DESIGN SUBSTRATE INTEGRATED WAVEGUIDE SLOT ARRAY ANTENNA AT X-BAND

By

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In the name of Allah, Most Gracious, Most Merciful.

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LIST OF SYMBOLS

Θ	Theta, angle
π	Pi
S	Via hole spacing
D	Via hole diameter
A	Substrate integrated waveguide width
B	Substrate integrated waveguide height
a_{RWG}	waveguide width
F	Frequency
E	electric field
H	magnetic field
X	Offset
Vs	Slot voltage
Fc	cutoff frequency
Co	Speed of light
W	Slot width

LIST OF ABBREVIATIONS

RT	Return loss
BW	Bandwidth
Zo	High impedence
ADS	Advance design system
CST	Computer Simulation Technology
RWG	Rectangular Waveguide
BI-RME	Boundary Integral-Resonant Mode Expansion
Λg	Guide Wavelength
SIW	Substrate Integrated Waveguide
TE	Transverse Electric
SIW	Substrate integrated waveguide
H	Dielectric substrate
Er	Dielectric constant
dB	Decibel

REKA BENTUK SUBSTRATE PEMANDU GELOMBANG BERSEPADU SLOT PENYIAR ANTENA PADA JALUR X

ABSTRAK

Pandu gelombang bersepadu Substrat (SIW) adalah pandu gelombang berisi segiempat dielektrik, yang disintesis dalam satu satah substrat dengan tatasusunan laluan logam yang mengambil kira dinding sebelah dua hala dan peralihan dengan struktur satah. Laluan ini bertindak sebagai dinding pemandu gelombang yang menyokong aliran semasa, sekali gus membolehkan pemanduan gelombang mod mencapah. Substrat pemandu gelombang bersepadu dicadangkan untuk mengurangkan kehilangan gelombang yang minima, kos dan sesuai untuk aplikasi bersepadu yang bekepadatan tinggi. SIW mengekalkan kelebihan dari kedua-dua hala gelombang tradisional segi empat tepat dan mikrostrip untuk integrasi yang mudah. Ia digunakan dalam mereka bentuk litar pasif seperti resonator, Pengganding, penapis, pembahagi kuasa dan antenna

Dalam tesis ini, kami mengkaji gelombang SIW dan mencadangkan SIW sebagai slot antena pemandu gelombang antena. Slot pemandu gelombang antena direka mengikut prosedur reka bentuk yang diubahsuai oleh Elliot. Prosedur reka bentuk diubahsuai Elliot mengambil kira kesan-kesan gandingan bersama daripada slot penyiar bersebelahan. Antena ini kemudiannya ditukar kepada substrat antena bersepadu slot

pemandu gelombang dengan cermat dan meletakkan dua baris logam melalui lubang untuk mensimulasi dinding sisi dari pandu gelombang segi empat tepat. Saiz dan lokasi melalui lubang dikira seperti yang terkandung pada medan elektromagnet dalam substrat pemandu gelombang bersepadu dengan mengabaikan kehilangan dan substrat pemandu gelombang bersepadu mempunyai ciri impedance dan penyebaran berterusan yang sama seperti pemandu gelombang segi empat .

Antena tersebut disokong kepada garisa; garis mikrostrip adalah salah satu jenis yang paling popular dalam talian penghantaran satah terutamanya kerana ia boleh direka oleh proses fotolitografi yang mudah, bersaiz kecil dan bersepadu dengan kedua-dua peranti mikro pasif dan aktif.

SIW direka dalam band-X, dengan radiasi yang baik pada sidelobes -51.78 dB di bawah rasuk utama diperhatikan. Antena ini mempunyai jalur lebar impedans 280 MHz pada frekuensi operasi 10 GHz.

DESIGN SUBSTRATE INTEGRATED WAVEGUIDE SLOT ARRAY ANTENNA AT X-BAND

ABSTRACT

Substrate integrated waveguide (SIW) is a rectangular dielectric-filled waveguide, which is synthesized in a planar substrate with arrays of metallic vias to realize bilateral side walls and its transitions with planar structures. These vias act as walls of the waveguide supporting current flow, thus allowing for waveguide mode propagation. SIW is suggested for low-loss, low-cost and high density integration applications. SIW preserves the advantages from both the traditional rectangular waveguide and microstrip for easy integration. It is used in designing passive circuits such as resonators, couplers, filters, power dividers, circulators, and antennas.

In this thesis substrate integrated waveguides were investigatedand their application as a slotted waveguide antenna. The standard slotted waveguide antenna is designed following Elliot's modified design procedure. Elliot's modified design procedure takes into account the effects of mutual coupling from the neighboring slots in the array. The antenna is then converted to a slotted SIW antenna by carefully placing two rows of metallic via holes to simulate the sidewalls of the rectangular waveguide. The size and location of the via holes are calculated such that they contain the electromagnetic fields inside the SIW with negligible leakage loss and that the SIW has the same propagation constant and characteristic impedance as its equivalent rectangular waveguide.

The antenna is fed by a microstrip line, microstrip line is one of the most popular types of planar transmission lines primarily because it can be fabricated by photolithographic processes and is easily miniaturized and integrated with both passive and active microwave devices.

The SIWis designed on X-band, a good radiation pattern with sidelobes -51.78 dB below the main beam is observed. The antenna has an impedance bandwidth of 280 MHz at the operating frequency of 10 GHz.

