DESIGN AND ANALYSIS OF WIDEBAND BANDPASS FILTER USING SLOTTED SIW RESONATOR FOR 5G COMMUNICATION SYSTEM

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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2020

DECLARATION

I declare that this report entitled "DESIGN AND ANALYSIS OF WIDEBAND BANDPASS FILTER USING SLOTTED SIW RESONATOR FOR 5G COMMUNICATION SYSTEM" is the result of my own work except for quotes as cited in the references.

Signature:

Author : NUR AZIMAH ADILIN BINTI MOHD JOHAN

Date: 21 August 2020

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

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Date	:	21 August 2020

DEDICATION

For JC Generation.

ABSTRAK

Dalam kajian yang telah dilakukan, penapis jalur lebar untuk komunikasi 5G dicadangkan menggunakan unit pandu gelombang bersepadu (SIW) substrat slotted baru. disyorkan dan direka bentuk. Ianya mempunyai 2 pasang dumbbell slot pandu gelombang bersepadu diukir diatas lapisan atas dan bawah metal. Slot berfungsi sebagai resonator shunt, yang menghasilkan sifar penghantaran. Selain itu, melalui lubang digunakan untuk mengalihkan frekuensi kepada “cut-off” frekuensi yang lebih tinggi. Frekuensi “cut-off” adalah antara 26GHz sehingga 28GHz. Dalam menghasilkan penapis ini substrat yang digunakan adalah Rogers Duroid RT/5880 dengan dielektrik 2.2 dan ketebalan 0.254mm. Dalam reka bentuk pecahan lebar jalur adalah 41.81% dengan kehilangan sisipan pada -1.323dB dan kehilangan pulangan lebih kecil dari -18.174dB di “cut-off” frekuensi. Penemuan ini dibincangkan dan persetujuan yang adil dicapai antara mereka.

ABSTRACT

In this study, a wideband bandpass filter for 5G communication is proposed and designed using novel slotted substrate integrated waveguide (SIW) units. It consists of a two pairs of dumbbell slots etched on both top and bottom metal planes of the SIW. The slots act as shunt resonators, which produce transmission zeros simultaneously. The added via holes shift the center frequency to a high frequencies. The defined center of the frequency is between 26GHz and 28GHZ. In this proposed filter, the substrate used is Rogers Duroid 5880 with dielectric of 2.2 and the thickness is 0.254mm. The 3dB fractional bandwidth is 41.81% is developed with the insertion loss of -1.323dB and return loss smaller than -18.174dB at the center frequency. The findings are discussed and a fair agreement is reached between them.

ACKNOWLEDGEMENTS

There is a race of existence in the present world of competition in which these having to succeed. In the name of ALLAH the most merciful and with help of Him. All spiritual inspirations, devotions, good words and prayers are for ALLAH whose grace and encouragement helped me throughout this whole venture.

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LIST OF SYMBOLS AND ABBREVIATIONS

G	:	Giga
Hz	:	Hertz
Mm	:	Milimeter
w	:	Width
d	:	Diameter of Metalized Via Hole
w_{eff}	:	Width of Rectangular Waveguide
R		Resistor
C		Capacitor
L		Inductor
h		Height
dB		Decibel
5G		5 Generation
3D		3 Dimension
SIW		Substrate Integrated Waveguide
PCB		Printed Circuit Board
EM		Electromagnetic
ADS		Advance Design System
BPF		Bandpass Filter
UWB		Ultra wideband
FBW		Fractional bandwidth

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CHAPTER 1

INTRODUCTION

In this chapter a brief introduction of this filter project was explained in depth. This includes the goals to be achieved, some problems during the project and also the project limitation that needs to be focused

1.1 Introduction

Communication is one of our everyday life's most critical and effective innovations. Because of the technological breakthroughs and compelling value propositions, it has become an integral part of over billions of people around the world. We noticed the phenomenon of rapid development of wireless device users, growing demands for video streaming and increased popularity in software services such as video banking, online shopping, video games and navigation. Industries are now under relentless pressure to increase the effectiveness of the filters. Latest papers on filters show that the architecture requires continuous creation or enhancement. Their performance can be improved by the use of advanced materials to design the filters. Use of advanced materials to design the filters will boost their performance.

