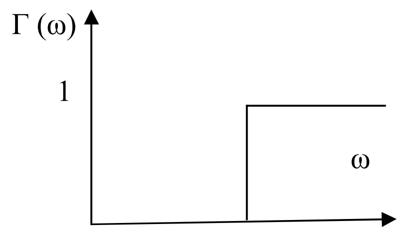
Γ (ω) = 1 − T (ω)

Ideally, the functions could be quiet simple:

1. T (ω) = 1 and Γ (ω) = 0, (frequencies in the pass-band) and
2. T (ω) = 0 and Γ (ω) = 1, (frequencies within the stop-band)

Example of ideal low-pass filter:





Adding to this, a linear phase response it would be a perfect microwave filter. There is one problem with these perfect filters, it is impossible to build. We must limit ourselves to filter functions which can only be expressed as finite polynomials.

Order N of the polynomial denominator is the order of the filter. Types of polynomials are many and each type has its own characteristics and they result in good filter response.

2.9.1 Three most popular types of microwave filters

a. Elliptical

Three primary characteristics of an elliptical filter. Fig.1 in the beginning of this chapter shows these characteristics.

- Steep roll-off, meaning that transition from pass-band to stop-band is very fast. In terms of selectivity from pass-band to stop-band it has optimum response [5].
- Pass-band exhibits ripple, there would be slight variation of "T" within the pass-band.

- Ripple in the stop-band, slight variation of “T” within the stop-band.

So this type is equiripple in both the stop-band and the pass-band

b. Butterworth

Butterworth known as maximally flat filters have the following characteristics.

- Gradual roll-off.
- No ripple in the pass-band and stop-band.
- Based on very simple polynomials
- There is some overshoot and ringing in the time domain, but less than Chebyshev
- Butterworth poles lie on a circle in the complex plane.
- Is an amplitude filter.

c. Chebyshev

Equal-ripple is another name for chebyshev filters and they also have the characteristics.

- Steep roll-off, but not as steep as elliptical.
- Ripple in the pass-band, but does not have ripple in the stop-band.
- Chebyshev poles lie on an ellipse in the complex plane
- Based on z-transform
- Based on the chebyshev polynomials
- The come in two types:

  Type I: Monotonic in the stop band. Equiripple in pass band. The poles of this type I of chebyshev filter are spaced evenly about the ellipse in the left hand half plane.

  Type II: Monotonic in the pass band. Equiripple in the stop band. Poles of this filter are spaced evenly about the right half plane.

- The response in non linear
- Chebyshev overshoot and ring significantly

When designing these filters, four things need to be known:

I. Low pass or high pass response

II. Cut-off frequency

III. % ripple in the pass band

IV. Number of poles.

Elliptical filters look like they are the best because of the steepest roll-off but that is not true in real case. Phase response for filters play a big role and pose a big challenge in building filters. Butterworth phase response is close to a linear phase. Chebyshev phase response is not very linear and finally the phase response of elliptical filters is a very noticeable non-linear mess [10]. N which the degree of the network determines behavior of the transition. The larger the value of N, the transition becomes more rapid from pass band to stop band, it can be seen in fig.4 that as phase response gets worse as the roll-off of the filter improves [5].

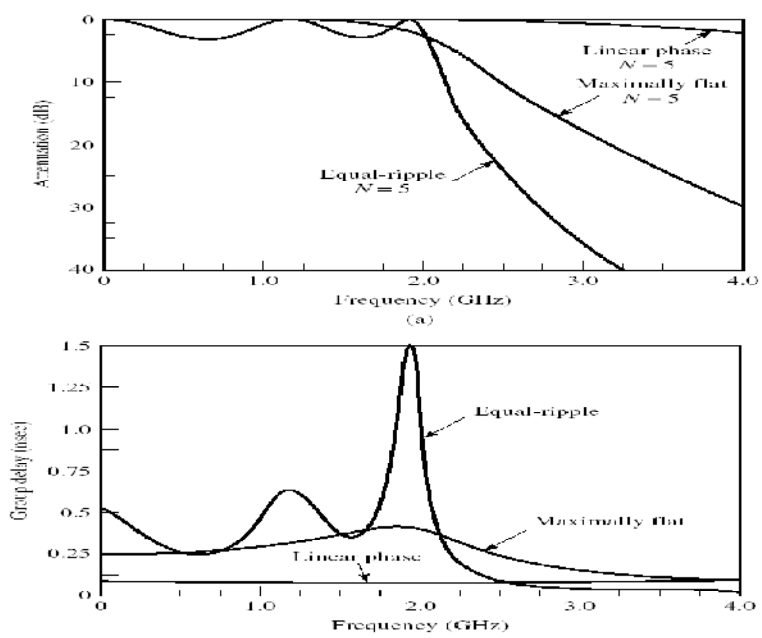


Figure 4: Filters response characteristics

2.10 Quasi-Elliptic Filter

Quasi-elliptic filter gives a response with the characteristics which are in between the elliptic filter and the chebyshev filter. Different articles and journals are studied to study theses characteristics of the quasi-elliptic filters. So different proposed designed by different authors will be thoroughly examined.