CHAPTER 1

INTRODUCTION

1.1 Overview

The slotted waveguide antenna is a type of antenna. It can provide a great gain and has high power handling abilities and finds a lot of applications. The physical structure of a waveguide is large and it needs complicated transitions for connection with planar circuitry. Rectangular waveguides and the transitions needed to integrate them with planar circuitry are expensive and bulky. Substrate integrated waveguides (SIWs) are a relatively new type of planar transmission line which essentially integrate a waveguide into a planar circuit such as a printed circuit board or a low-temperature co-fired ceramic. SIW incorporate the advantages of rectangular waveguides, such as high power handling capacity, high Q-factor and low loss, into planar circuitry(Deslandes and Wu, 2006). In addition SIWs allow for easy transition between other planar transmission lines and they are small, have a low-profile and weigh less compared to the rectangular waveguides (Deslandes and Wu, 2006).

SIW has the similar character of the rectangular waveguide (RWG), many design concepts of conventional RWG could be transferred to this new platform, such as the waveguide divider, filter, antenna, etc.(Yao and Zhiyuan, 2005).SIW is used for radar and communication systems which require narrow- beam or shaped-beam.

Rectangular waveguide can be used to design high Q components in wireless systems but requires complex transitions to integrated planar circuits(Nam et al., 2005).Integrating rectangular waveguide into microstrip substrate reduce Q- factor of waveguide because of dielectric filling and volume reduction(Deslandes and Wu, 2001).

In this research, the conventional RWG slot array antennawas transferred to the SIW slot array antenna, which is fed by a microstrip line. As a result, not only the size, weight and cost of the waveguide slot array antenna are reduced, but also the manufacturing repeatability and consistency are enhanced. But comparing them with RWG slot array antenna, the gain and efficiency are lesser and the side lobe level is higher because of the leakage.

1.2 Problem statement

Rectangular waveguide components have broadly been used in millimeter-wave systems. Their relatively high cost and hard integration prevent them from being used in low-cost high-volume applications. The recently proposed SIW scheme provides an interesting alternative. In this case by transferring the conventional waveguide resonant slot array antenna to the SIW structure, could get the advantages of the resonant slot array antenna as well as the advantages of the SIW such as small size, low profile, low cost.

1.3 Thesis aims and objectives

The aim in this work is designing SIW five- slot array antenna at band 8-12 GHz using substrate integrate waveguide theory at resonance freqency of 10 GHz. In order to fulfil the implementation of this research there are main objectives need to be achieved:

1. To use the mathmatical equations to calcualte the physical parmeters of the SIW slot array antenna.
2. Using the physical paramters of SIW slot array antenna to design it through CST microwave studio.
3. To characteristic the SIW five slot array antenna.

1.4 Scope of research

SIW slot array antenna will be designed at band 8-12 GHz using RO4003 through CST microwave studio and show the return loss at resonance frequency of 10 GHz, after that discussing the effect of using microstrip feed line in feeding the slot antenna. Finding the physical parameters of the SIW slot antenna will be calculate using the equations in the theoretical part.

1.5 Motivation and applications

The slotted waveguide antenna is an aperture antenna. Big arrays can be molded with this type of antenna. Figure 1.1 shows a picture of a slotted waveguide antenna.

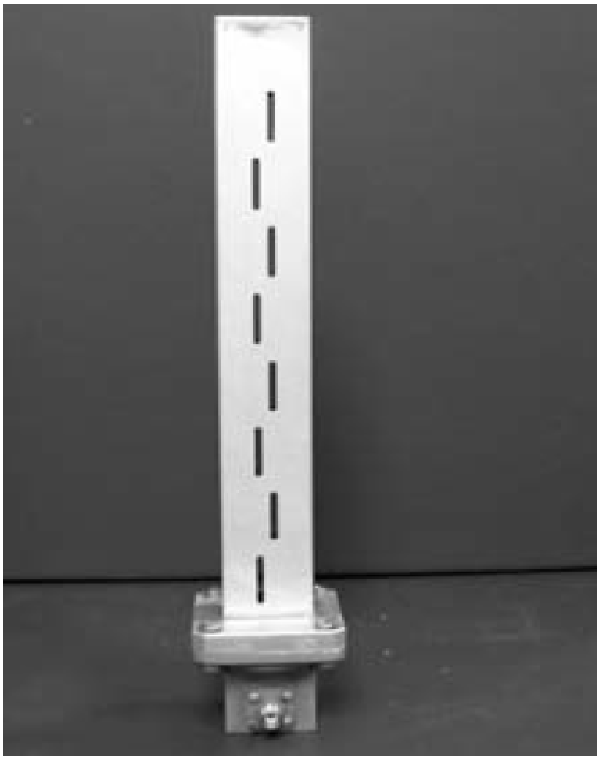

Figure 1.1: Picture of a slotted waveguide antenna (Gilbert, 2007).

This property lets designers to design slotted waveguide antennas with a large amount of gain and similarly a very narrow beam width. A waveguide itself is very durable and has a high power handling capacity. waveguide antenna used in many applications. The slotted waveguide antenna is especially well fitted for radar applications thanks to its large gain and small beam width.