Often, a multi-gigabit-per-second communication system can offer a fast data transfer rate [1,2]. Therefore, millimeter wave transmission technology is recognised as a feasible technology which can be used as a cornerstone to satisfy and support the rising demand for spectrum-based connectivity for the next generation of 5G mobile networks. In general, millimeter wave spectrum is defined to include frequencies between 30GHz and 300GHz. But in the 5G sense, frequencies between 24GHz and 90GHz have been typically targeted by carriers and regulators.

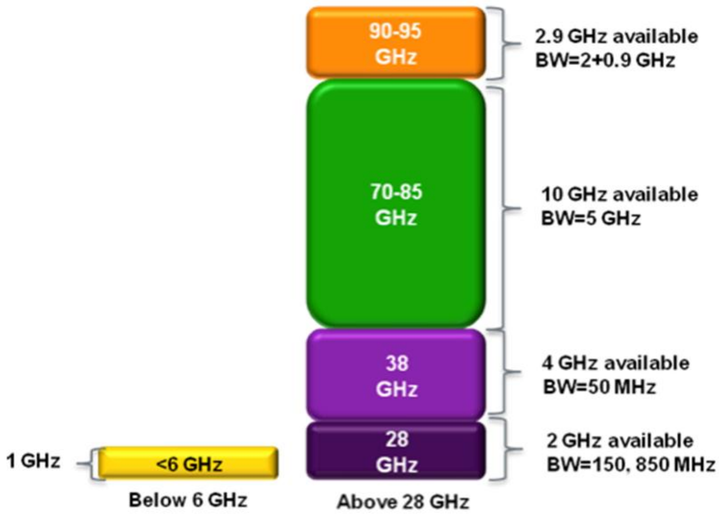
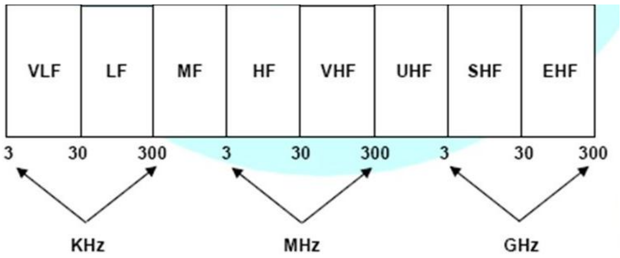


Figure 1.1.1: Potentially available licensed spectrum in the millimeter wave range

The 300 MHz to 3 GHz Ultra High Frequency (UHF) band is currently being used in almost all commercial radio communication channels including TV, satellite, cellular, GPS, Zigbee / Bluetooth and AM / FM radio. [1, 2]. A wide range of 3-300 GHz occurs from figure 1.1.2. Frequency is generally classified as the Super High Frequency (SHF) band in the 3-30 GHz range, while the Extremely High Frequency (EHF) band is defined as 30-300 GHz. As both the SHF and EHF bands share common values frequency response and have wavelengths ranging from 1 to 100 mm, the frequency spectrum of 3-300 GHz is referred to as the millimeter waveband. [2]. In order to meet the increasing market for spectrum-based networks, the underutilised millimeter wave band draws the interest of researchers around the world and is encouraged to investigate the millimeter wave frequency range to tackle lack of global bandwidth. [3].



Band	Frequency
LF	30– 300kHz
MF	300kHz– 3MHz
HF	3 – 30MHz
VHF	30 – 300MHz
UHF	300MHz– 3GHz

Figure 1.1.2: Frequency Band

In this context, filters are one of the main tools that play an important role in the interaction of the millimeter-wave. They are used to separate the frequencies of the desired and the unwanted signals. The key problem in filter designs is the inverse proportion of the bandpass insertion loss to the filter bandwidth. The problem in the existing filter technologies contribute to the need for creativity in the development of waveguide filters. A waveguide filter filled with air makes an extremely high resonator level of up to 20,000 [4]. The best equipment to be used in future 5G mobile networks will be the characteristics of a waveguide filter that provides a low bandpass entry loss and a high suppression requirement.