In [3], a proposed filter with a quasi-elliptic frequency response was designed. To suppress the harmonics and also to reduce the insertion loss, the U-shaped coupling feed with some enhancement was used in the design of the filter, figure 3 below. Since in modern microwave development microstrip is of the best choice, even in this design the designer proposed using microstrip because it's low cost, light in weight and for its simplicity in design structure. The other reason of using the microwave using variations of stepped impedance resonator is because lot of researches that have been done found that it plays a big role in reducing the size of the circuit and in eliminating the harmonics.

A quarter-wavelength microstrip resonator is the one that most designers consider for their filter structures because it does not consume more space compared to other conventional half-wavelength microstrip resonators. It is for this reason that the designers of the quasi-elliptic bandpass filter use a quarter-wavelength stepped impedance resonators over half-wavelength resonators.

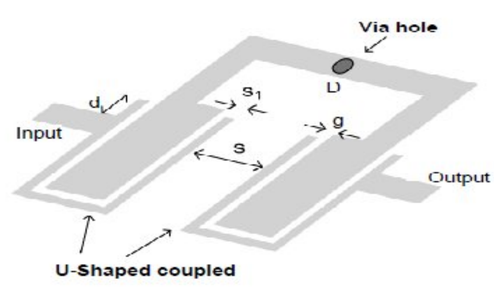


Figure 5: Structure of a quarter-wavelength SIRs bandpass filter.

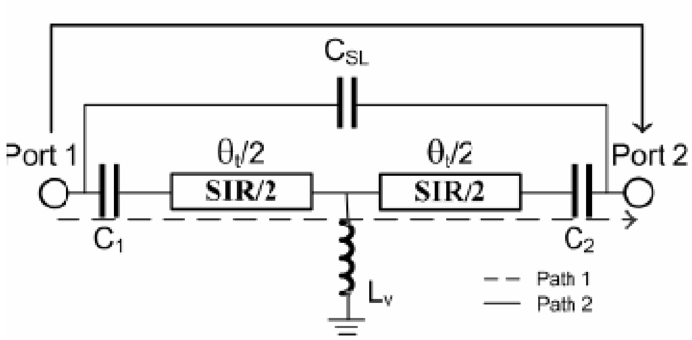


Figure 6: Equivalent circuit of a quarter-wave SIRs bandpass filter.

In [19], the designer of a microwave proposed a quasi-elliptic bandpass filter based on stepped impedance with elimination of first spurious response. The basic configuration of the structure is shown in fig. 5. The structure in fig. 6 is the proposed folded structure of the same stepped impedance resonator in fig. 5. The structure has a very small dimension and also a wider rejection bandwidth when being analyzed with other resonators that are commonly used. Fig. 6. is representation of a capacitive loaded lossless transmission line resonator [19].

