HIGH PERFORMANCE 3-DIMENSIONAL WAVEGUIDE CAVITY BANDPASS FILTER OPERATES AT 5.1 GHZ FOR SPECTRUM ANALYZER

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BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : High Performance 3-Dimensional Waveguide Cavity Bandpass Filter Operates at 5.1 GHz for Spectrum Analyzer

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Signature	: ....
Supervisor's Name	: PM Dr. Badrul Hisham bin Ahmad
Date	: 13th June 2016

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ABSTRACT

Microwave systems have a vast impact towards the modern society due to the development and advanced of microwave applications. Filters are one of the important parts in microwave applications that are used to discriminate between wanted and unwanted frequencies in a device. In any devices, filters play as the main key to distinguish the devices in term of the device's performance and cost especially in the congested spectrum. Thus, this thesis presents the design of High Performance 3-D Waveguide Cavity Bandpass Filter for Spectrum Analyzer Application. The filter will provide high frequency selectivity and low insertion loss that will be the main keys criteria for high Q filter design which will result in high performance of the filter. The design process will be used the lossless Chebyshev lowpass prototypes as the starting point and followed by the transformation of the lowpass prototype to waveguide cavity bandpass filter. The simulation of the design with the aid of HFSS software will be tuned and optimized in order to obtain the desired specification for the waveguide filter. The 3-D waveguide cavity bandpass filter would be very useful in the microwave systems especially in spectrum analyzer since the low insertion loss and high frequency selectivity that is provided by the filter are essential factors in obtaining high performance filter. Besides, the filter is designed in a simpler design with a smaller size since the minimum number of resonator will be used in the design thus it will decrease the manufacturing cost of this filter. By comparing between the research done and this project, it can be said that the smaller the size of the waveguide cavity bandpass filter, the higher the value of Q factor obtained. Since the project provides a smaller size filter, it is successfully provide a high performance 3-D waveguide cavity bandpass filter for spectrum analyzer application.

ABSTRAK

Sistem gelombang mikro telah memberi kesan yang besar terhadap masyarakat moden disebabkan oleh perkembangan dan kemajuan aplikasi gelombang mikro. Penapis adalah salah satu bahagian yang penting dalam aplikasi gelombang mikro dan digunakan untuk membezakan antara frekuensi yang dikehendaki dan frekuensi yang tidak diingini dalam peranti. Di dalam mana-mana peranti, penapis berfungsi sebagai alat utama untuk membezakan satu peranti dengan peranti yang lain iaitu dari segi prestasi peranti dan kos terutamanya dalam spektrum yang sesak. Oleh itu, kertas kerja ini akan membentangkan reka bentuk penapis pas band 3-D pemandu gelombang berongga untuk aplikasi penganalisis spektrum. Penapis ini akan menyediakan pemilihan frekuensi tinggi dan kehilangan pemasukan rendah yang akan menjadi kunci kriteria utama dalam merekabentuk penapis dengan Q tinggi dimana akan menghasilkan penapis yang berprestasi tinggi. Proses rekabentuk akan menggunakan prototaip Chebyshev berturas rendah sebagai titik permulaan dan diikuti oleh transformasi prototaip berturas rendah ke penapis pas band pemandu gelombang berongga. Simulasi rekabentuk dengan bantuan perisian HFSS akan ditala dan dioptimumkan untuk mendapatkan spesifikasi yang dikehendaki untuk penapis pemandu gelombang. Penapis pas band 3-D pemandu gelombang berongga akan menjadi sangat berguna dalam sistem gelombang mikro terutamanya dalam penganalisis spektrum memandangkan kehilangan pemasukan rendah dan pemilihan frekuensi tinggi yang disediakan oleh penapis adalah faktor penting untuk mendapatkan peranti berprestasi tinggi. Selain daripada itu, penapis ini juga akan direka dalam rekabentuk yang lebih mudah dengan saiz yang lebih kecil kerana hanya bilangan resonator yang minimum akan digunakan dalam reka bentuk dan seterusnya ia akan mengurangkan kos pembuatan penapis ini. Dengan

membandingkan antara penyelidikan yang dilakukan dan projek ini, ia boleh dikatakan bahawa, lebih kecil saiz pandu gelombang rongga penapis laluan jalur, semakin tinggi nilai faktor Q yang diperolehi. Disebabkan projek ini menyediakan penapis yang bersaiz lebih kecil, 3-D pandu gelombang rongga penapis laluan jalur untuk aplikasi spektrum yang berprestasi tinggi telah berjaya dihasilkan.