1.2 Problem Statement

The most latest wireless communication network is 5G networks have made strong commercial arena worldwide. As noted, 5G wireless communications networks ' multiple-function promises with their "instant data and video" assurances will require wideband channels and for many of them so much so that 5G infrastructure designers with their wide bandwidth. Systems are defined as wideband or narrowband depending on the transmission bandwidth. Wideband system supports transmission of a higher rate. The bandwidth channel is evaluated and is associated with the coherence bandwidth, the frequency band where all components can be equally affected. The signal loss always happens when the signal and frequency is transmitted. The conventional waveguide filter was discovered to provide high Q factor, high selectivity and low loss of insertion but they are hard to integrate. It also has a voluminous size and is costly to manufacture. SIW technology, having the similarity between SIW structures and rectangular waveguides. Components of the SIW are lower than the appropriate microstrip devices, and no problems with the radiation and packaging. From all the techniques mentioned above to have a better filter thus were used in this project to develop a wideband bandpass filter using slotted SIW resonator for 5G communication that will operate between 26GHz to 28GHz.

1.3 Objective

- To design wideband bandpass filter using slotted substrate integrated waveguide between 26GHz to 28GHz.

- To analyse the performance of the wideband bandpass filter using slotted substrate integrated waveguide for 5G communication system.

1.4 Scope of work

In this project there are certain details of the work that will be completed. Since there are many forms of SIW Bandpass Filter (BPF) available, some scopes of work are to be concentrated. This is for achieving the better design goals. The work is development of a wideband bandpass filter that used a slotted SIW resonator between 26GHZ/28GHz for 5G communication. Advanced Design Software, the project is simulate in it with the correct parameter. The results obtain then will be analyzed to get high performance wideband filters referring term S-parameter insertion loss (S_{21}) and return loss (S_{11}).

1.5 Chapter review

Chapter 1 provides a general overall view of this project primarily. Chapter 1 explains the project's introduction, statement of the issue, objective and scope. In addition, this chapter also reviews all the project chapters.

Chapter 2 outlines the results of a study of the project's literature. This includes a band-pass filter and ongoing studies. The episode begins with the simple and fundamental definition of a band-pass filter. The understanding of the Substrate Integrate Waveguide (SIW) band pass filter with via holes on it. The design of the SIW must follow all of its rule.

The most important section of this chapter focuses on literature on the various methods used to construct a band-pass filter. The plan will be introduced in depth in Chapter 3. The wideband band pass filter design using slotted SIW will be shown in detail. In addition, the design process for this project will be developed. There are a number of basic processes for modeling band-pass filters, such as estimation, simulation, manufacturing and measurement.

Chapter 4 illustrates, explains, discusses and presents the analysis results and measurement of the wideband bandpass filter. For the development of this project, the design begins with the ideal transmission line structure, the rectangular waveguide structure, the next dynamic layout formation and the last structural characteristics of the SIW Resonator passband.

The conclusion, environmental sustainability, commercials and future work for this undertaking will be stated in this chapter 5.

CHAPTER 2

LITERATURE REVIEW

This chapter explains the review of the literature that was done for the development of project purposes from various developed projects. It will discuss the information details extracted from a few specific elements and topics.

2.1 Background study

The growing need for high performance filters in the field of radio frequency and wireless connectivity contributes to improvements in the development and installation of resonator filters. The design of filters is one of the most interesting fields of microwave technology. Several experiments have been carried out in the past in this section to develop the electrical characteristics of inductive waveguide filters. Inductive microwave window filters, for example, have been explored. Any of the design factors or parameters of filters, such as selectivity, expense, thickness, impact resistance, power handling capacity, in-band and out-of-band efficiency metrics, are critical factors when it comes to radio frequency (RF) output and electromagnetic interaction front ends.

2.2 Types of filters

A filter is a circuit that, while attenuating certain frequencies, may move (or amplify) other frequencies. Signals which also include unnecessary or insignificant frequencies may be excluded from a filter. There are also two styles of filters, which are active filters and passive filters. A passive filter does not require an external power supply while an active filter needs a power supply. A passive filter does not require an external power supply while an active filter needs a power supply. Low-pass filter, , band-pass filter, bandstop (or band-reject) and high-pass filter are four primary filter types.Passive Filter includes a combination of passive components such as resistors (R), inductors (L) and capacitance (C), while the active element consists of mechanical amplifiers, resistors and condensers, excluding inductors. A low-pass filter that ignores high frequency and enables signals from the input to the output of lower frequency signal. High-pass filter that rejects lower frequencies while providing signals from transmitter to receiver of greater range signals. Ultimately a band-stop filter is basically the inverse of a band-pass filter in terms of responses A band-stop filter requires all frequencies to move, except those under a certain stop band. A band-pass filter excludes all frequencies below and above the passband thus allowing passage and attenuation of a certain band of frequencies.

