STUDY OF DESIGN CONSIDERATION AND PERFORMANCE ANALYSIS OF SUBSTRATE INTEGRATED WAVEGUIDE COMPONENTS

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ABSTRACT

This paper studied a design scheme and measurement results of circuit discontinuities on the basis of the recently proposed substrate integrated waveguide technology. Design considerations are discussed with respect to H-plane step, post resonator, 90° bend and 90° curvature, which are analyzed using an equivalent rectangular waveguide model. The results show a good agreement between design predictions and practical measurements will be compared within the paper was studied. Loss properties of the discontinuities are also examined. It is demonstrated that the radiation loss of the new substrate integrated waveguide is smaller as compared to dielectric and conductor losses. The boundaries of the SIW are realized by a series of a via holes, the size of which and distance between adjacent ones are determined by following a set of design rule. All simulation has been done by using Advanced Design System (ADS). To validate the theory and simulation, some of design has been fabricated and tested using Agilent analyser. All design has been realized by using a standard PCB process as a result, the cost of fabrication is cheap and reproducible.

ABSTRAK

Laporan ini membuat kajian tentang hasil ciptaan dan ukuran litar berdasarkan teknologi asas *Substrate Integrated Waveguide*. Ia membincangkan *H-plane step, post resonator, 90° bend* dan *90° curvature* yang menganalisa menggunakan model yang setara dengan *rectangular waveguide*. Hasilnya menunjukkan ciptaan dan ukuran yang dipratikkan akan di bandingkan dengan kertas kerja yang dikaji. Ia menunjukkan kehilangan radiasi *Substrate Integrated Waveguide* lebih kecil apabila dibandingkan dielektrik dan kehilangan konduktor. Saiz diantara lubang dimana jarak berdekatan diantara satu sama lain ditentukan oleh peraturan yang ditetapkan. Semua simulasi dibuat menggunakan perisian Advanced Design System (ADS). Untuk mengesahkan antara teori dan simulasi, beberapa ciptaan difabrikasi menggunakan *Printed Circuit Board (PCB)* proses sebagai hasilnye. Kos untuk fabrikasi adalah murah dan direproduksi.

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LIST OF ABBREVIATIONS

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

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Rectangular waveguide components have widely been used in millimeter-wave systems. Their relatively high cost and difficult integration prevent them from being used in low-cost high-volume applications. The recently proposed substrate integrated waveguide (SIW) scheme provides an interesting alternative. In this case, the rectangular waveguide components are synthesized using arrays of metallic via and transitions with planar structures (microstrip, cpw) are designed and integrated on the same substrate, thus providing a compact and low cost platform. The feasibility of the concept has been proved for microstrip transitions by Deslandes and Wu [1] and Jain and Kinayman [2]. Coplanar Waveguide transition has also been designed by Deslandes and Wu [3] and Ito and al. [4]. Simple waveguide filter has been presented by Ito and al. [4] and Tzuang and al. [5]. However, no other components has been studied and measured. Furthermore, the radiation loss generated from gaps between vias has been unknown.

This paper presents a simple design method for SIW discontinuities that are characterized over a wide bandwidth using an equivalent rectangular waveguide model. Loss properties of the structures are also analysed, confirming the inherent low radiation loss.

1.2 Objectives of Project

1. To study the design consideration and performance analysis of Substrate Integrated Waveguide Components.

2. To analyzed H-plane step, Post resonator, 90° Bend and 90° curvature using an equivalent rectangular waveguide model compared the results with paper study[6].

1.3 Scope of Project

This project will focus primarily on the making literature review which will survey on the journal, magazine, conference paper or textbook. During literature review all the information such as the theory and design of microwave filter will explore. Then, by using that information calculation will be made. In addition, the preliminary work will use simulation tools and the result will be compared with the theoretical result. The frequency was used is X-Band which is range 8-12GHz, center frequency 9GHz.

1.4 Problem Statement

Rectangular waveguide components have widely been used in millimeter-wave systems. Their relatively high cost and difficult integration prevent them from being used in low-cost high-volume applications. The recently proposed substrate integrated waveguide (SIW) scheme provides an interesting alternative. In this case, the rectangular waveguide components are synthesized using arrays of metallic via and transitions with planar structures (microstrip, cpw) are designed and integrated on the same substrate, thus providing a compact and low cost platform.

1.5 Organization

Based on the objectives of the PSM, this report will provide all the works or progress that has been done during PSM period. There is also a review of introduction of SIW and how this development implemented in four structures of SIW.

The organization of this report is as follow:

- **Chapter 2**

  Chapter Two focuses on literature review. It is mainly explain the concept of the project in details. It is also include the review of several projects that have been made by researchers from other university. With doing this, the results between these projects with others can compare and the differences more clearly. Focuses on the theory of rectangular waveguides and the Substrate Integrated Waveguide. It includes formulae to calculate the relative width and size of via holes and the distance between adjacent via holes of the SIW. The formulae how to get the wavelength waveguide also discussed in theoretical of TE mode.

- **Chapter 3**

  Chapter Three is a methodology. It is included with block diagram, the method used to complete this project.

- **Chapter 4**

  Chapter Four shows the results and discussions. It will cover all the result of the analysis and designing the project and one of them is the progress of the project. The design, simulation and measured results are presented and analyzed.

