# DESIGN OF QUASI-ELLIPTIC DUAL MODE FILTER

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(10696)

**FYP REPORT**

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
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# CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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(Electrical & Electronics Engineering)

Approved:

__________________________

Dr. Wong Peng Wen
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2011

## 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.

Kylie

Kylie Tan Yuen Pynng

# ABSTRACT

Microwave filters are usually designed to operate in the megahertz to gigahertz frequency range. The filters are used in many applications like broadcast radio, television, wireless communication and GSM [1]. So, these microwave devices will have some filter which decides which of the signals are transmitted or received. It is still a challenging problem for most designers today to build a filter that gives low loss and a sharp cut-off response with physically reduced size and complexity. For example cellular radio needs a remarkable filter performance [2]. Thus the project aims to design an elliptic dual mode resonator. This project is going to discuss in depth of the analysis and design of a quasi-elliptic dual mode filter. This project background study will include problem statement to justify this study, objectives, scope of study, relevance and feasibility study. Literature review will cover aspects like the characteristic of the dual-mode resonator, stepped impedance resonator, the even-odd mode analysis, transmission zero, insertion loss, spurious resonance frequency and quasi-elliptic filter that determines the filter response. The research methodology to be used and implemented will be discussed further. The data and information that have been collected and analyzed in this study will be used to design, fabricate and test the filter within the given period of time. Thus, some discussion and conclusion will be elaborated in the end.

## ACKNOWLEDGEMENTS

Thanks to the Lord that I manage to complete this study during my final year. It is a very short duration to do the report while working to complete the project. I would also like to thank Dr. Wong, my supervisor who has guided and helped me to accomplish and correct my mistakes in completing the project. I would like to appreciate Mr. Sovuthy who has kindly helped me to solve some problems during the design of this project. Lastly, thank you to those people who has contributed helped and guided me directly or indirectly along this journey.

**TABLE OF CONTENTS**

# LIST OF TABLES

# LIST OF FIGURES

# CHAPTER 1
# INTRODUCTION

This chapter gives a basic review of the background study of the project. Problem statement, the research objectives and scope of study are stated.

## 1.1 Background of Study

Microwave and radio frequency (RF) filters are designed to operate on signals in the medium to extremely high frequency range where this frequency may be from 300MHz to 300GHz which correspond to wavelengths of 1m to 1mm in free space [3]. These frequency ranges are used by most broadcast radio, television, wireless communication, GSM, civil and military radar systems [4]. So, these microwave devices will have some filter which decides which of the signals are transmitted or received. Most microwave filters are often made up of one or more coupled resonators. The resonator's unloaded quality factor will normally set the designed filter selectivity.

The fast expansion of wireless and mobile communications have highly demanded for new technologies and innovations to meet the challenge in making smaller filters with better performance and lower costs [5]. Dual mode filters are used widely in today's wireless communications systems because they have many advantages. These include their low loss, size which is small and largely being planar [6]. This means that each dual-mode resonator can act as a doubly tuned resonant circuit and therefore the quantity of resonators required for a given filter degree is halved resulting in a compact topology [7]. Most of the dual mode filters are designed by using patch resonator or dual mode ring where two orthogonal resonant modes create a dual mode response [8]-[10].

The microwave filter which acts like an elliptic filter has equalized ripple behaviour in both the passband (signals are allowed to flow) and stopband (signals are not allowed to flow). The amount of ripple in each bands are independently adjustable. Elliptic behavior gives the fastest transition between passband and stopband among the other kinds of filter but shows ripples on the whole bandwidth.

## 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 [2]. The proposed project aims to design a quasi-elliptic dual mode microwave filter and then it must be tested to verify that the design gives both elliptic and also a dual mode in its response.

## 1.3 Objective & Scope of Study

The objectives of this project are;

1. To understand the characteristics and behavior of the different types of microwave filters
2. To compare the ideal dual mode microwave filter with the new designed that will be developed by this project.
3. To investigate, design and simulate the quasi elliptic dual-mode microwave filter
4. To build and test by means of a prototype and verify simulation results

## 1.4 Relevancy

Today microwave systems have an enormous impact on modern society. There is still a high demand of smaller and better performance microwave band pass filters due its usage in a variety of applications. It is yet a challenging problem for most designers to come up with the best filter design. For example, communication base stations like GSMs need a very good performance filter to filter certain range of signal frequencies [1]. Satellite television and radars also needs a very good band pass filter in its transmission and receiving systems. So, future engineers like us must design better microwave filters to accommodate such requirements.

## 1.5 Feasibility

It is feasible to complete the project within the scope and time frame, while gaining knowledge for future improvements in this project.

During the first semester (FYP I), the scope and task that will be covered are;

1. Literature review on microwave filter designs.
2. Perform mathematical and theoretical analysis
3. Design an ideal circuit simulation in ADS
4. Design a microstrip simulation in ADS

For the following semester (FYP II), the scope and task that will be covered are;

5. Perform momentum simulation in ADS
6. Build and simulate the prototype simulation
7. Design and fabricate the prototype
8. Testing and measuring the filter response
9. Implementing the filter prototype
10. Improving the filter design

# CHAPTER 2
# LITERATURE REVIEW

This chapter will cover about the characteristics of the dual-mode resonator, stepped impedance resonator, the even-odd mode analysis, transmission zero, insertion loss, spurious resonance frequency and quasi-elliptic filter which determines the filter response.

## 2.1 Dual-Mode Resonator

Microwave filter with low insertion loss and small in size are demanded in the next generation mobile and wireless communication systems [1]. A compact design can be done with a planar microstrip technology with multi-mode resonators. Most of the dual mode filters are designed by using patch resonators or dual mode rings where two orthogonal resonant modes create a dual mode response [8]-[10].

Dual mode half-wavelength resonators has also been designed by introducing a transmission line of electrical length 180° shunt stub at mid point to achieve a dual mode response [11]-[12]. However the electrical length needed for the first design is still too large especially at lower microwave L or C bands while the second design has limited rejection bandwidth introduced by higher order resonance. This all can be overcome by the realization of a dual mode response using a stepped impedance dual mode resonator [13].

The dual mode resonator in microstrip is very attractive in most research is because the filter size can be reduced. This happens as the amount of resonating element can be decreased. The number of resonators required for a given degree of filter by using a dual mode resonator will be reduced to half compared to using a single mode filter [14].

## 2.2 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 [13]. They will be designed to be symmetrical for easier mathematical analysis and fabrication.

The design parameters usually taken for a microwave filter design are insertion loss, number of resonators, selectivity and bandwidth. As the number of resonators increase, the insertion loss also increases for a given bandwidth. As the bandwidth also gets narrower for given filter design, the filter insertion loss increases [15].

## 2.3 Even-odd mode analysis

An odd-even mode analysis is usually used to analyze such a proposed design as the design structure is symmetrical. For the odd mode analysis, the symmetry plane of the circuit design is virtually short circuited. On the other hand, for the even mode analysis, the symmetry plane of the circuit design is virtually open circuited [16].

## 2.4 Transmission Zero (TZ)

Transmission Zero (TZ) defines as the value of frequency for which there is zero transmission of power to the load or the signal is not able to pass through the network. Microwave filter uses the transmission zero frequencies together with the passband edge frequencies and passband ripple to form the transfer function between the input and output of the filter. Later this can be used for shaping the response of the filter to obtain the desired values [13].

The proposed design will improve the stepped impedance dual mode filter design by introducing a coupling between the source and load. This creates a quasi-elliptic response with two transmission zeros near the center frequency at any desired finite frequency. Transmission zeros created from the source–load coupling enhances the selectivity of the filter designed.

## 2.5 Insertion Loss

Insertion loss(dB) is the ratio of the amount of power received at the end of the line to the amount of power transmitted into the line. Microstrip line bandpass filters with low insertion loss must be designed by direct coupling and not using gap coupling because of the radiation loss [17]. The filter's bandpass insertion loss can be estimated based on the equation below [2].

$$\text{Insertion Loss (dB)} = \frac{4.343 * f0}{\Delta f * Q} * \sum_{i=1}^{N-1} g_i$$

The estimated insertion loss is calculated and compared to the measured insertion loss for analysis. To determine the position (frequency) of the two transmission zeros which describes when there is no power transmission to the load, we just need to solve $|S_{12}(j\omega)|^2 = 0$

## 2.6 Spurious Resonance Frequency

Microwave filters with effective suppression of spurious signals are highly desired for in wireless applications. In communication systems, the bandpass filter is a significant part which is usually used in both receivers and transmitters which is why the quality of the communication filters is extremely essential [18]. A wider upper stopband is necessary in order to reduce noise by keeping out of-band signals from reaching a sensitive receiver [19]

Spurious resonances are repetitions of the bandpass characteristics of the designed filter at frequencies other than the designed centered frequency. They are usually unwanted near the bandpass of the designed filter. In a filter design it is preferably to push the spurious frequency to higher frequency at least like multiples of the centered frequency [20].