2.3 Bandpass Filter

Bandpass filters are mainly used by cellular transmitting and receiving. The primary purpose of such a filter in a transmitter is to restrict the bandwidth of the output signal to the minimum necessary to transfer the signal at the speed and in the form required.. A bandpass filter enables the reception or decoding of signals in a receiver within a specified frequency range, thus preventing the transmission of signals at unwanted frequencies. In both receiving and transmitting capabilities, possibly the best-designed bandpass filters that use optimal level bandwidth for mode and interaction frequency optimize the number of signals that can be transmitted over the network even when reducing interference problems. In Hertz, the resonant frequency between the lower and upper 3dB cut-off points of the RC configuration is known as the "bandwidth" filter.

Another of the common basic approaches in the design of filters is the Chebyshev method, which can be useful when it comes to sharp ejection and the low transient lag between passing and rejection bands, due to the ripple response of the Chebyshev technique to the frequency response of any filtration system specified, in general the bandpass filter.

A bandpass filter is an electronic that transmits frequencies over a certain range and disregards frequencies beyond that band (attenuates). Formulate these filters, too, by integrating a low-pass filter with a high-pass filter. Zhang et al. also presented a second-order tunable dielectric substrate bandpass and band-stop filter by the use of diodes[4], using the Δ/2 resonator concept, respectively. A band-pass system is a device that transmits frequencies within that range and removes frequencies (attenuates) beyond it's range. Such filters can also be manufactured by integrating a low-pass filter with a high-pass filter. The bandwidth of the filter is just the difference between the above and below cut-off frequencies.

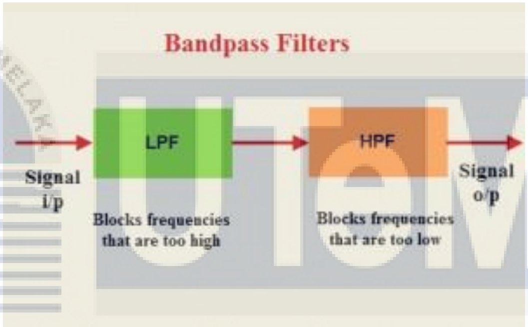


Figure 2.3.1: Flow of LPF and HPF

BW as the distinction between the low frequency range of cut-offs (F_L) and the higher frequency of cut-offs (F_U). Apparently for a pass band filter in order to function properly, the low pass filter cut-off frequency must be larger than the high pass filter cut-off frequency.

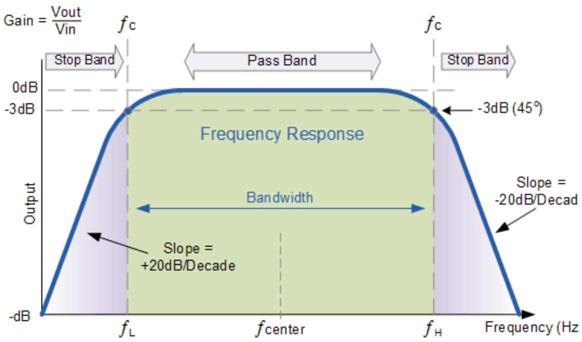


Figure 2.3.2: Bandpass filter with high and low frequency

2.4 Basic properties of filter

Basic filter properties are needed to describe the performance. The filter is designed with some basic properties

a. Insertion Loss

The entry failure in the RF switch, according to Bacon et al(2014), determines the amount of signal attenuation that occurs for a given switch direction. In other words it is a signal power ratio at a closed switch's input and output ports (Berezniak & Korotkov, 2013). Loss of incorporation is measured in decibels and is representative of negative quantities. The better the loss of insertion, the higher the loss value of insertion. In other words, it will be a smaller negative number.

b. Return loss

The general definition of return loss is a reflected signal ratio at an input circuit or network to the incident signal. Most designs of RF switches need a very strong loss of return at used terminal. Loss of return is expressed in decibels and reflects negative amount. The higher the lack of revenue, the greater the amount of missed gain. This will be a greater negative number, in other words.

c. Bandwidth and fractional bandwidth

The subtraction of the upper frequency cut-off and the lower frequency of cut-off is defined as bandwidth in a continuous frequency band. A device's bandwidth, separated by its middle frequency, is called fractional bandwidth. The larger the number, the broader the bandwidth.