Unfortunately waveguides are heavy objects. They cannot be easily integrated with other microwave circuitry. Expensive transitions must be designed and built in order to connect the waveguide to the rest of the microwave circuit (Xu and Wu, 2005). This work is concerned with taking a slotted waveguide antenna and integrating it directly into the substrate.

This work also develops a feeding scheme that allows the integrated antenna to be fed through a basic microwave transmission line, the microstrip. There are some definite advantages to integrating a slotted waveguide antenna directly into the substrate. First of all, the transitions between a waveguide and a planar circuit are no longer needed. These transitions must be carefully built and are very difficult to mass produce.Having the waveguide integrated into the substrate allows the overall circuit to have a smooth low profile appearance.

1.6 Thesis outline

The organization of this report is as follow:

- **Chapter 1**

Chapter 1 consists of the introduction part of the project such as the background, problem statement, objectives of the project, the scopes of the project and Motivation & Applications.

- **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. Focusing on previous work on the design of a slotted waveguide antenna and the improvements on design procedure are discussed. Works on substrate integrated waveguides and how their characteristics are extracted are presented. Work on slotted substrate integrated waveguide antennas are mentioned with some results listed. Previous work concerning transitions between microstrip lines and SIW are discussed in chapter 2.

- **Chapter 3**

Chapter Three is a methodology. It is included with block diagram, the method used to complete this project. And simulation of SIW slot antenna using CST microwave. During this, it will review about the model.

- **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 results are presented and analyzed.

- **Chapter 5**

The conclusion will be discussed in Chapter Five. The conclusion has been made and for the future works, there is also recommendation added. The recommendation is added to give an opinion and also an improvement on how the future works should have done.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Previous research related to slotted waveguide antennas, substrate integrated waveguides, substrate integrated waveguide antennas and transitions between microwave transmission lines and substrate integrated waveguides are discussed in this chapter.

Conventional waveguides, the first generation of microwave guiding structures had the benefits of having high power carrying capacity and high Q-factor, but also had the disadvantages of being big. The next generation of microwave guiding elements was the strip-like or slot-like planar printed transmission lines used in Microwave Integrated Circuits (MICs).These were planar low profile structures but lacked the high power carrying capacity and high Q-factor of the conventional waveguides. To link the gap between MIC structures and conventional waveguides, Substrate Integrated Circuits (SICs) were developed which are planar low profile structures like MIC structures, also having high power carrying capacity and high Q-factor like waveguides(K.wu, 2003). Principle of operation of SIC was to build artificial channels within the substrate to guide the waves. Two techniques are used to build these channels (which are embedded in the substrate).One is to use metallic vias which act as sidewalls. Other technique uses contrast in values of εr so that phenomenon of total internal reflection can take place and the wave gets confined within the artificial channel (Wu, 2010). A SIW is one of the topologies of SIC. The SIW technology has been well applied to several microwave and millimeter-wave components, including active circuits, passive components and antennas (Srivastava., 2012).

The feasibility of the concept has been proven for microstrip transitions by Deslandes, Wu, Jain and Kinayman. Coplanar waveguide transition has also been designed by Deslandes and Wu and Ito and al. Simple waveguide filter has been presented by Ito and al. and Tzuang and al. Furthermore, the radiation loss generated from gaps between vias has been unknown (Samah, 2011.).

Integrating rectangular waveguide intomicrostrip substrate reduce Q-factor of waveguide because of dielectric filling and volume reduction (Deslandes and Wu, 2001).

SIW is equivalent to a conventional rectangular wave guide filled with dielectric, hence it can be analyzed just by using width of equivalent waveguide(Yan et al., 2004). The width of equivalent RWG is calculated by an experiment formula, Figure 2.1 shows the physical parameter required in the equivalent rectangular waveguide

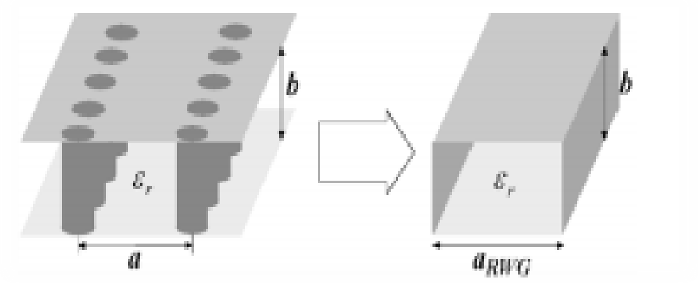

Figure 2.1: Substrate integrated waveguide and the equivalent rectangular waveguide (Yan et al., 2004).

Recently, the concept of the integrated rectangular waveguide has been proposed in which an artificial waveguide is synthesized and constructed with linear arrays of metalized via-holes or posts embedded in the same substrate used for the planar circuit. This waveguide can also be realized with complete metallized walls. Several transitions have been proposed to excite the waveguide. In all these structures, the planar circuits, such as a microstrip line or coplanar waveguide, and the rectangular waveguide are built onto the same substrate and the transition is formed with a simple matching geometry between both structures. Judging from its electrical performance, the synthesized integrated waveguide is a good compromise between the air-filled rectangular waveguide and planar circuit (Surarman, 2011).