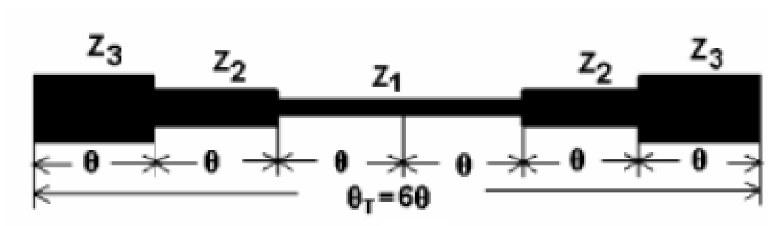


Figure 7: Structure of the stepped impedance resonator

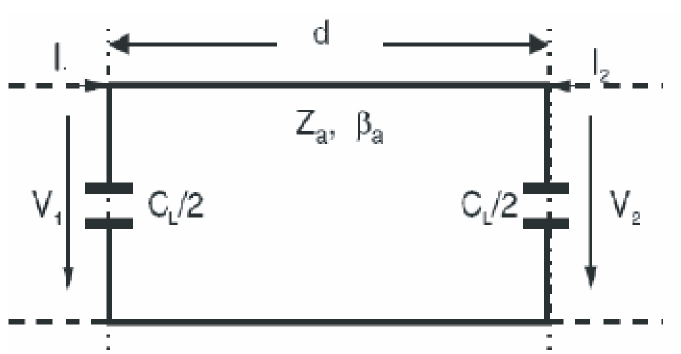


Figure 8: Equivalent circuit of proposed stepped impedance resonator

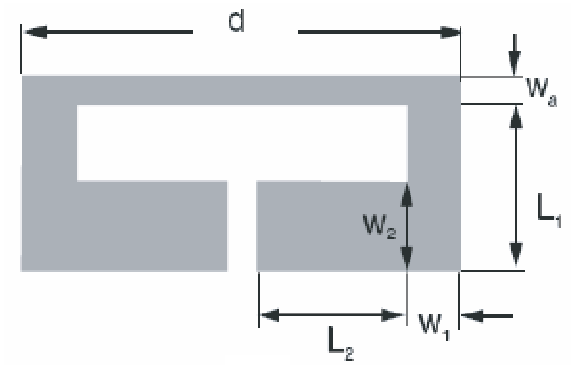


Figure 9: Proposed folded stepped impedance resonator

The response of the circuit in fig. 6 is described as below:

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdot \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

And the matrix [ABCD] is described as:

$$\begin{aligned} A &= D = \cos\theta_a - \frac{1}{2}\omega C_L Z_a \sin\theta_a \\ B &= jZ_a \sin\theta_a \\ C &= j\left(\omega C_L \cos\theta_a + \frac{1}{Z_a}\sin\theta_a - \frac{1}{4}\omega^2 C_L^2 Z_a \sin\theta_a\right) \end{aligned}$$

CHAPTER 3
INTRODUCTION

In this chapter we will cover the methodology used to accomplish this project. Process flow and activities, key milestone table and Gantt will be used to briefly explain the activities of this project.

3.1 Methodology

AWR microwave Office was used to design the filter in ideal state and the Advanced Design System (ADS) was used to convert the filter form ideal to microstrip simulation.

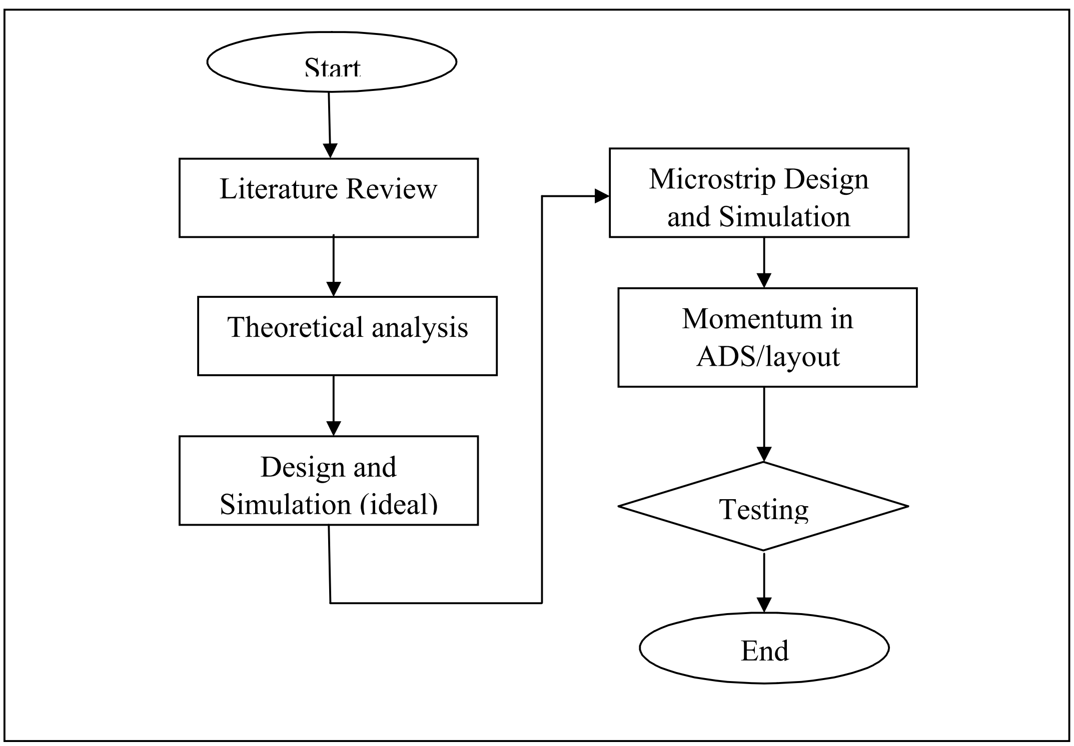


Figure 10: Methodology for the project

3.2 Project Activities

The following are the activities in this project

- Reading and doing research to broaden knowledge of microwave filter design
- Theoretical and mathematical analysis of filter design
- Design and Simulation of the filter
- Layout design