$$BW = fU - fL \qquad (2.1)$$

Where:

f_U = *Upper frequency cut off*

f_L = *Lower frequency cut off*

BW = *Bandwidth*

$$fc = \frac{fL + fU}{2} \qquad (2.2)$$

Where:

f_U = Upper frequency cut-off

f_L = Lower frequency cut-off

f_c = Center frequency

$$FBW = \frac{BW}{fc} \times 100 \qquad (2.3)$$

Where:

FBW = Fractional bandwidth

BW = Bandwidth

Fc = Center frequency

The larger the bandwidth, the greater the frequency range and the greater the fractional bandwidth. The band structure type and the FBW percentage are shown in Table 1.

Type of band	FBW (%)
Narrow band	<20
Wideband	≥20
Ultra-wideband	>50

Table 1: Type of band and the percentage of FBW

2.5 Substrate Integrated Waveguide (SIW)

With the rapid advent of the new microwave and transceivers system, its role is becoming increasingly complex., the electrical quality requirements are increasingly high, while the size is becoming smaller and lighter; the entire structure is miniaturized, lightweight , high durability, flexible and low cost position. [5] Low-cost, high-performance and high-performance microwave transceivers technologies are very vital for the future of a commercialized low-cost electromagnetic millimeter wave broadband network. Consequently, the development of a new integrated microwave and millimeter wave technology is urgently needed. A waveguide structure based on the dielectric substrate Substrate Integrated Waveguide (SIW) has been proposed to resolve these contradictions.

The Integrated Wave Guide (SIW) is some kind of three-dimensional constant configuration that allows the structural transformation through the use of PCB, LTCC and so on, through the metal through hole or air through holes, restrict the outward radiation of electromagnetic waves which replaces the conventional rectangular waveguide or non-radiative dielectric waveguide (NRD). At the same time, the elements of the integrated substrate waveguide technology have the advantages of high voltage gain, large capacity capacity, low cost and simple integration.

2.5.1 Characteristics of substrate integrated waveguide

All the advantages of the SIW microstrip line set and the rectangular waveguide are simple to execute and have high efficiency. SIW compared with the standard rectangular waveguide structure is more compact, has the advantages of light weight, small volume, easy integration processing etc. Unlike standard rectangular waveguide, SIW has similar propagation characteristics, for example, it can achieve high antenna efficiency and a high quality factor in millimeter wave band. After designing and processing. SIW can modify its efficiency to the design requirements by choosing the length of the metal via-hole and its input validation is more useful than the traditional rectangular waveguide. Most microwave active filters are surface deconstruction or chip form, so they need a coplanar circuit component , such as a cpw waveguide and a microstripe. SIW can make a good transition with the coplanar transmission line, which highlights the advantages of easy integration.

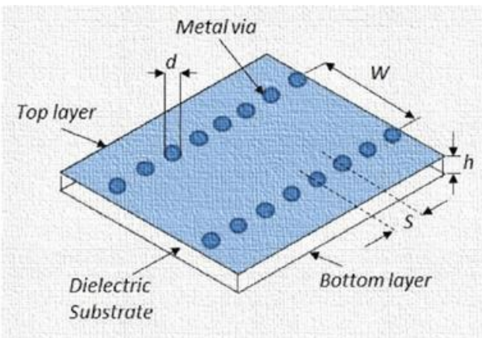


Figure 2.5.1: Geometry of a Substrate Integrated Waveguide

2.5.2 Via Holes

Justification of the integrated waveguide substrate material is a rectangular waveguide created by two strong conductor planes, a dielectric substrate, with permeable walls surface supported by metal cross-sections, as shown in Figure 2.5.2. The SIW is a waveguide synthesis inside a substratum and the propagating wave is delimited by holes.

