DUAL MODE SIW BANDPASS FILTER

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Specially dedicated to my beloved parents
Mr Ab Halimb Kudin and Mrs Zainoriah Bt Mohamed,
brothers, sisters and all my fellow friends
who have encouraged, guided and inspired me throughout my journey of education

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ABSTRACT

Filter is highly desirable in communication system. It functions to pass through the desired frequencies within the range and block unwanted frequencies. In addition, filters are also needed to remove out harmonics that are present in the communication system. The objective of this project is to design, construct and fabricate dual mode SIW bandpass filter suitable for land based satellite communication application centered at 9GHz. The filter must operate within the unlicensed 9GHz band. This application is in the X band range (8-12GHz) currently being used for military and satellite communication applications. A dual mode SIW bandpass filter prototype filter was produced; with the bandwidth is 400 MHz The filter covers the 9GHz band and the bandwidth from 8.5GHz to 9.5 GHz. The antenna was fabricated on FR4 board, that had a relative dielectric constant, $\varepsilon r = 4.7$, a loss tangent $\tan \delta = 0.019$ and thickness, height of 1.6 mm.

ABSTRAK

Peranti penapis sangat diperlukan dalam sistem komunikasi. Ia berfungsi membenarkan satu julat frekuensi yang dikehendaki dan menghalang satu julat frekuensi yang tidak dikehendaki. Di samping itu, penapis juga diperlukan untuk membuang harmonik yang tidak dikehendaki dalam sistem komunikasi. Projek in bertujuan untuk merekabentuk dan membina penapis jalurmikro yang boleh digunakan untuk darat. Antenna tersebut beroperasi dalam frekuensi 9GHz. Aplikasi in didalam ukuran X band (8-12GHz), yg selalunya digunakan untuk tentera dan komunikasi satelit. Pasangan SIW ini menghasilkan lebarjalur 400 MHz iaitu dari frekuensi 8.5GHz sehingga 9.5GHz. Antenna tersebut dibina pada FR4 yang mempunyai $\varepsilon r = 4.7$,tan $\delta = 0.019$ dan ketebalan, h of 1.6 mm.

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LIST OF ABBREVIATIONS

LPF	-	Lowpass filter
BPF	-	Bandpass filter
BSF	-	Bandstop filter
IL	-	Insertion loss
RT	-	Return loss
BW	-	Bandwidth
PCB	-	Printed circuit board
I/O	-	Input/output
Zo	-	High impedence
ADS	-	Advance design system
dB	-	Decibel
εr	-	Dielectric constant
h	-	Dielectric substrate
SIW	-	Substrate integrated waveguide
TEM	-	Transverse electromagnetic
NEMA	-	National Electrical Manufacturers Association
FR	-	Fire resistant
HFSS	-	High Frequency Structure Simulator
N	-	Number of element
TE	-	Transverse Electric
TM	-	Transverse Magnetic
SIW	-	Substrate Integrated Waveguide
λg	-	Guide Wavelength

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CHAPTER 1

INTRODUCTION

This project is involved researching and analysis about dual mode band pass filter using SIW characteristics. In microwave engineering, microstrip is widely used in the design of all kinds of passive circuits due to its compact size, easy integration and readiness. But with frequency increasing, as an open structure, a microstrip circuit shows undesirable radiation. Such radiation not only introduces additional losses in the circuit but it also has negative impact on the surrounding components.

Alternatively, the traditional waveguide circuit has minimum radiation loss as it is closed structure and all the electromagnetic energy is bounded inside the waveguide, but it is cumbersome compared to its microstrip counterpart. With frequency increasing, the physical dimensions of the waveguide decreases, but the integration of many waveguide circuits is still not as easy as that for the microstrip circuits.