The presence of undesired spurious frequencies is a fundamental limitation of microwave wave circuits [21]. Pushing the spurious resonances to higher multiples of the centered frequency away from the desired centered frequency is important in communication devices. This is because it defines the high performance and selectivity of our bandpass filter. The presence of spurious resonance near the center frequency can seriously degrade the performance of the bandpass filter. This feature might be critical in certain communication applications. The wide stopband bandpass feature is usually needed in filters coupled with nonlinear components like power amplifiers which functions to remove the undesired interference or noise in the stopband [22].

The spurious frequency of the designed filter can be estimated using the equation below assuming *fr* and *fs* are the fundamental passband resonance and the lowest spurious frequency respectively [13].

$$f_n = \frac{f_r}{f_s} = \frac{\Pi}{\tan^{-1}(\frac{1}{\sqrt{R}})} - 1$$

In the design where R=1/3 using the equation above, it can be calculated that the first spurious frequency occured at five times the fundamental frequency. This enables the filter to deliver a very broad rejection band desired by many communication filter researches.

## 2.7 Quasi-Elliptic Filter

A quasi-elliptic filter gives a response that has characteristics in between a chebyshev filter and an elliptic filter. The butterworth filter is a type of filter that has a flat as possible frequency response in the passband. It is also known as the maximally flat filter.

On the other hand, the chebyshev filters are filters with a less steeper roll than the elliptic filter. They also have more passband ripple (type I) and stopband ripple (type II) than the butterworth Filter. Unlike a chebyshev filter, the elliptic filter has equalized ripples in both the passband and the stopband.

High-performance bandpass filters with low insertion loss, compact in size, wide stopband, and higher selectivity are essential for today's communication systems [23]. An elliptic filter is preferred as it gives a sharp roll off because of its finite transmission zeros. Unfortunately its transmission zeros are fixed and cannot be changed according to preference. So, we have to use a generalized chebyshev approximation to obtain a nearly like elliptic response known as a quasi-elliptic response.

In this design, using the generalized chebyshev approximation function we can place the required transmission zeros at any desired finite frequency. Recently the microstrip filters with a generalized chebyshev response attract substantial interest because it is light in weight, easy to fabricate and able to produce finite transmission zeros for sharp skirts [24]. The transmission zeros can be placed at both symmetric and asymmetric frequency responses to give high filter selectivity.

Better performance and higher selectivity for a dual mode bandpass filter is needed because frequency spectrums get more crowded each day and narrower channels have to be specifically filtered with no interference. Thus the design incorporates a stepped impedance dual mode resonator design with a source-load coupling to give it a quasi-elliptic dual mode response. This design will also be able to reduce size and complexity in future filters designs which are needed in today's wireless communication systems such as cellular radios [23].

The method used to introduce the two transmission zeros for the quasi elliptic dual mode filter is by coupling the source and load ports by a capacitive element. In the design, the center capacitive element parameters will affect the positions of the transmission zeros in the filters response. For this design topology, as the capacitance value increases, the two finite transmission zeros will grow closer towards the center frequency of 1GHz. However, the return loss at the stopband decreases and the filter's bandwidth increases as well. This is an important design trade off that should be taken into account for future design improvements.

This filter will be designed to have a bandwidth less than 5% of its centered frequency in S11and two transmission zeros in S12 to achieve a high selectivity like in an elliptic filter. It is required to have some ripples of more than 20dB in the passband and small insertion loss.

# CHAPTER 3
# METHODOLOGY

Methodology is a chapter that will cover the process and flow through this project. Although we have project activities and Gantt chart, we will also brief the milestone and equipment used.

## 3.1 Methodology

Method to be adopted are as follows:

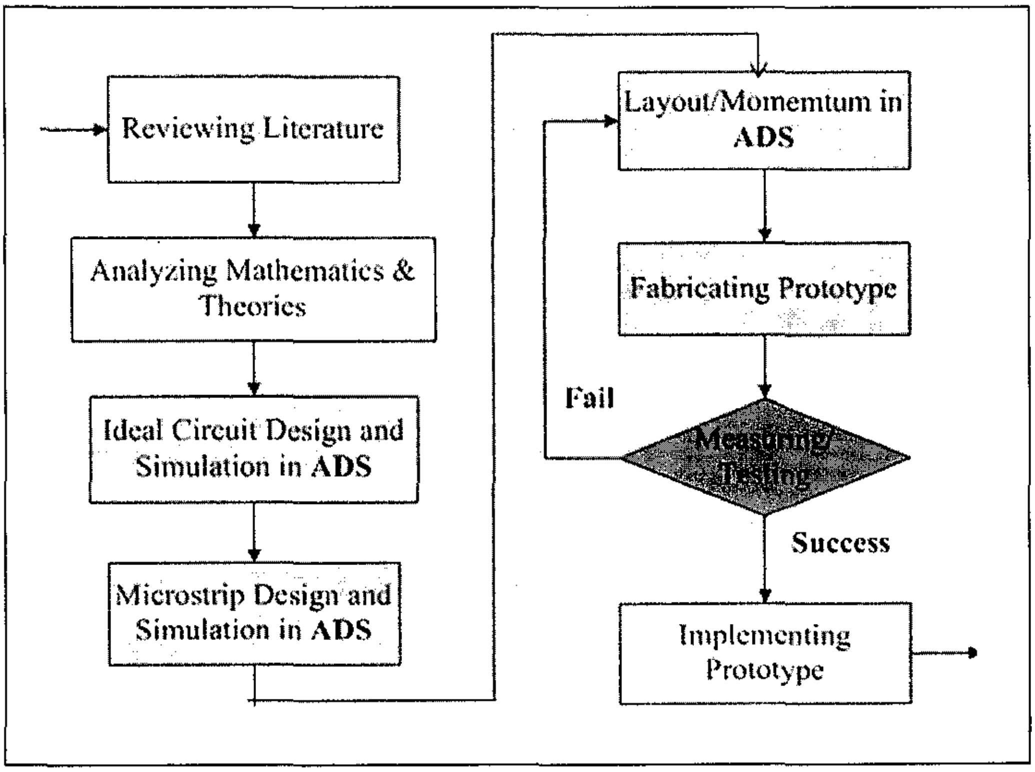



**Figure 3.1: Methodology for the project**

### 3.2 Project Activities

The activities in this project are;

1. Reading and research materials that could expand knowledge on microwave filter design
2. Mathematic and theoretical analysis on the filter design
3. Designing the filter (ideal and microstrip) in ADS
4. Layout or momentum simulation in ADS
5. Build Prototype in PCB lab
6. Testing and measuring the filter response where some modifications might need to be made to improve the results given
7. Implement the completed prototype

### 3.3 Gantt Chart & Key milestone

The Gantt Chart for FYP I and FYP II are as shown below:

**FYP I Gantt Chart**

| Detail week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Selection of Project Topic | ■ | ■ | | | | | | | | | | | | |
| Preliminary Research Work | | ■ | ■ | ■ | | | | | | | | | | |
| Submission of Preliminary Report | | | | ■ | | | | | | | | | | |
| Seminar 1 (optional) | | | | | ■ | ■ | ■ | | | | | | | |
| Mathematic and Theory Analysis | | | | | ■ | ■ | ■ | | | | | | | |
| Designing in ADS | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Simulation in Momentum ADS | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Seminar 2 (compulsory) | | | | | | | | | ■ | ■ | ■ | ■ | | |
| Prepare reports and documents | | | | | | | | ■ | ■ | ■ | ■ | ■ | | |
| Submission of Interim Report Final Draft | | | | | | | | | | | | | ■ | |
| Oral Presentation | | | | | | | | | | | | | | ■ |