2.2 Substrate Integrated Waveguide (SIW)

SIW is a new form of transmission line that has been promoted in the past few years by some researchers. A large variety of components such as couplers, detectors, isolators, attenuators and slot lines, are commercially available for various standard waveguide bands from 1 GHz to over 220GHz. Because of these trends towards miniaturization and integration, most microwave circuitry is currently manufactured using planar transmission lines such as microstrips transition, coplanar transition and so on. At the same time, the waveguides needs many applications such as high power systems, millimetre wave systems and some precision test systems.

Cassiviet analyzed substrate integrated waveguides (SIWs) using the BI-RME method combined with Floquet's theorem to determine the dispersion characteristics of the SIW (Cassivi et al., 2002). The SIW is composed of a substrate covered on the top and bottom with a thin metallic sheet and metallic via holes are used to simulate the side walls of a rectangular waveguide.

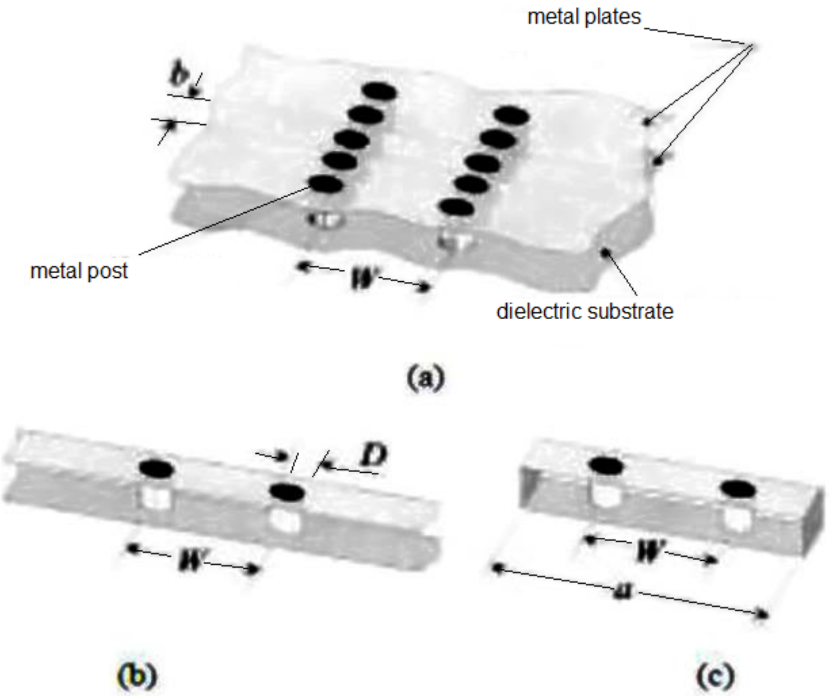

Figure 2.2: a) Sketch of a SIW. b) Periodic cell of SIW. c) Enclosed periodic cell.(Cassivi et al., 2002)

The SIW is a periodic structure; figure 2.2 shows a picture of a SIW and of a periodic cell of a SIW. A generalized admittance matrix of the periodic cell is determined using the BI-RME method. Due to the periodic nature of the SIW, Floquet's theorem can be used to obtain an eigenvalue system. The eigenvalues give the propagation constants of the TE modes propagating through the SIW and the eigenvectors give the pattern of the modal fields. Their works have shown that substrate integrated waveguides have the same basic guided wave characteristics as rectangular waveguides. They have derived empirical formulas which estimate the cutoff frequencies of the first two dominant modes of the SIW.

$$f_{c_{TE10}} = \frac{c_0}{2\sqrt{\varepsilon_r}}\left(a - \frac{d^2}{0.95 \cdot s}\right) \tag{2.1}$$

And

$$f_{c_{TE20}} = \frac{c_0}{\sqrt{\varepsilon_r}}\left(a - \frac{d^2}{1.1 \cdot s} - \frac{d^3}{6.6 \cdot s}\right) \tag{2.2}$$

Where (a) is the SIW width, (d) is the diameter of via holes, (s) is the spacing between adjacent via holes and Co is the speed of light. By comparing equation (2.1) with the equation that determines the cutoff frequency of the dominant mode of rectangular waveguides, Cassivietalhave derived an equation that relates the width of a SIW to an equivalent width of a rectangular waveguide(Cassivi et al., 2002).

$$a_{RWG} = a - \frac{d^2}{0.95 \cdot s} \tag{2.3}$$

SIW is a periodic structures which are much more complex to design when compared to a conventional waveguide. Deslandes and Wu have developed a simple design procedure which transforms an SIW into an equivalent rectangular waveguide (Deslandes and Wu, 2006).Use available finite element software package. This allows the designer to design a system using a conventional waveguide then follow their procedure to find an equivalent SIW to replace the rectangular waveguide.

Deslandes and Wu have developed a method for determining the complex propagation constant of a SIW using the concept of surface impedance to model the rows of conducting cylinders which act as the sidewalls of a SIW (Deslandes and Wu, 2006). The proposed model is solved using a method of moments and a transverse resonance procedure. An electromagnetic field of a TE mode wave propagating through a waveguide can be represented by a superposition of two waves propagating at an angle 0 to the z-axis, in this case the direction in which the energy is propagating (Deslandes and Wu, 2006). At the cutoff frequency the TEM waves are scattered by the two conducting rows of metallic via holes. Each row of via holes can be represented by surface impedance Z_S. Figure 2.3 shows a diagram of the two rows of via holes.