TABLE OF CONTENT

CHAPTER 5 – CONCLUSION AND FUTURE WORK

LIST OF TABLE

LIST OF FIGURE

LIST OF SYMBOL

ω	Angular frequency of passband frequency
ω_c	Angular frequency of cut-off frequency
λ_{g1}	Guide wavelength at lower frequency
λ_{g2}	Guide wavelength at upper frequency
λ_{g0}	Center guide wavelength
f_0	Center frequency
f_c	Cut-off frequency
c	Speed of light
a	Waveguide width
l	Waveguide length
b	Height of waveguide
L_A	Stopband insertion loss
L_R	Passband return loss
N	Degree of Chebyshev / Number of stages
S	Ratio of stopband to passband frequencies
ε	Ripple level

α	Attenuation constant
K	Characteristic impedance of impedance inverter
Z	Impedance
B	Susceptance
ψ	Electrical length
C	Capacitor
L	Inductor
r	Element number
Q	Quality factor

CHAPTER 1

INTRODUCTION

This chapter will explain about the overview project of High Performance 3-D Waveguide Cavity Bandpass Filter. This chapter will cover the summary of the project, objectives, problem statement, project scope and project methodology that will be implemented throughout the project until it successfully done.

1.1 Background of Project

Microwave technology is the current important technologies that have significant impact to the modern society. Since the microwave technology is widely being used, the market demand for an improved and high performance technology of microwave. In microwave technology, microwave filter is used to discriminate between the wanted and unwanted frequencies. Waveguide cavity filter is one of the most common microwave filters and it is a suitable candidate in designing a high performance microwave filter since waveguide has a very high Q factor, high power capability and low loss compared to other TEM resonator.

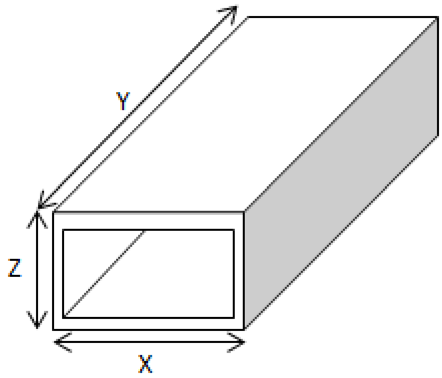

Figure 1.1: Rectangular waveguide cavity

This project will propose a 3D waveguide cavity bandpass filter to be applied in the Spectrum Analyzer that will help in optimizing the performance of the device. The proposed filter will operate at 5.1 GHz frequency with 250 MHz bandwidth. In order to design a high performance filter for the application of Spectrum Analyzer, a very selective bandpass response and a very low insertion loss at the passband must be achieved. Based on the literature study, the waveguide cavity filter will provide both high frequency selectivity and low insertion loss while the bandpass filter will only select the wanted frequencies and reject undesired frequencies. This is the main reason why waveguide cavity bandpass filter is being proposed in this project. Besides, both properties of selective bandpass response and low insertion loss are the key criteria for high Q filter design.

However, by using conventional lumped element or planar technologies, high performance specification of bandpass filter is difficult to achieve. Due to this reason, a 3D waveguide filter is proposed. The 3D design of the waveguide cavity bandpass filter will use the High Frequency Structure Simulator (HFSS) software and the simulation results will be analyzed in order to get the most suitable and optimize performance of the filter.

1.2 Problem Statement

In this modern and development years, the microwave technologies such as waveguide filters, strip-line filters and microstrip filters are widely being used. Due to the massive usage of the filters, the market demand for a high performance narrow bandpass filters that having low insertion loss and high selectivity.

In the recent trend toward miniaturization, planar technologies such as microstrip and strip-line filters are more preferred than waveguide filters. However, the planar technologies are difficult to meet the high performance specification of bandpass filter application. Among all the filters, the cavity filters are the one that can meet the market demand. Cavity filter is a part of spectrum analyzer, thus, cavity filter requires operation with high performance to result in high accuracy and fine reading and provide high sensitivity. However, the main disadvantage of cavity filter is that it has a large size.