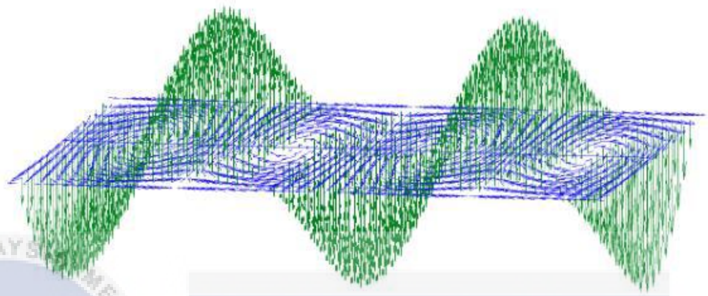


Figure 2.5.2: Wave propagation in SIW

Bilateral edge walls of the main size of the SIW are to be rendered through gaps. Miniaturization and large-scale system integration have created a fascinating demand for multi-layer connectivity geometry, with holes is among the most major interruptions in multi-layer circuits. There are also other research on the behavior of via holes. The formula to get the diameter of each via holes (2.4).

$$d < \frac{\lambda_g}{5} \qquad (2.4)$$

2.5.3 Application of SIW

SIW technology finds opportunities in diverse microwave and millimeter wave circuit components, such as numerous passive and active SIW items. [6]. Variants of SIW materials have recently been discovered for microwave and mm - wave applications. They can be used by passive, active components and antennas. Few compact components, such as millimeter-wave resonators, have recently been published. [7], Oscillators[8], power dividers[9], phase shifters[10], Diplexers[11], Directional couplings[12], RF Mixer[13], Amplifier[14] compared to standard technologies, the use of SIW technology has been shown to be efficient, small and inexpensive. In addition to these parts, a lot of research Filter and antenna design was already completed in the last few years. Filters are the most commonly used passive components in microwave circuits. There has also been strong growth and involvement in SIW-based antennas over the last few years. SIW technology has recently been successfully designed to achieve lightweight and greater-gain antennas in a number of shapes and configurations.

2.5.4 Slotted SIW

One of the metallic surfaces, the SSIW has a small longitudinal opening. Allows simple propagation mode in half mode away from standard full SIW mode[15]. It also enables the integration of passive components or active components and allows the waveguide to be filled with impedance matching.

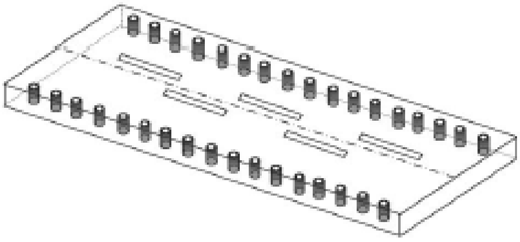


Figure 2.5.4: Slotted SIW [15]

These resonators are made by gravitation of the microstrip slot on the upper surface of the SIW. In addition to the radiator, these slots serve as a sequence condenser. Since its operating frequency was below the cut-off frequency of the waveguide, it resulted in significant structural compactness. This featured a V-shaped (inverted) hole on a waveguide constructed into a substrate. The slot added to the capacitance of the show and also acted as the radiator. Using this method, the volume dimension was decreased by approximately 50%.When applying this method to half-mode SIW (HMSIW) and quarter-mode SIW (QMSIW) resonators, 90 per cent was achieved compared to traditional full-mode SIW resonators and 95 per cent of miniaturization was achieved. In 2015, Alkhafaji et al presented a bandpass filter configured to load two half-circular slots in the SIW structure from the input and output sides. With a reduction of approximately 70% in size relative to traditional SIW, the proposed filter was highly compact.

2.6 5G Communication

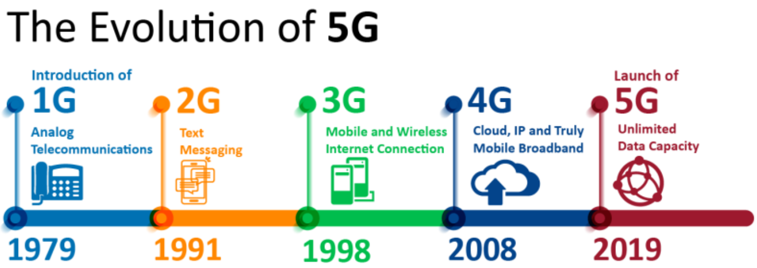


Figure 2.6: The evolution of 5G

Current cellular systems such as LTE, LTE advanced and 5G use multiple radio frequency bands instantaneously to distribute the spectrum needed to maximize data speeds. The need for reconfigurable filters is therefore increased. RF interference is an extremely serious concern in current wireless networking technologies such as 5G and wide-band radar systems. Most recent books and papers address the use of "natural" versatile RF antennas in 5G applications. Currently, 5G cellular networking infrastructure is being discussed for use in 700 MHz, 3.6 GHz and 28 GHz ranges. Spectrum which is nationally set-aside for vertical industries priority 5G (i.e. 3.5/26/28 GHz) bands pose several threats to 5G greater success [16].