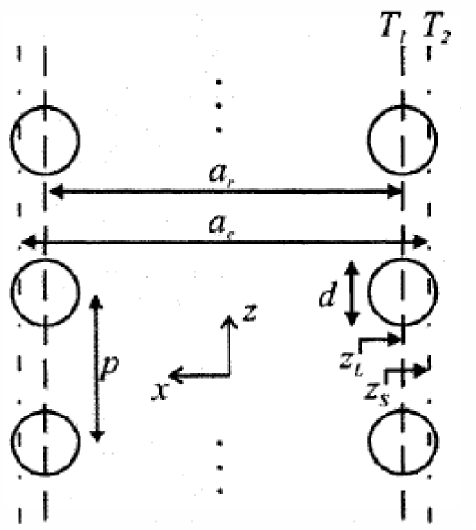

Figure 2.3: Diagram of via holes with the surface impedance concept (Deslandes and Wu, 2006).

A rectangular waveguide equivalent width (a_e) of the SIW can be calculated with a transverse resonance procedure. The propagation constant of the SIW can be considered by the reflection coefficient of the row of via holes at the wanted cutoff frequency. The reflection coefficient of the via holes at the cutoff frequency can be calculated with a method of moments technique. The novelty of this method is that the propagation constant of the SIW can be calculated both accurately and quickly. This method can be further used to extract not only the guided-wave properties of the SIW but also the leakage characteristics of the periodic structure. From these results design rules have been suggested to follow in order to minimize leakage and avoid band gaps in the operating bandwidth and to overall assist the designer design substrate integrated waveguides. The first design rule is straight forward and states that the separation distance (s) must be larger than the via hole diameter (d). The second design rule states that the separation distance must be smaller than a quarter wavelengths at the cutoff frequency. In order to confirm negligible leakage loss between the metallic cylinders a third design rules states that the separation distance should be smaller than 2d. Good experimental results were shown to validate the theory described above.

2.3 Longitudinal slots

Yan et al. have designed a 4x4 SIW slot antenna array(Yan et al., 2005). The whole antenna and feeding system are integrated in one substrate which leads to small size, low profile and low cost. Longitudinal slots were etched on the top metallic surface of a SIW making use of work done by Elliot. They determined the equivalent width of a rectangular waveguide for a SIW through the following equations.

$$\bar{a} = \xi_1 + \frac{\xi_2}{\frac{s}{d} + \frac{\xi_1 + \xi_2 - \xi_3}{\xi_3 - \xi_1}} \tag{2.4}$$

Where

$$\xi_1 = 1.0198 + \frac{0.3465}{\frac{a}{s} - 1.0684} \tag{2.5}$$

$$\xi_2 = -0.1183 - \frac{1.2729}{\frac{a}{s} + 1.2010} \tag{2.6}$$

$$\xi_3 = 1.0082 - \frac{0.9163}{\frac{a}{s} + 0.2152} \tag{2.7}$$

The equivalent width of a rectangular waveguide in terms of the width of the corresponding SIW is given by

$$a_{RWG} = \overline{a}a \tag{2.8}$$

Where a; is the width of the SIW. This method for determining the equivalent width is precise to within 1%. This method is more accurate than the one described by Cassivi et al. in equation (2.3). A picture of the antenna is given in figure 2.4. The antenna is fed through a network of microstrip lines feeding each SIW. Results show a l0 dB bandwidth of 600MHz centered at 10GHz, however the return loss at the center frequency is found to be 1ldB.(Cassivi et al., 2002)

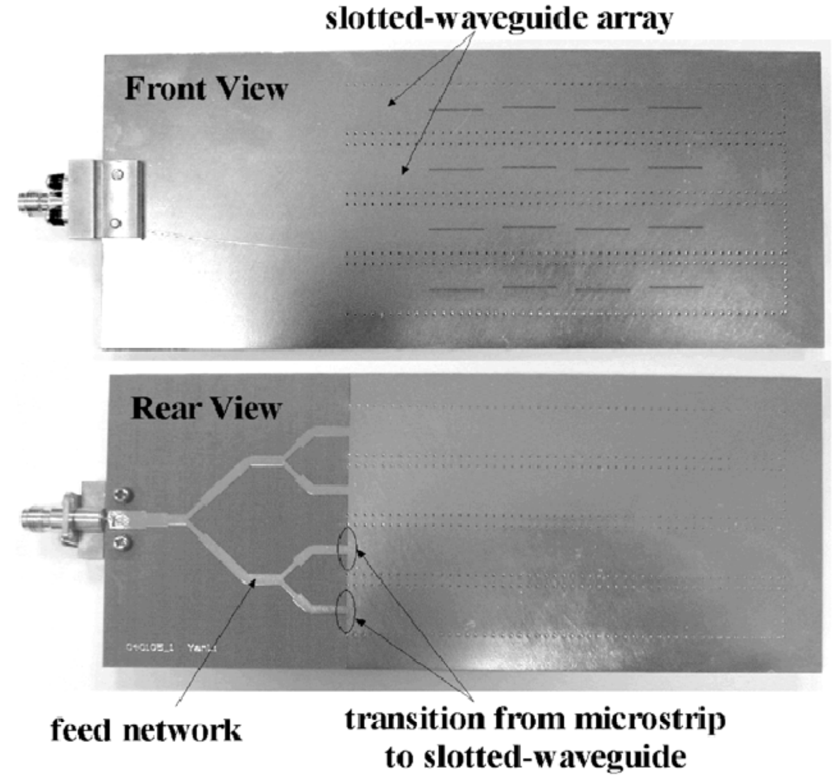

Figure 2.4: Front and rear view of the slotted SIW array antenna (Yan et al., 2005)

Weng et al. have designed a 5-slot SIW antenna array for the Ku-band.(Weng et al., 2006) Longitudinal slots are etched on the top metallic surface of an SIW in a manner similar to (Yan et al., 2005) The whole antenna is integrated on one substrate for small size and easy manufacturability. A picture of the antenna they built is given in figure 2.5 Results show a l0 dB bandwidth of 500MHz centered about 14.7GHz with a center frequency return loss of 20dB.