3.3 Key Milestone

Key milestones of this project will be as follows

	Activity	Start	End
FYPI	Literature review	Week 1	Week 13
	AWR lab	Week 2	Week 3
	Theory analysis	Week 5	Week 9
	Preparation and submission of Interim report	Week 9	Week 13
FYPII	Simulation in AWR (Ideal)	Week 1	Week 8
FYPII	Simulation in ADS (Microstrip)	Week 8	Week 12
FYPII	Layout design	Week12	Week 13
FYPII	Final report	Week 13	Week 13
FYPII	Viva	Week 14	Week 14

Table 2: Key milestone

3.4 Gantt Chats

The following are Gantt chats for the project (fyp1 and fyp2)

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of project topic	■	■												
Preliminary Research work		■	■											
Preliminary report submission						■								
Proposal defense presentation							■							
Literature review			■	■	■	■	■	■	■	■	■	■	■	
Theory analysis					■	■	■	■	■					
Learning AWR Software		■	■											
Preparation of report											■	■	■	
Submission of Interim Report													■	

Table 3: FYP1 Gantt chat

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Designing in AWR	■	■	■	■	■	■	■	■	■	■	■			
Simulation in AWR	■	■	■	■	■	■	■	■	■	■	■			
Progress report submission								■						
Project work continue									■	■	■	■	■	
Poster exhibition											■			
Preparation of Dissertation											■	■	■	
Oral presentation														■
Submission of Project Dissertation														■

Table 4: FYPII Gantt chat

3.5 Material and Facilities to be used for this project

- Journals about microwave filter design and Microwave theory text books
- AWR and ADS software in the post-graduate lab

CHAPTER 4
RESULTS AND DISCUSSION

In this chapter will cover the explanation of the results and discussion about the quasi elliptic dual mode filter and the analysis that needs to be done to design a microwave filter

4.1 Proposed Structure

The topology design that will be used for the quasi-elliptic dual mode resonator in this project will be the one in fig.10. For simplicity this topology will be designed to be symmetrical. The impedances of Z2 at both ends are selected to be equal to each other, and their length therefore is equal to each other. The same applies for Z1 impedance and its length but this time with high impedance and small in length compared to Z2.

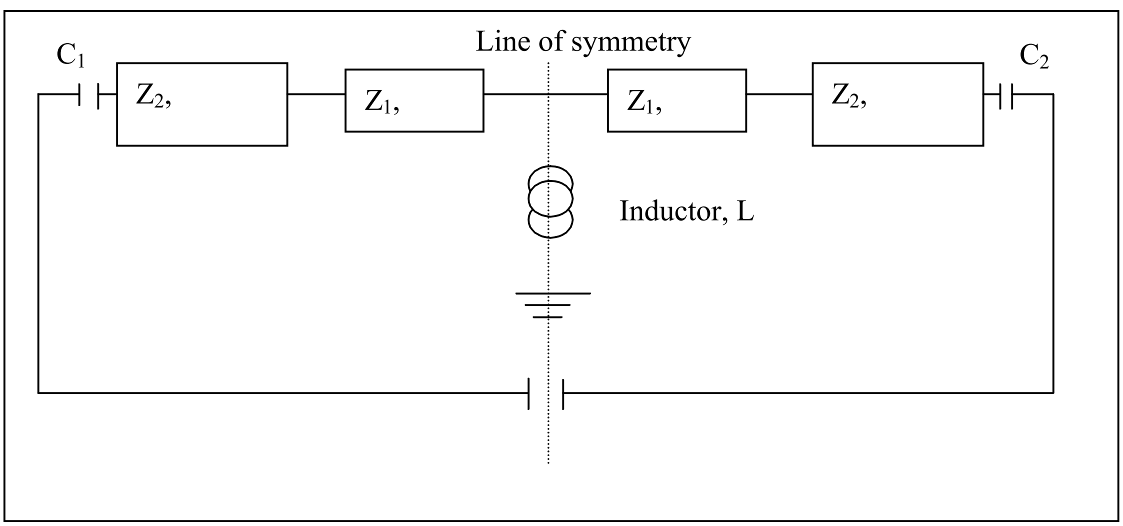


Figure 11: Filter design topology

4.2 Coupling and Routing Structure

Coupling and routing structure is another way that can be used to represent our filter design topology. The circuit of this topology can be analyzed using the ABCD and Y matrix to obtain the desired response. The lines K1, K2 and K3 shown in the figure below are the inverters and there are input and output ports. The poles of the filter are represented by the circles.