5G networks use mm-wave frequencies provide the fast 100 Mbps service in urban centers. The key drawback is the limited usable fractional bandwidth (FBW) for 4G and LTE networks. The higher bandwidth of the same FBW is given at the mm-wave frequency. The additional issue of MBMS RF smartphone approaches, literally carrier aggregation (CA), needs more ranges to be incorporated into the same user-equipment virtual form. Therefore, the ability to provide higher volumes of data to the end-user. This translates into rising sophistication of electronics.

2.6.1 Benefits of 5G

5G is a new type of connectivity technology network that will not only strengthen mobile broadband infrastructure today, but will also extend mobile networks to serve a wide variety of devices and infrastructure and link new markets with enhanced capacity, reliability and cost. 5G will redefine a wide variety of markets, from retail to training, transport to culture, and all in among. As revolutionary as the car and energy, we see 5G as engineering.

In a pioneering analysis of 5 G Economy, we found that the full economic effects of 5 G will be realized worldwide by 2035, benefiting a wide variety of sectors and potentially generating services and products worth up to $12 trillion. The report also indicated that the 5G value chain (OEMs, suppliers, content creators, app developers and consumers) could generate up to $3.5 trillion in total income by 2035 on its own and maintain up to 22 million jobs or even more than one job per person throughout Beijing, China. Of course, most new and evolving technologies still need to be completely developed or even understood today. That's why only time will tell you what the full "5 G effect" would be.

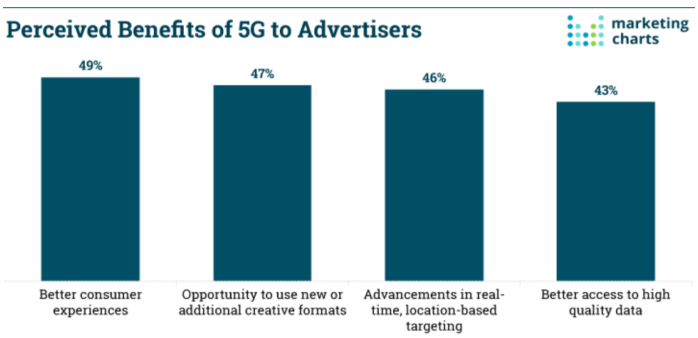


Figure 2.6.1: Benefits of 5G

2.6.2. How does 5G work

The 5G innovations include all sorts of advanced features that will make 5G mobile technology more competitive in the near future and in huge demand. Bluetooth technology and Pico nets have become available on the market for kids who are rocking fun. Users will also link their 5 G mobile phone devices to the broadband internet from their desktop. 5G technology will never imagine having cameras, 8 MP3 files, video players, massive phone memory, speed dialing, audio players, and more. Unlike 4G LTE, 5G is also built on OFDM and will be focused on the same concepts of wireless connectivity. Nevertheless, the new 5 G NR (New Radio) air network will further boost OFDM and seem to have greater versatility and usability. Also refer to this 5G waveform whitepaper for further detail on 5 G waveforms and multiple access strategies [17].

The image below, 5G Network Architecture, is a truly IP-based architecture designed for mobile and cellular networks. The system consists of a strong interface and a range of separate and independent radio access devices. Every radio technology is considered to be an IP link for the outside world of the Internet. IP technology is designed primarily to provide sufficient control data for the proper routing of IP packets linked to some system connections; i.e Sessions between client servers and clients mostly on Internet. In addition, packet sorting should be configured in accordance with the policies issued by the user to make it available.