**Table 3.1: FYP I Gantt chart**

**FYP II Gantt Chart**

| Detail week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Designing in ADS | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Simulation in Momentum ADS | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Building Prototype | ■ | ■ | ■ | | | | ■ | ■ | | | | | | |
| Submission of Progress Report 1 | | | | ■ | | | | | | | | | | |
| Project Work Continue | | | | ■ | ■ | ■ | ■ | | | | ■ | | | |
| Testing and verifying | | | | ■ | ■ | ■ | | | ■ | ■ | | | | |
| Submission of Progress Report 2 | | | | | | | | ■ | | | | | | |
| Seminar (compulsory) | | | | | | | | | ■ | ■ | | | | |
| Prepare for writing journals and documents | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Poster Exhibition | | | | | | | | | | | | | ■ | |
| Submission of Dissertation (soft bound) | | | | | | | | | | | | ■ | | |
| Oral Presentation | | | | | | | | | | | | | | ■ |
| Submission of Project Dissertation (Hard Bound) | | | | | | | | | | | | | | ■ |

**Table 3.2: FYP II Gantt chart**

The key milestones of this project are as follows:

| Status | Activity | Start | End |
|---|---|---|---|
| FYP 1 | Literature review | Week 1 | - |
| | Mathematical/Theory Analysis | Week 5 | Week 7 |
| | Ideal Circuit Simulation in ADS | Week 9 | Week 10 |
| | Microstrip Simulation in ADS | Week 10 | Week 13 |
| FYP 2 | Momentum Simulation in ADS | Week 1 | Week 4 |
| | Prototype Simulation | Week 4 | Week 7 |

| | | | |
|---|---|---|---|
| | Prototype Fabrication | Week 7 | Week 8 |
| | Testing/ Measuring | Week 8 | Week 9 |
| | Implementation | Week 10 | - |

**Table 3.3: Key milestone of project**

## 3.4 Materials & Facilities Used

**Materials**

- Hardware required: Network analyzer and PC
- Software required: ADS, Maple and Mathlab

**Facility**

- Computer Lab
- PCB Lab

# CHAPTER 4
# RESULTS AND DISCUSSIONS

This chapter will briefly explain the mathematical and theoretical analysis that has been done to design the microwave filter.

## 4.1 Mathematical and Theoretical Analysis

### 4.1.1 Quasi Elliptic Dual Mode Resonator Topology

Below is the design topology for the quasi-elliptic dual mode resonator topology that will be used for this project. This topology is designed to be symmetrical for simplicity. There is an inductor and an capacitive element at the line of symmetry. There are also transmission lines with different electrical lengths $Z_1$, $Z_2$ and electrical lengths of $\theta_y$, $\theta_x$ respectively at both sides of the topology.

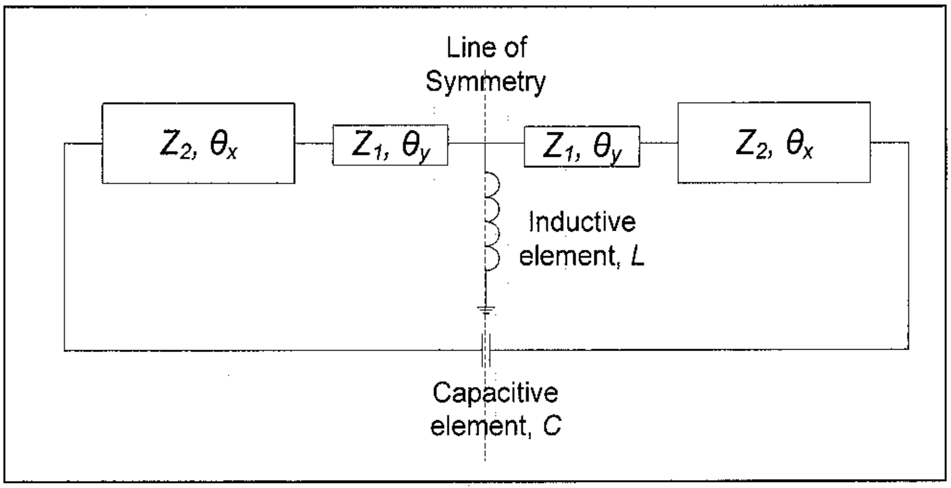



**Figure 4.1: Filter design topology**

### 4.1.2 Coupling and Routing Structure

Another way to represent our filter design topology is using the coupling and routing structure where further analysis will be shown below [24]- [29]. Shown below is the design structure of the project microwave filter using the coupling and routing structure. The circles represent the poles of the filter while the lines are the inverters of the filter. Later this circuit will be analyzed using the ABCD and Y matrix to obtain the desirable response. In the figure below, there are input and output ports where K1, K2 and K3 are the filter inverters.

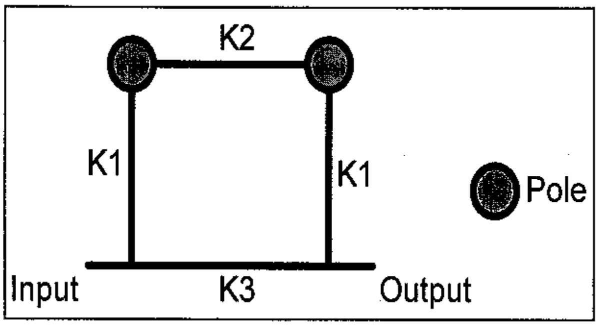



**Figure 4.2: Filter design in coupling and routing structure**

### 4.1.3 Transfer matrix

After drawing the coupling and routing structure, the coupling and routing structure will be analyzed using the ABCD and Y matrix as it's simpler. The upper and lower ABCD matrixes are as follows [30]:

$$T1 := \begin{bmatrix} 0 & k1 \cdot i \\ \frac{i}{k1} & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ i \cdot w & 1 \end{bmatrix} \cdot \begin{bmatrix} 0 & k2 \cdot i \\ \frac{i}{k2} & 0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 \\ i \cdot w & 1 \end{bmatrix} \cdot \begin{bmatrix} 0 & k1 \cdot i \\ \frac{i}{k1} & 0 \end{bmatrix};$$

$$T2 := \begin{bmatrix} 0 & i \cdot k3 \\ \frac{i}{k3} & 0 \end{bmatrix}$$

where *k1, k2, k3* are the filter inverters, i is the imaginary unit and *w* is the frequency. Taking both ABCD matrix and converting them into Y matrix and later adding them up to obtain the Y total matrix. Then we change the Y matrix to S-parameters to obtain input reflection coefficient, $S_{11}$ and the reverse transmission coefficient, $S_{12}$ [16]. The formula used are as follows:

$$S_{11} = \frac{(Y_0 - Y_{11})(Y_0 + Y_{22}) + Y_{12}Y_{21}}{\Delta Y}$$

$$S_{12} = \frac{-2Y_{12}Y_0}{\Delta Y}$$

Some conditions are set to obtain the required response for S11 and S12. Then, the values for k1 ,k2, k3 are obtained with the conditions given which are as below:

1. $\omega = \pm 0.5$, $S_{11} = 0$
2. $\omega = \pm 1.0$, $S_{12} = 0$
3. $\omega = 0$ , $|S_{11}|^2 = 0.99$

### 4.1.4 Result of Mathematical Analysis

- k1= 1.51970212
- k2= -0.86433789
- k3= -0.67578553
- S11 $= \dfrac{1.092e6\omega^4 - 5.433}{3.369^9\omega^4 - 6.035^9\omega^2 + 2.93^9}$
- S12 $= \dfrac{2.900^9(\omega^2 - 1)^2}{3.369^9\omega^4 - 6.035^9\omega^2 + 2.93^9}$

Below is the graphical representation of S11 and S21:

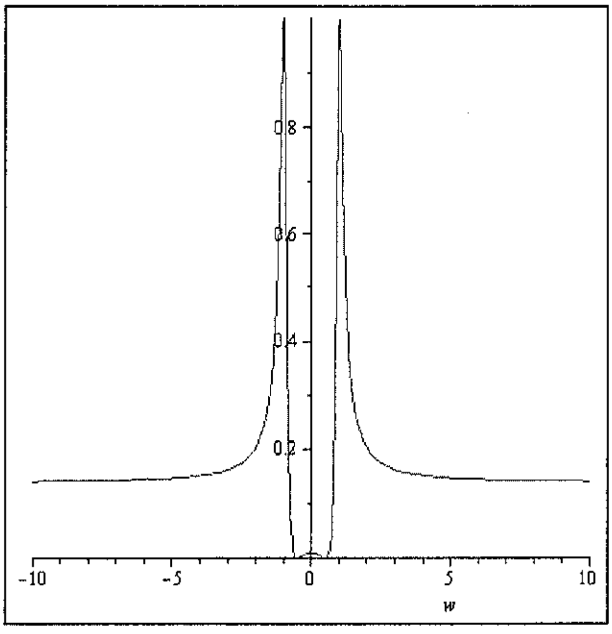



**Figure 4.3: Graphical representation of S11**

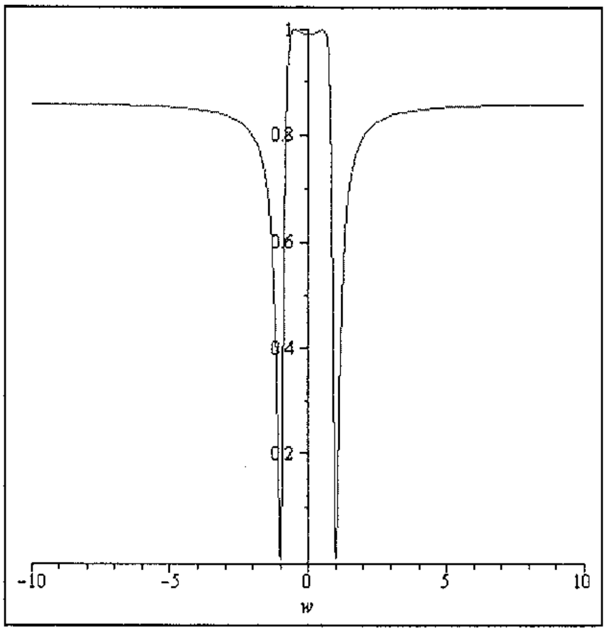



**Figure 4.4: Graphical representation of S21**

As it can be seen above, the mathematical and theoretical analysis of the microwave filter has been analyzed and will be successfully used in our work to design our microwave filter response. The design will be done using the mathematical analysis based on the conditions set earlier.

## 4.2 Ideal simulation in ADS

Please refer to Appendix A.1 for the schematic diagram for the ideal quasi-elliptic dual mode filter in ideal case. After some tuning to obtain the required filter response centered at 1 GHz, we change the filter design into microstrip using ADS as seen in Appendix A.2

After tuning the above microstrip design we will obtain the desired frequency response as below. The center frequency is at 1 GHz and we can see there are two transmission zeros in $S_{12}$. There is also a dual mode response at the center frequency show by $S_{11}$ where the ripple given is more than 20dB as desired. The bandwidth is also shown to be less than 5% of the centre frequency that gives a quasi-elliptic response.

The filter response should be like the simulated response using ADS in Figure 4.5.

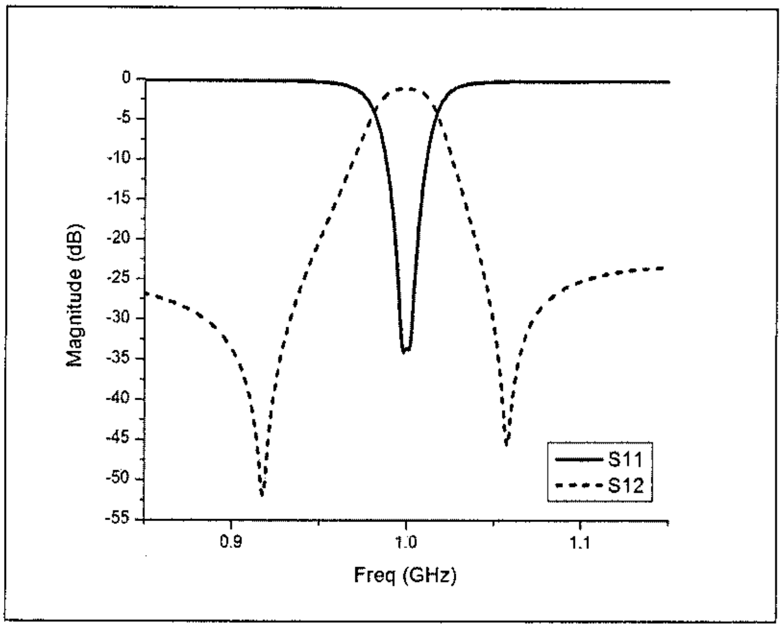



**Figure 4.5: The simulated quasi-elliptic dual mode filter response**

### 4.3 Momentum Simulation in ADS

The layout for this quasi-elliptic dual mode filter is then designed based on the filter design in microstrip using ADS. The layout substrate is based on the Duroid 5880 characteristics that will used later for fabrication. Figure 4.6 shows the layout that was designed in ADS.

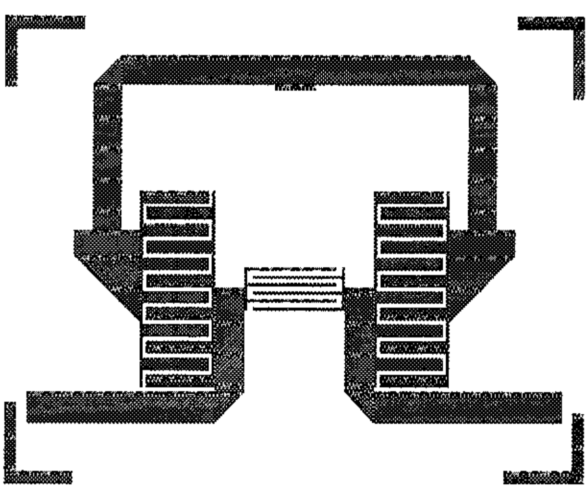
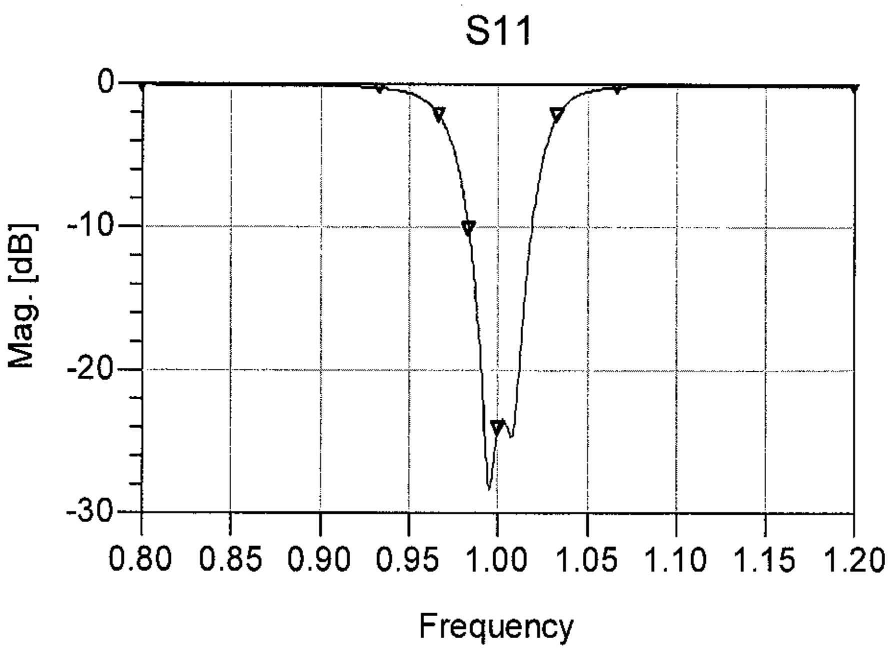


**Figure 4.6: The quasi-elliptic dual mode filter layout in ADS**

Then a momentum simulation will be done on the completed layout to obtain a more accurate filter response. After some modifications on the layout to obtain a preferable response, the $S_{11}$ and $S_{12}$ responses obtained are as figure 4.7.