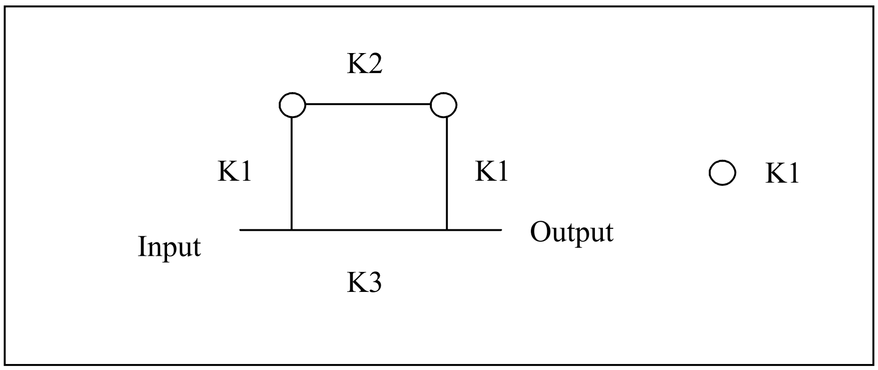


Figure 12: Coupling and routing structure filter design

4.3 Transfer matrix

It is simpler to analyze the coupling and routing structure using the ABCD and Y matrix. The matrix will be as follows:

$$1:= \begin{matrix} 0 & 1. \\ \frac{}{1} & 0 \end{matrix} \quad \begin{matrix} 1 & 0 \\ . & 1 \end{matrix} \quad \begin{matrix} 0 & 2. \\ \frac{}{2} & 0 \end{matrix} \quad \begin{matrix} 1 & 0 \\ . & 1 \end{matrix} \quad \begin{matrix} 0 & 1. \\ \frac{}{1} & 0 \end{matrix}$$

$$1:= \begin{matrix} 0 & 3. \\ \frac{}{3} & 0 \end{matrix}$$

K1, k2, and k3 are the filter inverters and i is the imaginary unit whereas w is the frequency. The ABCB matrix is to be converted into Y matrix and then add them up to a to obtain total Y matrix. Y matrix is changed into S-parameters so that we can get reflection coefficient, S11 and the reverse transmission coefficient, S12. The formulae below are the ones used for the conversion.

$$= \frac{(\; - \;)(\; - \;) +}{\Delta}$$

$$= \frac{-2}{\Delta}$$

To find the values of k1, k2 and k3 some conditions should be set to get the required response of S11 and S12.

$$= \pm 0.5, \qquad = 0$$

$$= \pm 1.0, \qquad = 0$$

$$= 0, \quad | \quad | = 0.99$$

The values for filter k1, k2 and k3 are as follows:

K1 =1.51970212

K2 = -0.86433789

K3 = -0.6757858553

The values obtained in the mathematical and theoretical analysis will be used to design microwave filter response. It will be based on the conditions set.

4.4 Ideal simulation in AWR

To get characteristics of the microwave filter such as transmission coefficient, S_{21} and reflection coefficient, S_{11} we used AWR Design Environment. Refer to Appendix A.1 for the schematic diagram of the of the quasi-elliptic dual mode filter in ideal.

As it can be seen the centre frequency is at 1GHz and there is also two transmission zeros in S_{12}. A dual mode response is shown by S_{11} at the centre frequency and ripple is more than 20dB as required. These responses are shown in fig.13, fig.14 and fig.15. This ideal filter design is to be changed into microstrip using AWR.