Recently, a new type of transmission line called substrate integrated waveguide or post-wall waveguide is invented. It is low cost realization of the traditional waveguide circuit for microwave and millimeter-wave applications. It inherits the merits from both the traditional microstrip for easy integration and the waveguide for low radiation loss. In such a circuit, metallic post are embedded into a printed circuit board, which is covered with conducting sheets on both side, to emulate the vertical walls of a traditional waveguide. It has the advantage of the traditional waveguide circuit, such as low radiation loss, high Q factor and high power capacity while can be readily fabricated with the existing technologies like printed circuit board and low temperature co-fired ceramic (LTCC) technologies. [1]

For the metal post that emulates a vertical wall, the post radius and separation should be carefully designed in order to reduce the wave leakage and to get a desired propagation constant. Specially, for two rows of periodic metal post, the wave propagation characteristics have been studied, and the design equations for the post walls been studied. [3]

Miniaturized high performance narrowband microwave band pass filters are highly desirable for the next generation of satellite and mobile communications systems. To meet this demand, it seems that the dual-mode microstrip filter is one of the prospective candidates. The dual-mode microstrip filter is composed of one or more dual-mode microstrip resonators which are usually in the form of a ring, a disk or a square patch [1].

For most single layer substrate integrated waveguide circuits, the top and bottom copper sheets are intact without slots and they are excited by a TE-like mode electromagnetic waves. These micro strip resonators can be treated as waveguide cavities with magnetic walls on the sides. The fields within the cavities can be expanded by the *TEmn* modes. Assuming no field variation normal to the substrate, thus the resonators may also be referred to as 2-D resonators since a resonance can occur in either of two orthogonal co-ordinates with only vertical electric and horizontal magnetic fields if the circuit is placed in the horizontal plane.

Therefore, it is desirable to develop new types of dual-mode microstrip resonators not only for offering alternative designs but also for miniaturizing filters. In this project, we present for the research of a dual-mode SIW for the design of compact microwave band pass filers. The characteristics of mode splitting are described. A novel dual-mode band pass filter composed of a proposed dual-mode microstrip resonator was designed and fabricated. The measured filter performance is also presented.

Radio frequency (RF) and 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. [2]

1.1 PROBLEM STATEMENT

High performance microwave band pass filters with low insertion loss, high selectivity, compact size and multiple bands are widely used for wireless and satellite communication systems. During the years, band pass waveguide filters have used all kinds of metallic and non-metallic insertions in order to improve performance and reduce size.

Table 1.1: Difference between single mode filter and dual mode filter.

Conventional Single Mode Filter	Dual Mode Filter
1. Produce one resonant	Able to produce two resonant.
2. Less selective compare with dual mode.	More selective response.
3. Needed two stages then size increase.	Size smaller.
4. Costly for extra stages to produce more resonant.	Low cost.

1.2 OBJECTIVE PROJECT

The objectives of this project are to produce a filter design that utilize substrate integrated waveguide band pass filter. The SIW cavity has higher Q factor than conventional microstrip resonator, and as result it will produce high performance filters. It also has the advantage of easy connection to other MIC or MMIC devices via a simple transition.

A summary of the objectives of this project follows:

a) To design, develop and test a dual mode band pass filter.
b) Study will be focus on the measurement site including the fabricated filter.

1.3 SCOPE OF THE PROJECT

The scope of this project is only involved the operating frequency at X band between 9 GHz until 14 GHz. The **X-band** is a segment of the microwave radio region of the electromagnetic spectrum. The term "X-band" is also used informally and inaccurately to refer to the extended AM broadcast band, where the "X" stands for "extended".