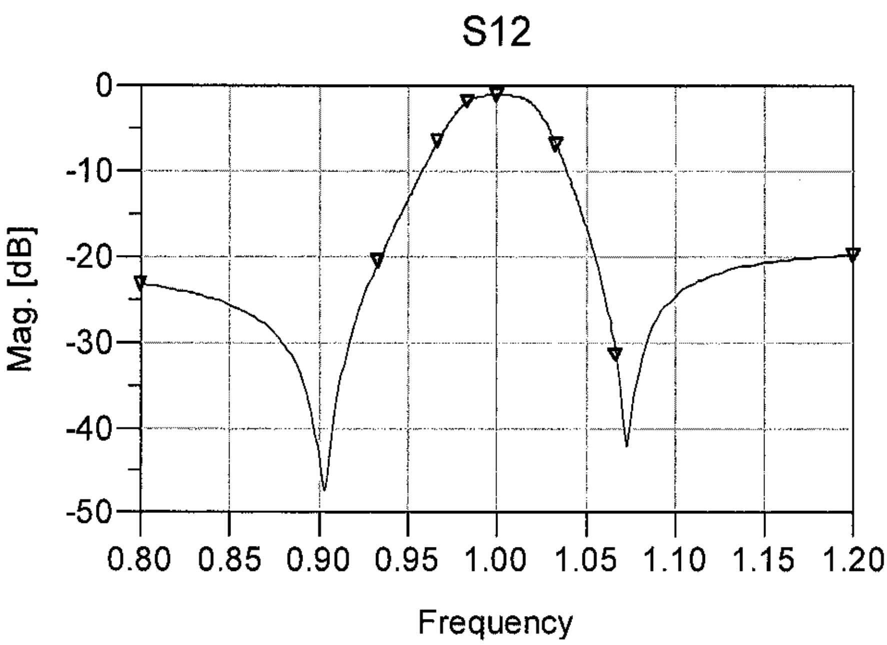




**Figure 4.7: Momentum quasi-elliptic dual mode filter response in ADS**

The responses are within the conditions that we require. The center frequency is at 1GHz and there are two transmission zeros in $S_{12}$. There is also a dual mode response at the center frequency show by $S_{11}$ where the ripple given is more than 20dB as desired. The bandwidth is also shown to be less than 5% of the centre frequency as required by an elliptic response.

The next step is fabrication of the filter in the PCB lab. The prototype will be tested and the response will be measured which hopefully will give us the same response like in the momentum simulation.

### 4.4 Prototype Fabrication

After a few days of fabrication in the PCB lab, the circuit has to be drilled at it's via hole of 1mm diameter. Then the hole should be soldered via the hole to the ground plane at the back of the circuit. The input and output ports will be soldered to pins for measurement using a network analyzer. The end result looks like Figure 4.8.

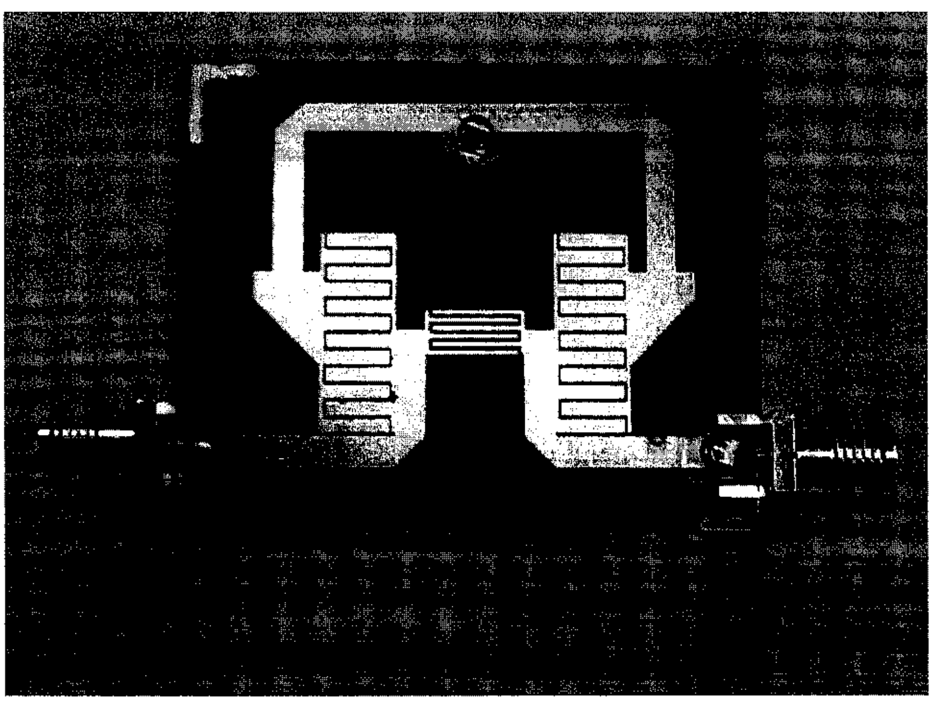


**Figure 4.8: Fabricated and soldered quasi-elliptic dual mode filter**

Later, we measure the filter response using a network analyzer available in the lab. Initially the network analyzer is calibrated with a set of instruments before measurement. The filter response obtained from the network analyzer is as below.

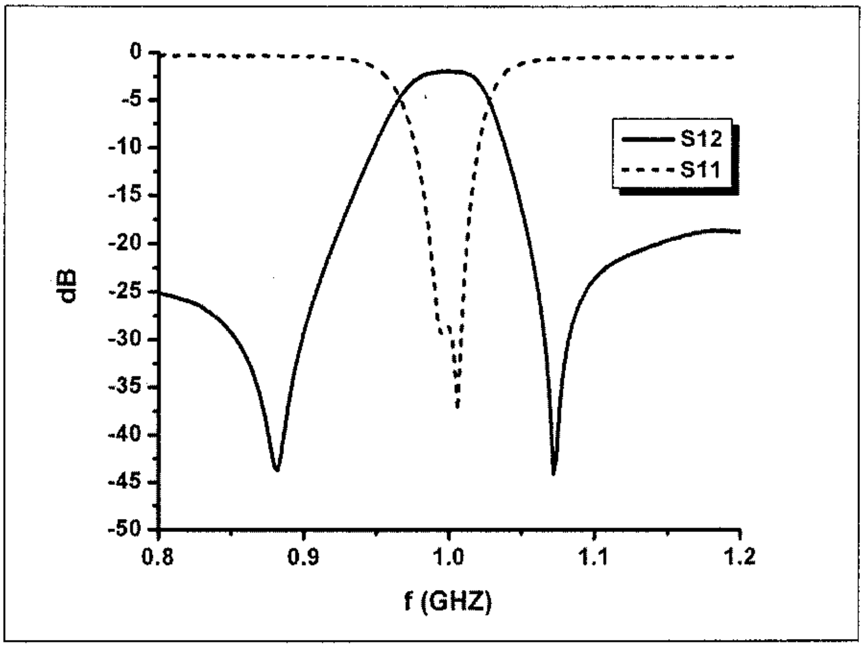



**Figure 4.9: Measured quasi-elliptic dual mode filter response**

We can observe the response is centered at around 1 GHz and there are two transmission zeros in $S_{12}$. There is also a dual mode response at the center frequency show by $S_{11}$ where the ripple given is more than 20dB as required. The bandwidth is also shown to be less than 5% of the centre frequency. This shows that we have successfully designed a quasi-elliptic dual mode filter.

## 4.5 Prototype Improvements

From a quasi-elliptic dual mode filter, we used the same concept to improve our filter into a quasi-elliptic four mode filter. Using the same procedures as above, we shall design such a filter.

Please refer to Appendix A.3 for the schematic diagram for the ideal quasi-elliptic four mode filter in ideal case. After some tuning to obtain the required filter response also centered at 1 GHz, we change the filter design into microstrip using ADS as seen in Appendix A.4

After tuning the above microstrip design we will obtain the desired frequency response as below. The center frequency is at 1 GHz and we can see there are two transmission zeros in $S_{12}$ like in the quasi-elliptic dual mode filter. However this time there is a four mode response at the center frequency show by $S_{11}$ as desired. The bandwidth is less than 5% of the centre frequency which gives a quasi-elliptic response.