A development and miniaturization of the cavity filter need to be done in order to ensure a longer sustainability of cavity filters in the market. Since it is very difficult to achieve high performance specification in planar technologies, a high performance of 3D waveguide cavity bandpass filter is proposed in order to achieve high selectivity of bandpass and low insertion loss thus will result in high Q factor.

1.3 Objectives

The objectives for the High Performance 3-D Waveguide Cavity Bandpass Filter are:

1) To design and validate the 3D waveguide cavity bandpass filter at 5.1 GHz through simulation using the Ansoft HFSS Software.
2) To propose the new 3D design of high performance waveguide cavity bandpass filter.

1.4 Scope of Project

In this project, we will include the study background, techniques, calculation, parametric study and the designing procedure of the 3D waveguide cavity bandpass filter. The design and simulation of the 3D waveguide cavity bandpass filter will use the HFSS software. The filter's design must meet the specification performance of Spectrum Analyzer:

Table 1.1: Design Specification

Center Frequency	5.1 GHz
Bandwidth	250 MHz
Steep Roll	More than 92.5 dB
Insertion Loss	Less than 2 dB
VSWR	Maximum 15 dB across 80% of the passband region
Filter's Dimension	Length: Less than 7 cm Width: Less than 2.5 cm Height: Less than 1.5 cm

However, waveguide has its own specification in order to determine its dimension since waveguide cannot propagate below the specified cut-off frequency. Due to the waveguide standard, the filter dimension will be different than the given specification. The final product of this project is in term of software simulation which the results need to meet the design specification. Since this project only include the simulation, thus this thesis will not cover on how to produce the filter's prototype, the study about the bigger system of the Spectrum Analyzer and the process of fabrication and validation of the 3D waveguide cavity bandpass filter.

1.5 Project Methodology

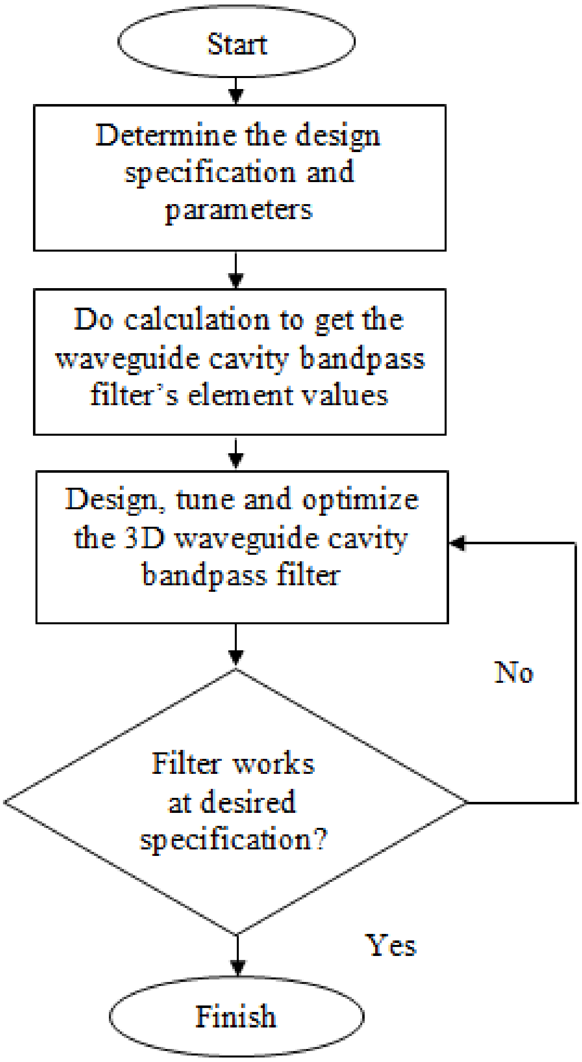

Figure 1.2: Project methodology flow chart

1.5.1 Literature Review

This project will be started by doing some literature review in getting background knowledge, concept and all related calculation about the waveguide cavity bandpass filter and the guide in constructing 3-D waveguide cavity bandpass filter in Ansoft High Frequency Structure Simulator (HFSS). HFSS will provide high-performance full-wave electromagnetic (EM) field simulation for arbitrary 3D volumetric passive device modeling. The main advantages using the HFSS for simulation is the different variable dimension can be parameterized to obtain