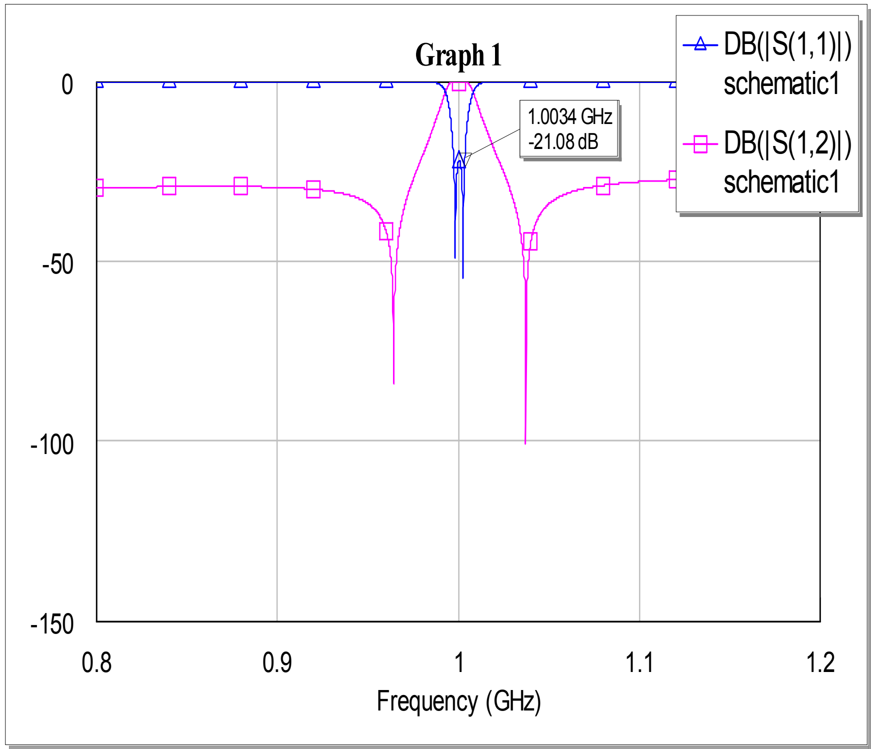


Figure 13: Simulated quasi-elliptic filter response

While simulating this ideal design, it was observed that when we change the electrical length of the filter, the filter will change its resonant frequency, its either it shifts centre frequency to higher frequency than the desired centre frequency of 1 GHz or to the lower frequency of below 1 GHz depending on whether you are increasing or decreasing the electrical length. This technique of playing with the electrical length helps to set the response to the desired centre frequency.

To bring the transmission zeros closer and also to make the transition from pass band to stop band is very fast, is where the capacitor that couples the input and the output comes into play. Without this coupling capacitor to couple the input and output together, the behavior of the filter response will be like that of a chebyshev filter. So this coupling capacitor plays a measure role in making the filter response look like an elliptic filter.

The figure below shows the transmission coefficient, S_{21} in ideal state with 0 dB losses, however this case cannot happen in microstrip because the material being been used will contribute to some losses. These losses should be kept to as minimum as possible though.

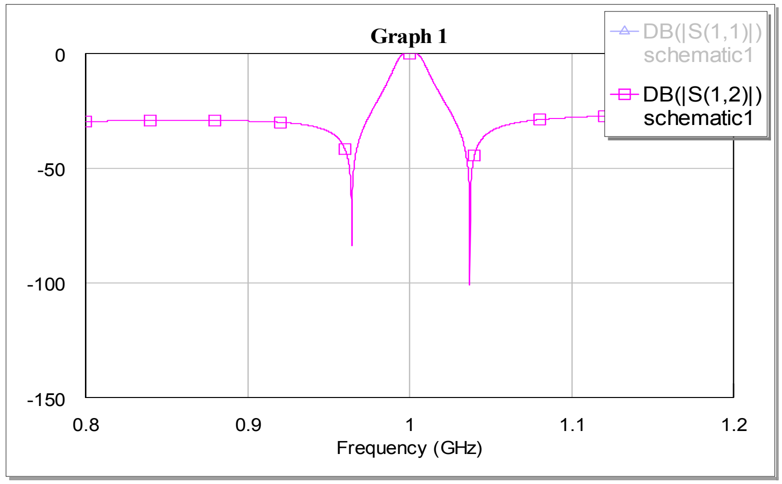


Figure 14: Transmission coefficient response, S21

The figure below shows the reflection coefficient, S_{11} in ideal state. This shows a dual mode response at the centre frequency where the ripple is more than 20dB as it is required.

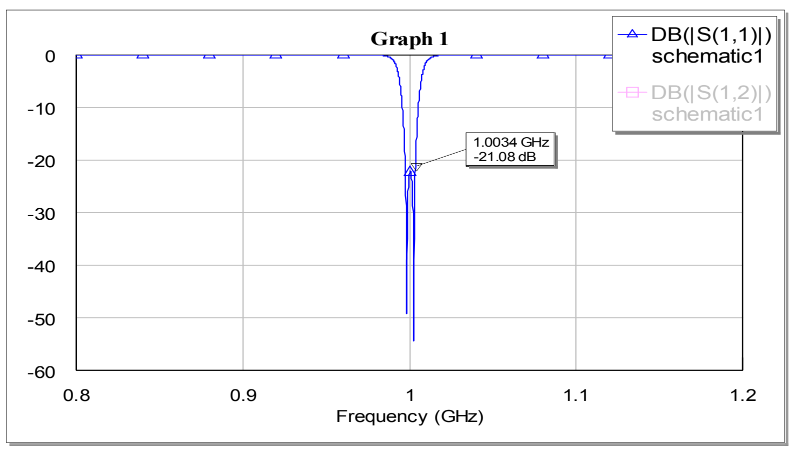


Figure 15: Reflection coefficient response

4.5 Microstrip simulation in ADS

The diagrams below will represent the responses of the dual mode quasi elliptic filter in microstrip. The schematic diagram of these responses is in appendix A.2