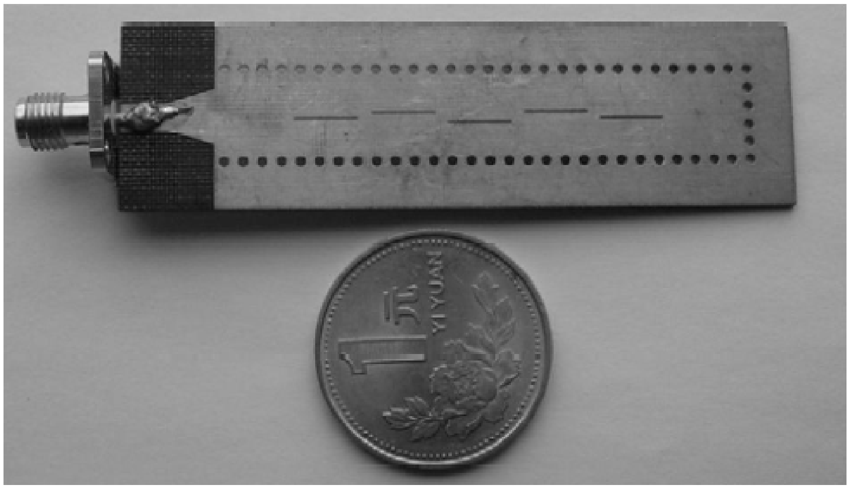

Figure 2.5: Slotted SIW array antenna fed by a microstrip line(Weng et al., 2006).

2.4 Waveguide slot radiator

Slot antennas are common omnidirectional microwave antennas. These antennas feature omnidirectional gain around the azimuth with horizontal polarization. Waveguide slot antennas are often used as omnidirectional microwave antennas. The slot array was invented in 1943 at McGill University in Montreal. Unique features of these antennas are horizontal polarization and omnidirectional gain around the azimuth. They are fairly easy to build. While they have been described in several articles in the ham literature, all the articles seem to have the same dimensions, suggesting a common genesis (Wade, 2001).

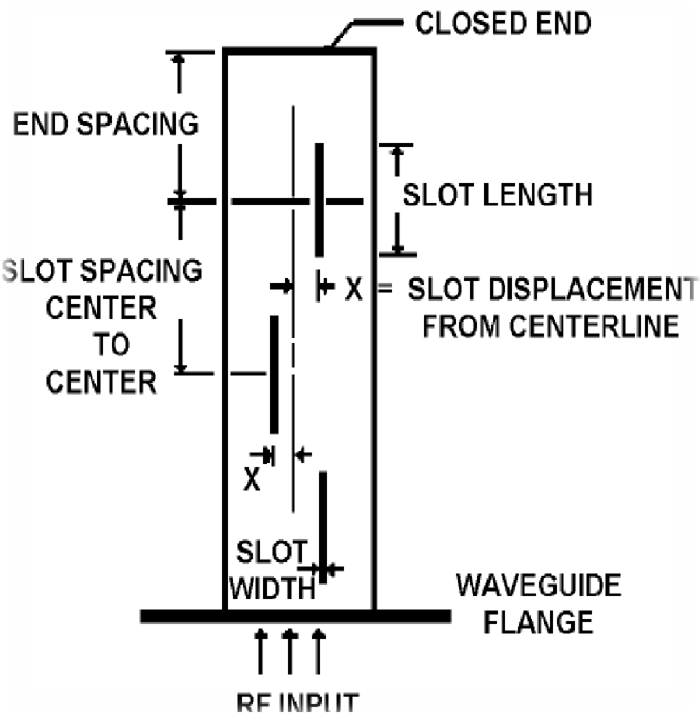

Figure 2.6: Waveguide slot antenna (Wade, 2001)

The radiating elements of a waveguide slot array are integral part of the feed system. A familiarization with the modal fields within a waveguide is a necessary to understand where to place slots. Narrow slots that are parallel to waveguide wall and it interrupt the flow of current forcing it to go around the slots, figure 2.6 shows that.