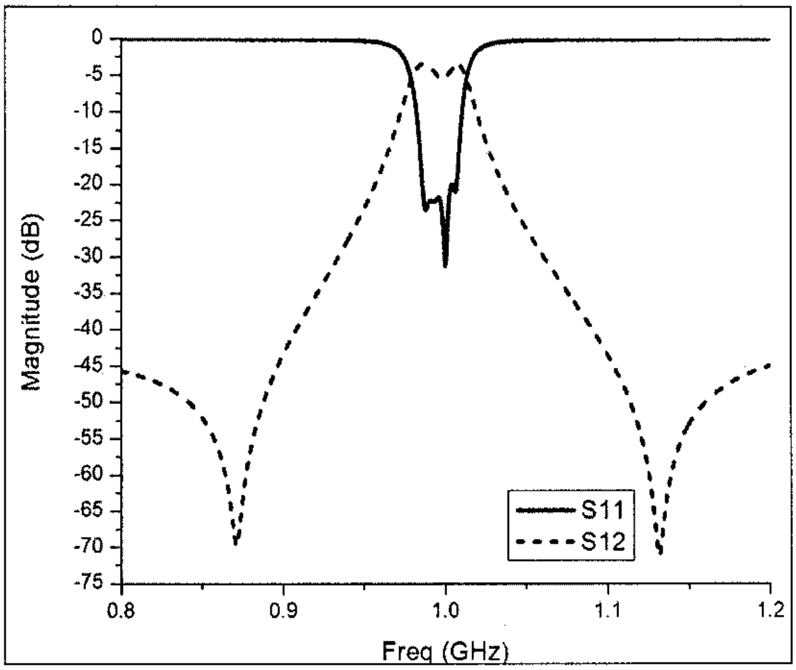



**Figure 4.10: The simulated quasi-elliptic four mode filter response**

The layout for this quasi-elliptic four mode filter is designed from the filter design in microstrip in ADS. The layout substrate is based on the Duroid 5880 characteristics that will used later for fabrication. Figure 4.11 shows the layout that was designed in ADS.

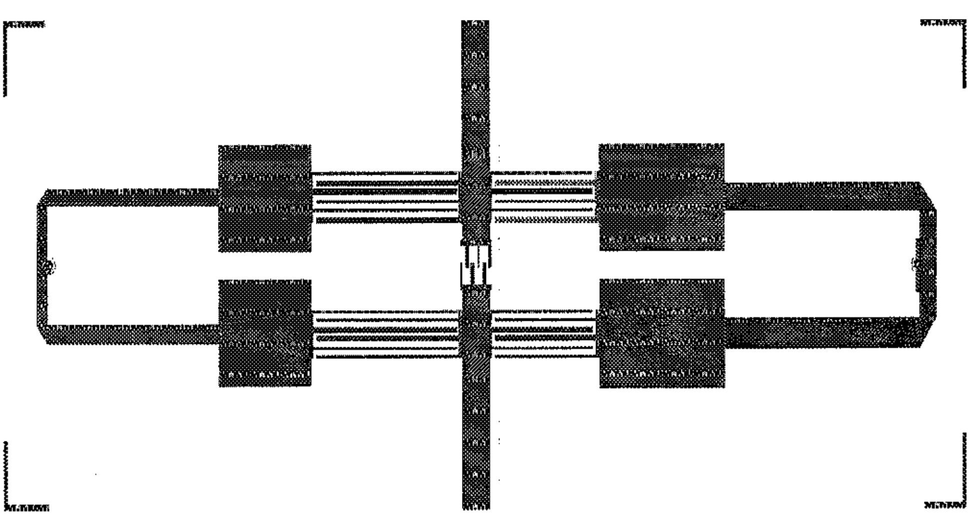


**Figure 4.11: The quasi-elliptic four mode filter layout in ADS**

Then a momentum simulation will be done on the completed layout to obtain a more accurate filter response. After some modifications on the layout to obtain a preferable response, the $S_{11}$ and $S_{12}$ responses obtained are as figure 4.12.

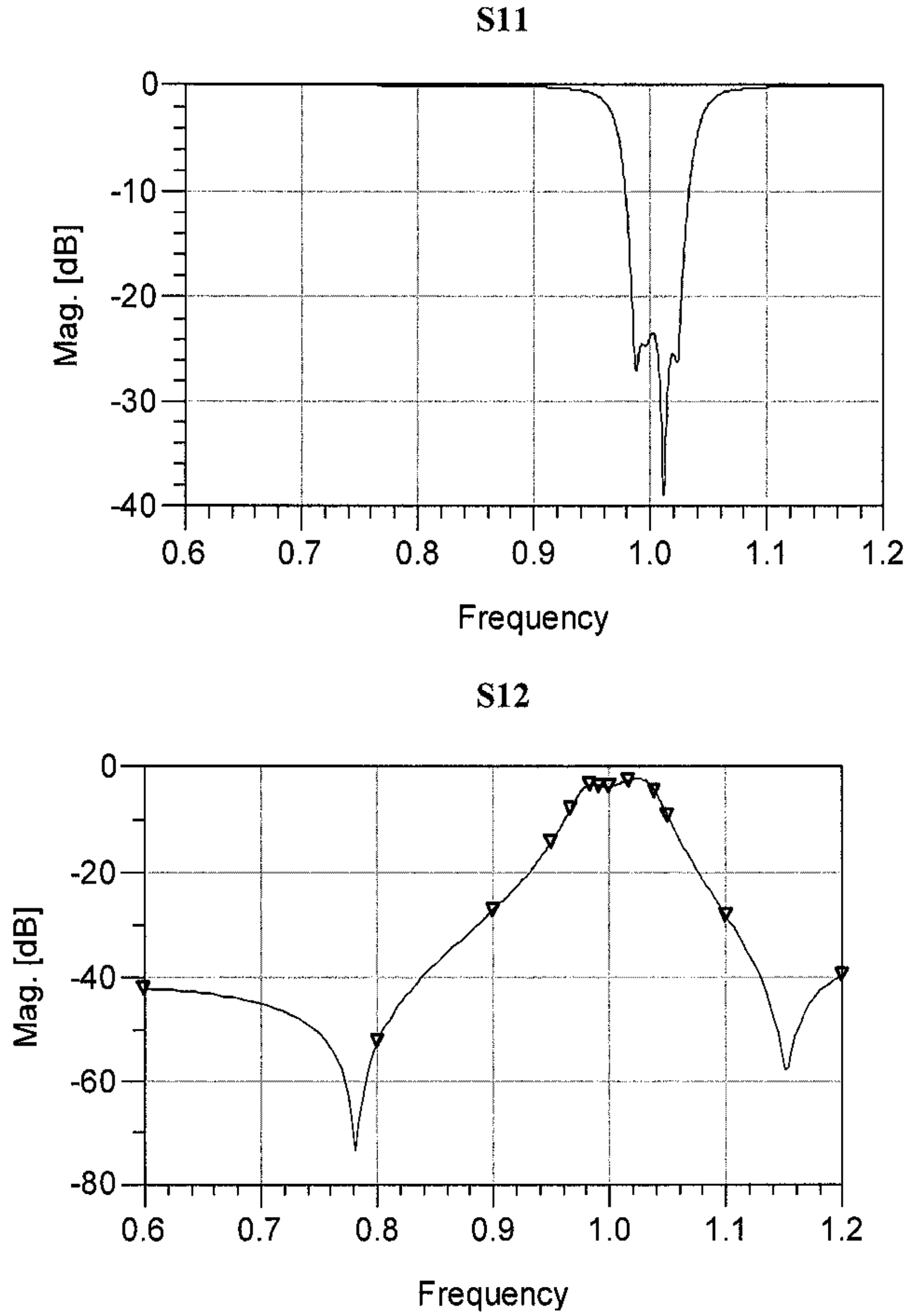



**Figure 4.12: Momentum quasi-elliptic four mode filter response in ADS**

The responses are within the conditions that we required. The center frequency is at 1

GHz and there are two transmission zeros in $S_{12}$. There is also a four mode response at the center frequency shown by $S_{11}$ where the ripple given is more than 20dB as desired. The bandwidth is also shown to be less than 5% of the centre frequency as required by a quasi-elliptic response.

The next step is fabrication of the filter in the PCB lab like the previous filter. The prototype in Figure 4.13 will be tested and the response will be measured which will hopefully give us the same response like in the momentum simulation.