The microwave spectrum is usually defined as electromagnetic energy ranging from approximately 1 GHz to 100 GHz in frequency, but older usage includes lower frequencies. Most common applications are within the 1 to 40 GHz range. Microwave frequency bands, as defined by the Radio Society of Great Britain (RSGB), are shown in the table below:

Table 1.2: Operating Frequency all band

L band	1 to 2 GHz
S band	2 to 4 GHz
C band	4 to 8 GHz
X band	8 to 12 GHz
K_u band	12 to 18 GHz
K band	18 to 26.5 GHz
K_a band	26.5 to 40 GHz
Q band	30 to 50 GHz
U band	40 to 60 GHz
V band	50 to 75 GHz
E band	60 to 90 GHz
W band	75 to 110 GHz
F band	90 to 140 GHz
D band	110 to 170 GHz

TE301 and TE102 were chosen as the two degraded modes in order to reduce the dimensions of the filter. A key factor of the dual-mode operation is to generate two orthogonal modes that resonate at the same frequency. Such two modes are typically regarded as a pair of degenerate modes. Suppose the index sets of these two degenerate modes are (m, 0, l) and (p, 0, q). The only additional constraint for the dual-mode operation is that $m \neq p$ and $l \neq q$ [4]. An obvious example is a square cavity (the case of $a = c$) since its TE301 and TE102 mode substantially resonate at the same frequency.

Transition from a microstrip to a rectangular waveguide within the same dielectric substrate that use is step impedance. The structure consists of a step impedance microstrip line section that connects a 50 ohm microstrip line and an integrated waveguide.

CHAPTER 2

LITERATURE STUDY

2.1 FUNDAMMENTAL SUBSTRATE INTEGRATED WAVEGUIDE

A substrate integrated waveguide circuit with metallic posts only is the simplest and most popular configuration because it can be easily fabricated using the existing printed circuit board technique.[5]

2.1.1 Introduction

A waveguide is a structure which guides waves, such as electromagnetic waves or sound waves. There are different types of waveguide for each type of signal. The original and most common [5] meaning is a hollow conductive metal pipe used to carry high frequency radio waves, particularly microwaves.

Waveguides differ in their geometry which can confine energy in one dimension such as in slab waveguides or two dimensions as in fiber or channel waveguides. In addition, different waveguides are needed to guide different frequencies: an optical fiber guiding light (high frequency) will not guide microwaves (which have a much lower frequency). As a rule of thumb, the width of a waveguide needs to be of the same order of magnitude as the wavelength of the guided wave. [6]

2.2 RECTANGULAR WAVEGUIDE

Waveguide as specifically refers to long metallic structures with only one piece of conductor between the source and load end. These metallic structures are usually hollow, so that EM fields are confined within the hollow and be guided along the axial direction. Applying Maxwell's Equations with the proper boundary conditions shows that propagating EM waves can be supported by the waveguide. Due to the absence of center conductor, only TE and TM mode exist.

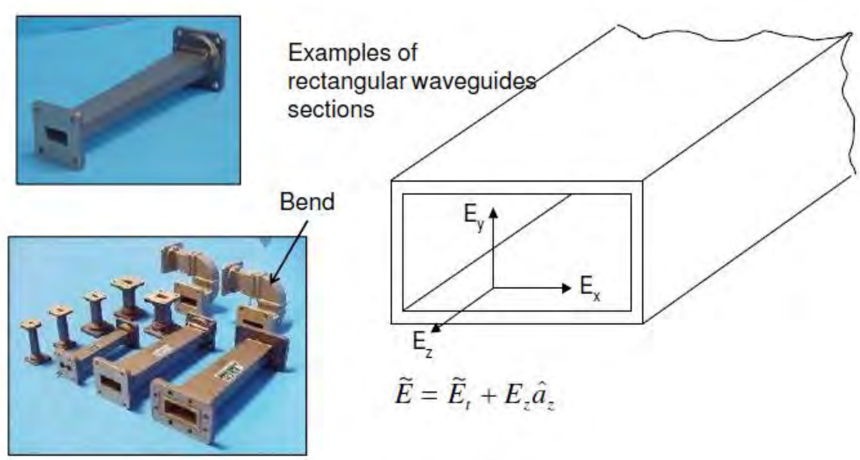

Figure 2.1: Rectangular waveguide [14]