Figure 2.7 shows the slots cut in the walls of a rectangular waveguide. Slot **g** does not radiate because the slot is lined up with the direction of the sidewall current. Slot **h** does not radiate because the transverse current is zero there. Slots **a**, **b**, **c**, **i**, and **j** are shunt slots because they interrupt the transverse currents (**Jx** ,**Jy**) and can be represented by two-terminal shunt admittances. Slots **e**, **k**, and **d** interrupt **Jz** and are represented by series impedance. Slot **d** interrupts **Jx**, but the excitation polarity is opposite on either side of the waveguide centre line, thus preventing radiation from that current component. Both **Jx** and **Jz** excite slot f. A Pi- or T-impedance network can represent it. (Gilbert, 2007)

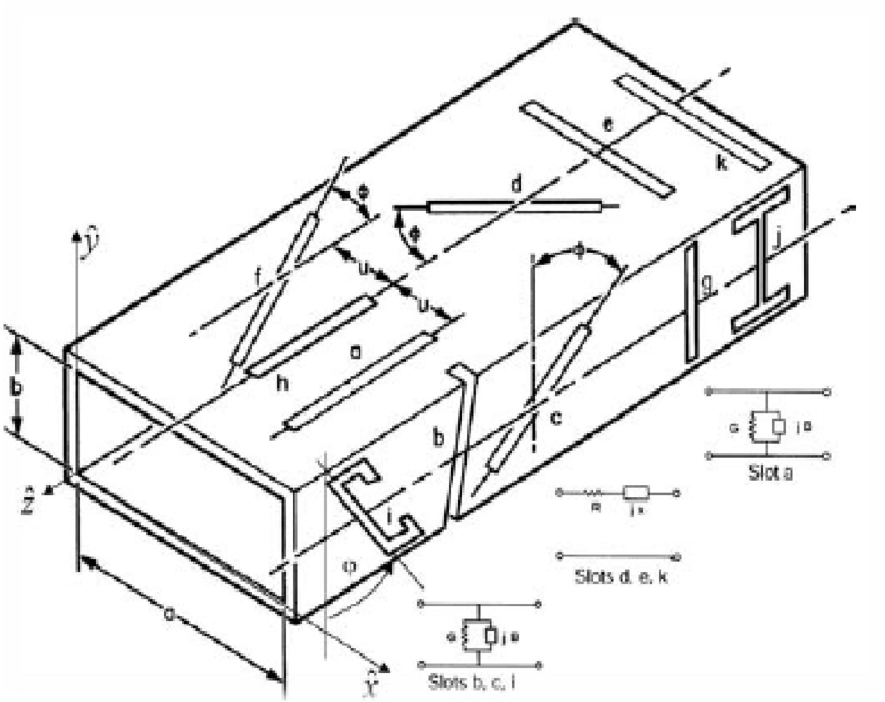

Figure 2.7: Slots cut in the walls of a rectangular waveguide. (Gilbert, 2007)

Slotted waveguide array designs, it contains a numerous stick arrays placed side by side; the mutual coupling between slots is high, it is used for radiating aperture and for feeding network that made from waveguide.

The distance between short circuit wave guide termination and first end slot is λg /4. The short circuit reflects as an open circuit, which has an admittance of zero, to the first slot from the end. This is in parallel with the conductance of the end slot.

Linear slotted arrays operate either longitudinal shunt slots or edge-wall shunt slots as radiating elements. Narrow longitudinal shunt slots radiate array patterns that have very high cross-polarization isolation. An example of an end-fed, dual-sided longitudinal linear slot array is an X-band array, as shown in Figure 2.8. For this array, slots have been placed on both wide walls of the waveguide. The array radiates an omni-azimuthal, horizontally polarized pattern. For a vertically polarized pattern, the array would have to be involved of edge-wall shunt slots, which are also excited by a single transverse current. However, the cross-polarization isolation with edge slots is not as good as with the longitudinal slots because every other element is canted in a different direction, and the polarization clarity is dependent on the uniform excitation of the slots and external cancellation of the cross-polarized field components. Rotated series slots also have a lower cross-polarization isolation level as compared with the longitudinal shunt slots and edge slots due to the rotation of the slots and due to some excitation of the slots by the transverse currents.

Slot elements are located on both sides at waveguide to provide an omni-azimuthally (Gilbert, 2007).