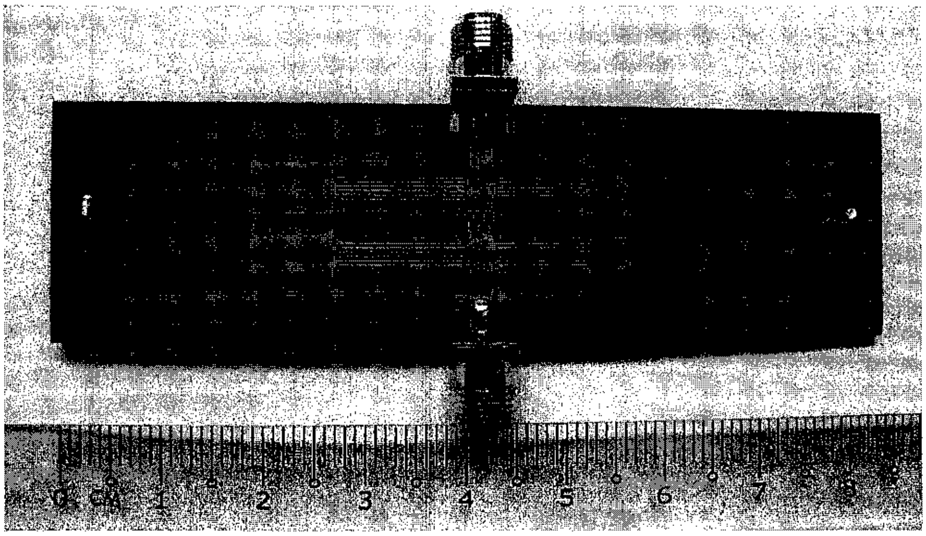


**Figure 4.13: Fabricated and soldered quasi-elliptic four-mode filter**

After a few days of fabrication in the PCB lab, the circuit has to be drilled with now two of it's via hole of 1mm diameter compared to the dual mode filter. Then the hole should be soldered via the hole to the ground plane at the back of the circuit. The input and output ports will be soldered to pins for measurement using a network analyzer. The end result looks like Figure 4.13.

The filter response is measured using a network analyzer available in the communication lab. The network analyzer is calibrated with a set of instruments before measurement. The filter response obtained from the network analyzer is as below.

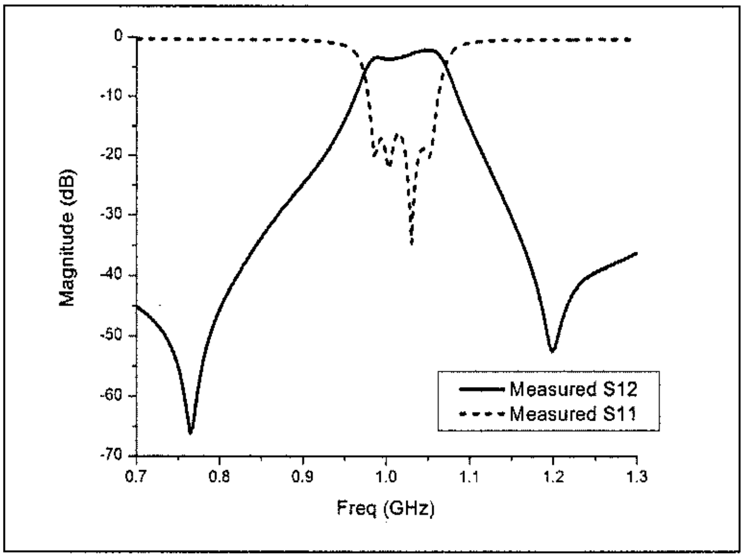



**Figure 4.14: Measured quasi-elliptic four mode filter response**

We can observe the response is centered at around 1 GHz and there are two transmission zeros in $S_{12}$. There is also a four mode response at the center frequency shown by $S_{11}$ where the ripple given is more than 16dB. The bandwidth is about less than 9% of the centre frequency. This measured result is not the same as our simulation as it there is some loss in the microstrip fabrication. We can improve this by using less lossy material for our substrate. However, the response still showed that we have successfully designed a quasi-elliptic four mode filter with some loss.

# CHAPTER 5

# CONCLUSION & RECOMMENDATION

This chapter provides discussion and conclusion of the Final Year Project Part I and II. All the topics are covered such as literature review of the microwave design, the mathematical/ theoretical analysis, the results and discussions for quasi-elliptic dual mode and quasi elliptic four mode filter design.

## 5.1 Conclusion

Overall, the project's objective is to design and build a quasi-elliptic dual-mode microwave filter. The mathematical analysis had been done to determine the response of the microwave filter. Later we designed the ideal and microstrip design of our quasi-elliptic dual mode filter. These objectives were done under Final Year Project I. Later in final year project II the design was build into a layout and a momentum simulation in ADS was done. Later the prototype is fabricated, tested and measured for the filter response.

We also improve the quasi elliptic dual-mode microwave filter by building the quasi-elliptic filter in a higher order. The filter gives us a four mode response for higher selectivity. This improved filter went through the same procedures used to design, simulate, build, test and measure the quasi-elliptic dual mode filter.

## 5.2 Recommendation

There are different factors that determine the design of microwave filters. Thus, these different factors should be analyzed to improve the filter design in the future like the filter's size. There are also different requirement and parameters that are needed in different microwave filter design like the medium or substrate used. We can always explore these other alternatives for a better filter response.