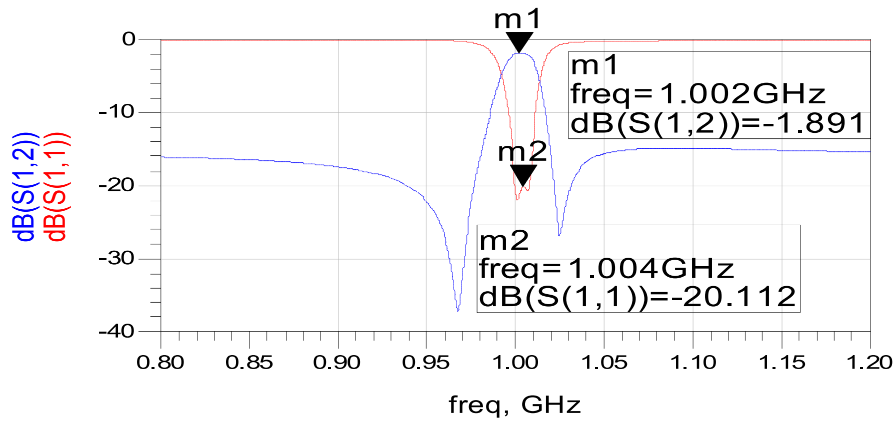


Figure 16: Simulated Quasi elliptic dual mode filter

It was observed in ideal situation that tuning the value of the electrical length it will shift the response to either higher or lower frequencies. It was again observed in the microstrip simulation that since we no longer use electrical length, we use instead length and width of the transmission lines, also tuning the value of the inductance in the line of symmetry to achieve the same purpose as in ideal.

The following graphs will represent the transmission and reflection response separately. As it can be seen, there is a loss of around 2dB in the transmission coefficient compared to 0dB in ideal case. In the reflection coefficient the ripple is more than 20 dB just like in ideal case. The loss in transmission coefficient S_{12} is because the design is in microstrip.

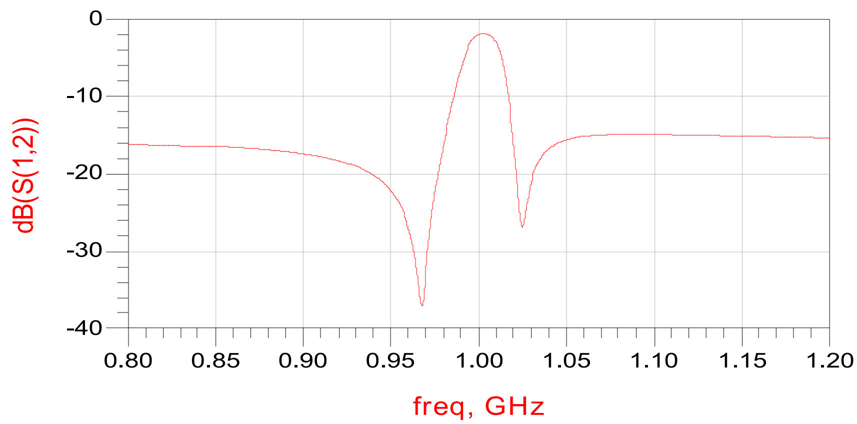


Figure 17: Transmission Coefficient in Microstrip

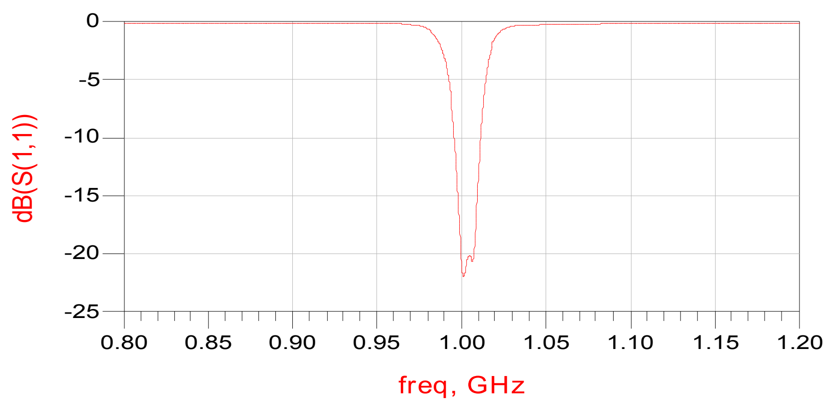


Figure 18: Reflection Coefficient in Microstrip

4.6 Momentum Simulation in ADS

This layout of the quasi elliptic filter was designed based on the microstrip simulation. It is generated from the physical design where microstrip elements were used. The layout is presented in fig 19. This layout is not quite exactly the way it should have been but it gives an idea of how the physical structure looks like. Because of limited time it has to be left the way it is here. With some effort to reduce the loss on transmission coefficient of the microstrip simulation it will have significant improvement in the physical structure of the layout. This is because it is generated from the microstrip simulation.