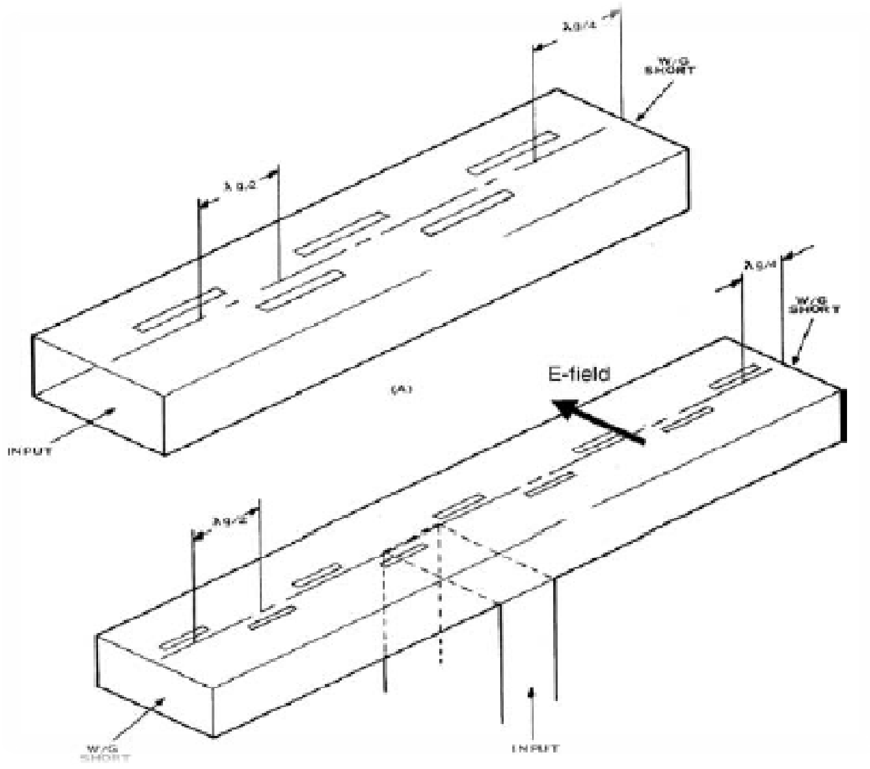

Figure 2.8: Linear resonant waveguide slot arrays with longitudinal slot elements. In (a) the array is fed from the waveguide end. In (b) the array is fed from the center through an E-plane T coupler (Gilbert, 2007).

2.5 Theory of transition microstrip line to Substrate Integrated Wave guide

Deslandes and Wu Have presented a transition between a microstrip line and planar dielectric-filled waveguide fabricated on the same substrate (Deslandes and Wu, 2001). The microstrip line and planar form waveguide are linked together through a tapered transition. A diagram of this transition is given in figure 2.9. Their results show a 12% bandwidth for a return loss less than 20dB centered around 28GHz with an insertion loss better than 0.3 dB.

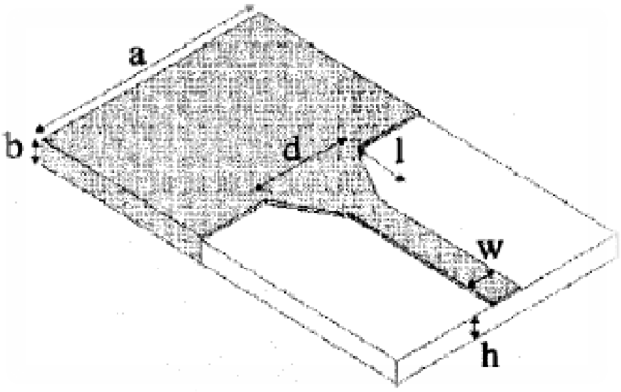

Figure 2.9: Transition between microstrip line and dielectric-filled waveguide (Deslandes and Wu, 2001).

Huang et al. have designed a transition between a microstrip line and a SIW using a tapered transition in the Ku-Band (Huang et al., 2010). The transition they designed is different than the one described above (Deslandes and Wu, 2001) A sketch of transition is given in figure 2.10

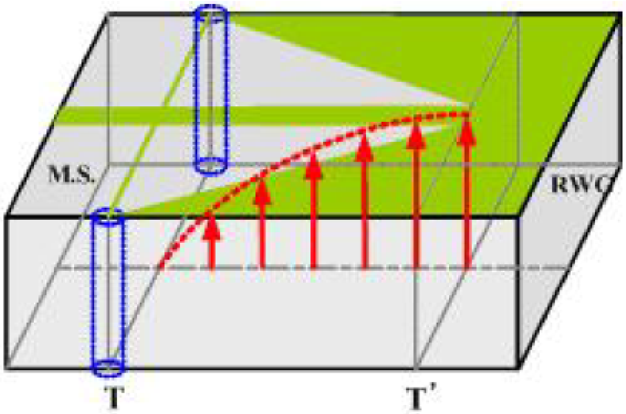

Figure 2.10: Transition between a microstrip line and a SIW (Huang et al., 2010)

Their results show a return loss of less than 15dB between the frequencies 1l-14GHz for a back-to-back transition. Over the same frequency band the insertion loss better than 0.7dB for the back-to-back transition.

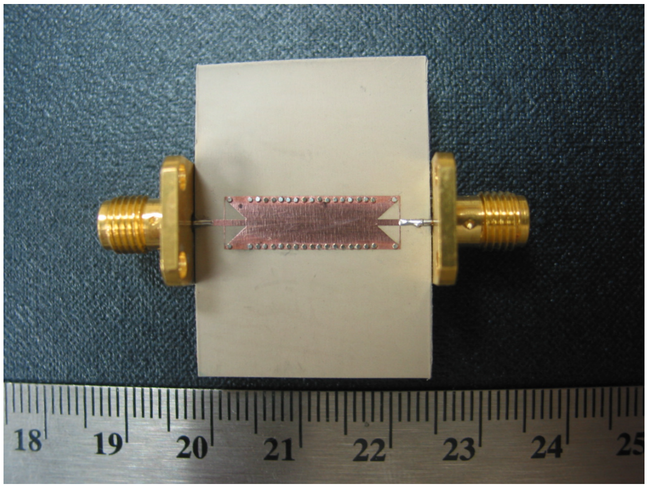

Figure 2.11: Back-to-back transition between a microstrip line to SIW (Huang et al., 2010)

Deslandes & Wu have planned a transition that connects a grounded coplanar waveguide to a SIW (Wu, 2005). The transition is composed of a current probe that descends from the grounded coplanar waveguide to the bottom ground plane of the SIW. The current flowing through the probe makes a magnetic field inside the SIW. This magnetic field matches the TE mode magnetic field in a waveguide and propagates through the SIW. A diagram of the transition between the two structures is given in figure 2.11.