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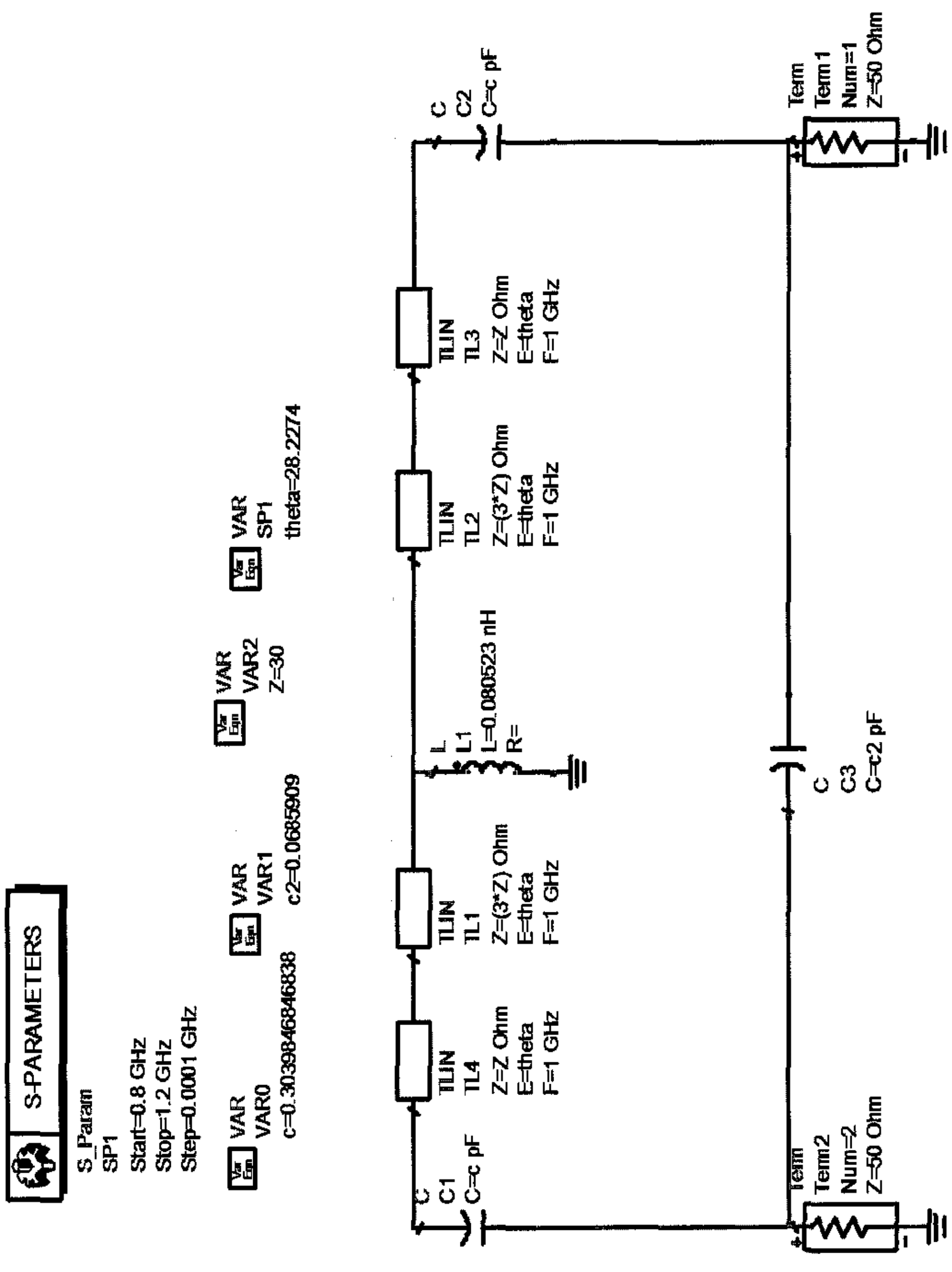
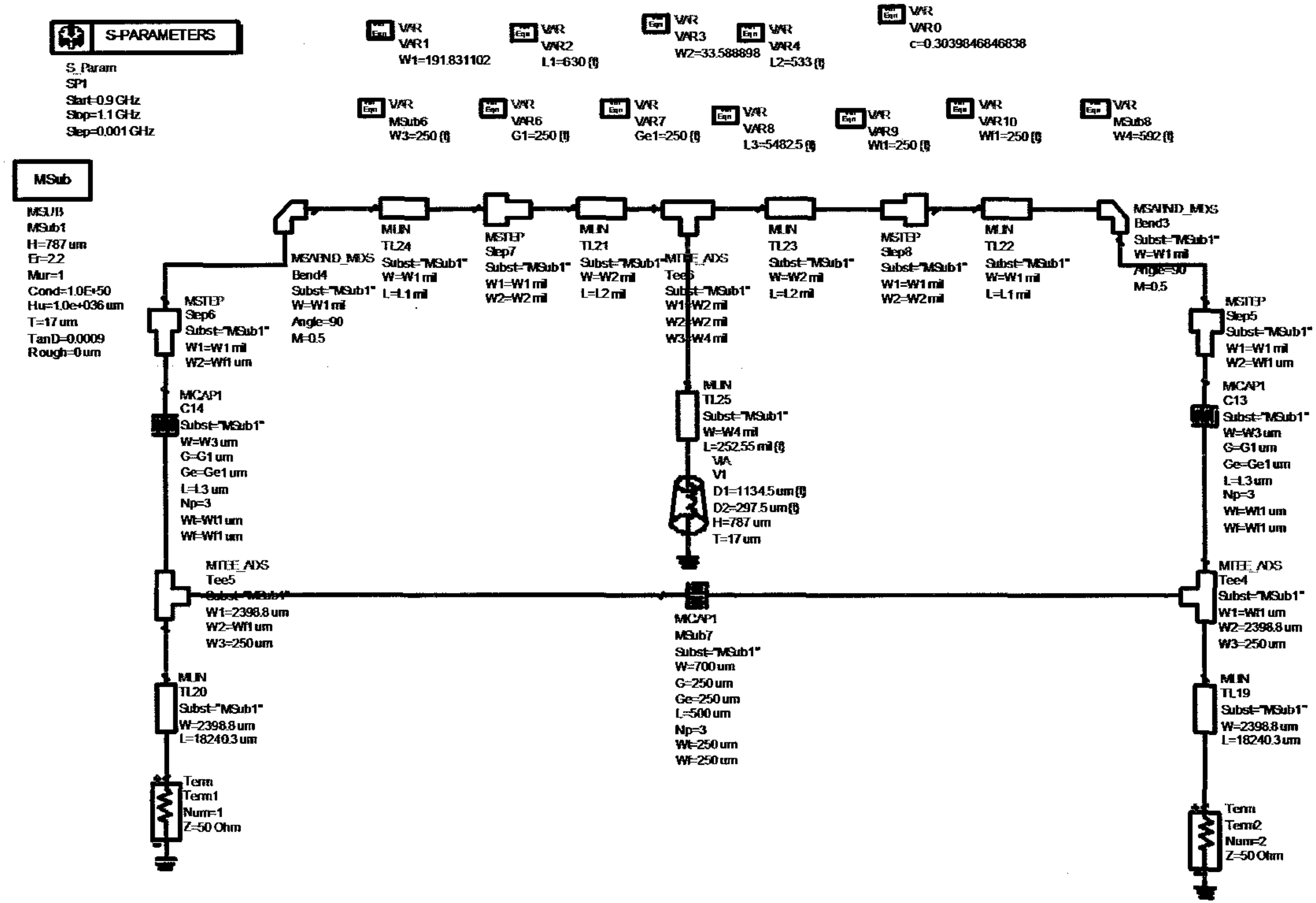
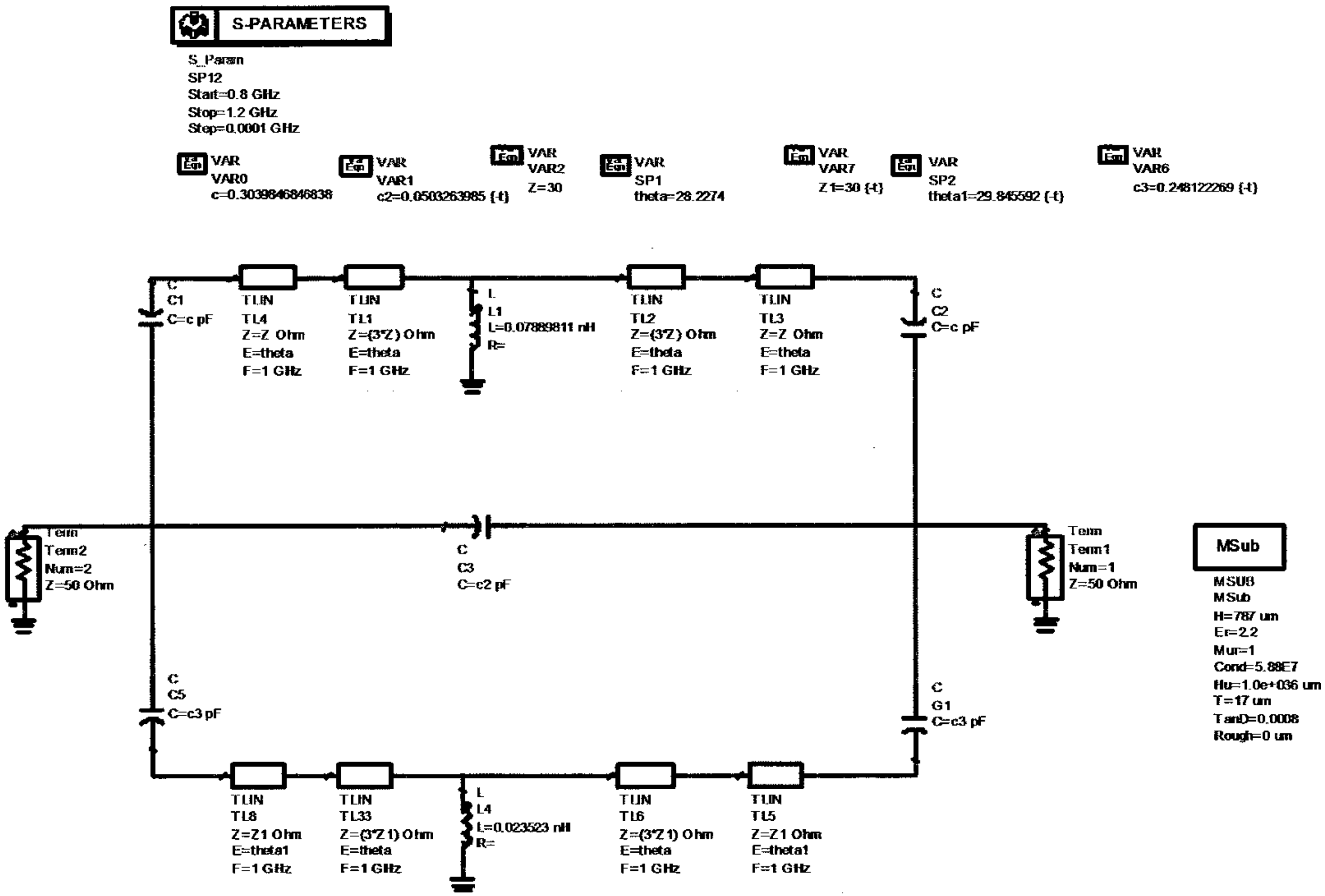
# APPENDIX A: FIGURES

## A.1. Schematic quasi-elliptic dual mode filter design in ideal






A.2. Schematic quasi-elliptic dual mode filter design in microstrip




## A.3. Schematic quasi-elliptic four mode filter design in ideal

# A.4. Schematic quasi-elliptic four mode filter design in microstrip