- **Chapter 5**

  The conclusion will be discussed in Chapter Five. The conclusions have been made and for the future works and also an improvement on how the future works should have done. It also offers further discussion on the measured results, a comparison with the simulation results and an analysis of the effect of losses on the performance.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Rectangular waveguides are the one of the earliest type of the transmission lines. They are used in many applications. A lot of components such as isolators, detectors, attenuators, couplers and slotted lines are available for various standard waveguide bands between 1 GHz to above 220 GHz.

A rectangular waveguide supports TM and TE modes but not TEM waves because we cannot define a unique voltage since there is only one conductor in a rectangular waveguide. The shape of a rectangular waveguide is as shown below. A material with permittivity e and permeability m fills the inside of the conductor.

A rectangular waveguide cannot propagate below some certain frequency. This frequency is called the cut-off frequency.

Here, we will discuss TM mode rectangular waveguides and TE mode rectangular waveguides separately.

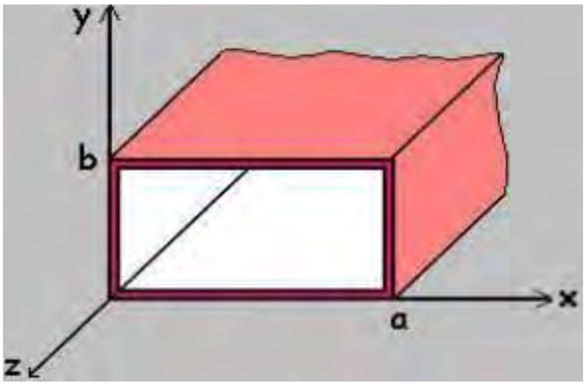

Figure 2.1 TE Mode

2.2 Transverse Electric (TE) mode

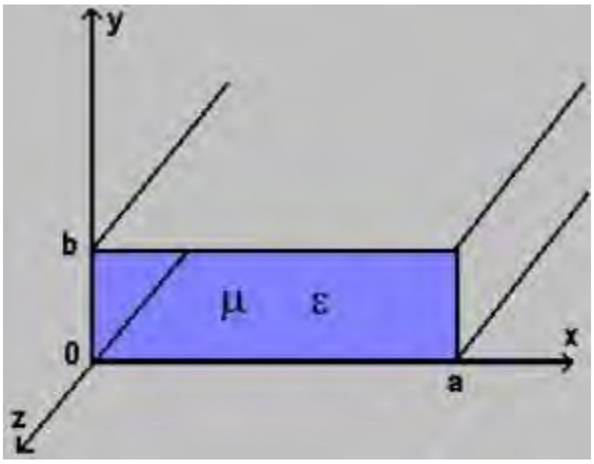

Figure 2.2 Transverse Electric (TE) mode

Consider again the rectangular waveguide below with dimensions a and b (assume a>b) and the parameters **e** and **m.** For TE waves $E_z = 0$ and H_z should be solved from equation for TE mode;

Ñ$^{2}_{xy}$ $H_z + h^2 H_z = 0$

Since $H_z(x,y,z) = H_z^0(x,y)e^{-gz}$, we get the following equation,

$$(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+h^2)H_z^0(x,y)=0$$

If we use the method of separation of variables, that is $H_z^0(x,y)=X(x).Y(y)$ we get,

$$-\frac{1}{X(x)}\frac{d^2X(x)}{dx^2}=\frac{1}{Y(y)}\frac{d^2Y(y)}{dy^2}+h^2$$

Since the right side contains x terms only and the left side contains y terms only, they are both equal to a constant. Calling that constant as k_x^2, we get;

$$\frac{d^2X(x)}{dx^2}+k_x^2X(x)=0$$

$$\frac{d^2Y(y)}{dy^2}+k_y^2Y(y)=0$$

where $k_y^2=h^2-k_x^2$

Here, we must solve for X and Y from the preceding equations. Also we have the following boundary conditions:

$$\frac{\partial H_z^0}{\partial x}=0(E_y=0)$$ *at x=0*

$$\frac{\partial H_z^0}{\partial x}=0(E_y=0)$$ *at x=a*

$$\frac{\partial H_z^0}{\partial y} = 0(E_x = 0)$$ *at y=0*

$$\frac{\partial H_z^0}{\partial y} = 0(E_x = 0)$$ *at y=b*

From all these, we get

$$H_z^0(x, y) = H_0 \cos\left(\frac{m\pi}{a}x\right)\cos\left(\frac{n\pi}{b}y\right)$$ (A/m)

From $k_y^2 = h^2 - k_x^2$, we have;

$$\boxed{h^2 = \left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$$

For TE waves, we have

$$H_x^0 = -\frac{\gamma}{h^2}\frac{\partial H_z^0}{\partial x}$$

$$H_y^0 = -\frac{\gamma}{h^2}\frac{\partial H_z^0}{\partial y}$$

$$E_x^0 = -\frac{j\omega\mu}{h^2}\frac{\partial H_z^0}{\partial y}$$

$$E_y^0 = -\frac{j\omega\mu}{h^2}\frac{\partial H_z^0}{\partial x}$$