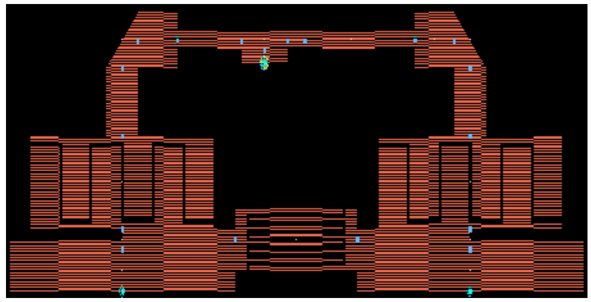


Figure 19: Layout of a quasi elliptic filter

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Conclusion

The main objective of this project was to study and understand the characteristics and behavior of the different kinds of microwave filters, then design a quasi-elliptic dual mode filter. The objectives were achieved but the latter part was not quite achieved because of the bigger loss in the transmission coefficient in microstrip simulation compared to the ideal case. It was found that there is a loss of around 2dB in the transmission coefficient compared to the 0 dB in the transmission coefficient of the ideal case. This loss is still considered to be large though. Some of the requirements of this quasi-elliptic filter were to have ripples of more than 20dB in its passband which has been archived in ideal state and microstrip simulation respectively. The centre frequency of 1 GHz and a bandwidth of less than 5% of the centre frequency were achieved.

Cost, size and weight of the microwave filters in today's microwave development seem to be of the importance. When designing a microwave filter focus must also be much on the mentioned factors and also not forgetting to design this filter in way that it will be of higher selectivity.

5.2 Recommendations

It is recommended to try and reduce the losses in transmission coefficient to be at least less than 1 dB, and the filter prototype be fabricated and then compare the results with the simulation results.

Since it is known that the higher the order of the filter the better the selectivity, so the order of this filter should also be increased for better selectivity. Using another substrate which might have low loss material properties might also be another way to improve the performance of the filter.

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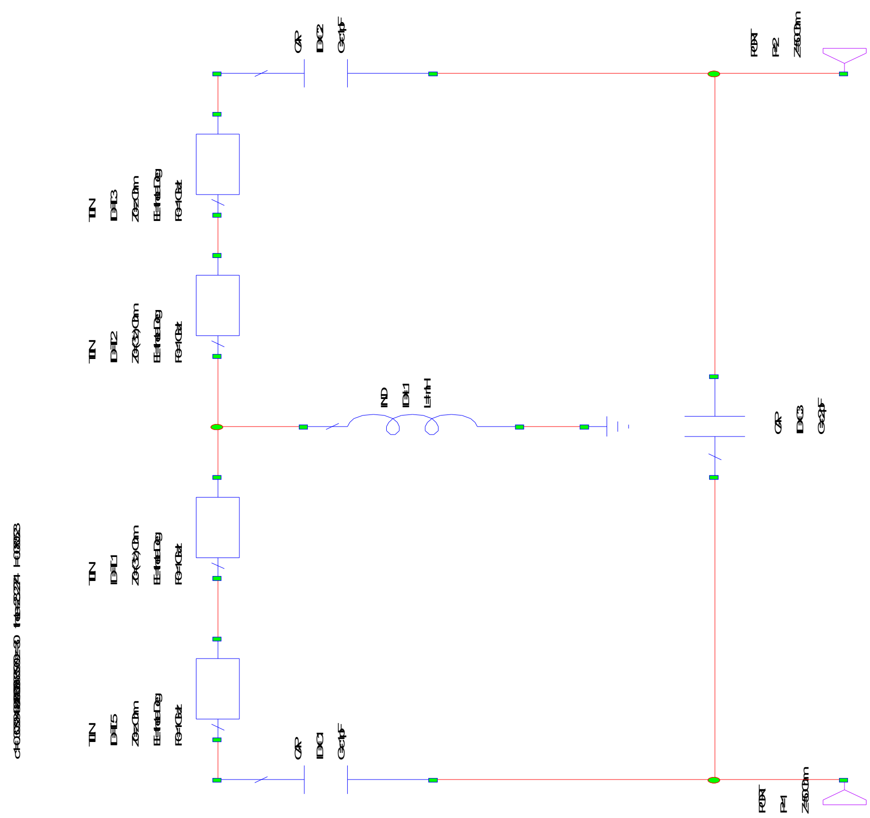
APPENDICE A: FIGURES

A1. Schematic of quasi-elliptic dual mode filter, ideal.



A:2 Schematic of Quasi-Elliptic dual mode filter design in Microstrip