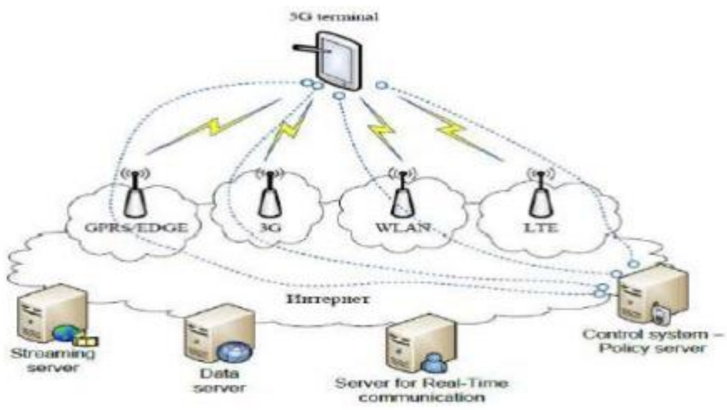


Figure 2.6.2: Basic architecture

Not only would 5 G offer quicker, improved mobile broadband coverage compared to 4 G LTE, it will also extend to new network areas such as mission-critical connectivity and comprehensive IoT networking. It is made possible by a range of creative 5G NR multiple access design approaches, such as a latest self-contained TDD subframe model; please refer to this 5G NR whitepaper for the more specific details on 5G and to explain the various 5G NR proper method.

2.7 Previous Research Study on Substrate Integrated Waveguide (SIW)

2.7.1 Embedded Microstrip and Rectangular Waveguide in 28GHz Planar Form

In this article, the implementation of a new planar framework In which line of microstrip and rectangular wave-guide Are totally incorporated and interconnected on the same substratum by actually tapering. Such 28 GHz tests show that an effective 12 percent bandwidth over 20 dB return loss is achieved with a loss of insertion in the inband greater than 0.3 dB. In order to check the principle suggested, a transition operating in the range of frequencies of LMDS is invented then determined. The whole lot the structure consists of two transitions back- to - back, separated by an integrated 16 mm long wave-guide. The circuit is built on a 0.254 mm thick dielectric substrate with a pitch = 2.33. Measured effects are closely correlated with those predicted for the transition sample made.

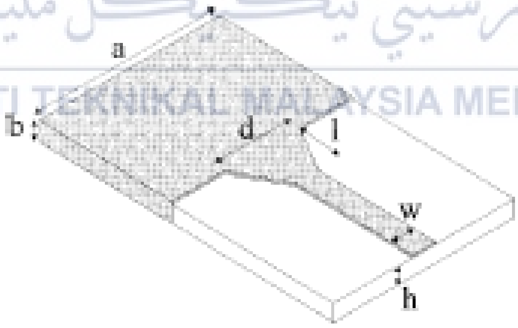


Figure 2.7.1.1: Structure of the planned transition from a microstrip line to a rectangular waveguide within the same substrate.

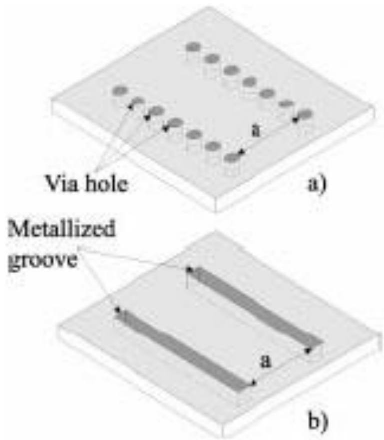


Figure 2.7.1.2: As of-substrate synthesized waveguide techniques: (a) silicone coated via-hole arrays and (b) metal grooves.

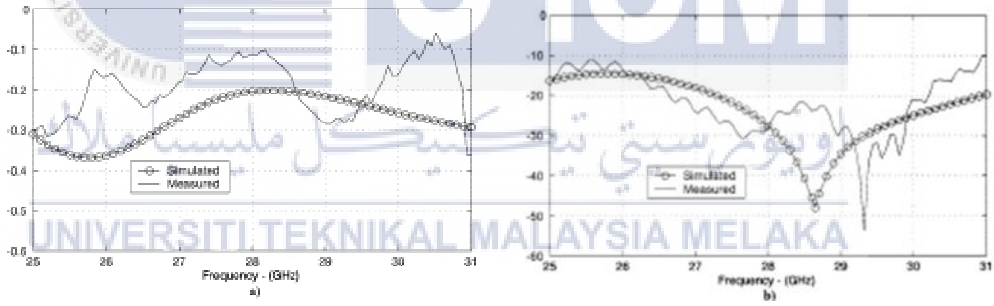


Figure 2.7.1.3: Frequency response

2.7.2 Ultra-compact Wideband Milimiter-Wave Crossover Using Slotted SIW Structure from 27.4-32.4GHz. [18]

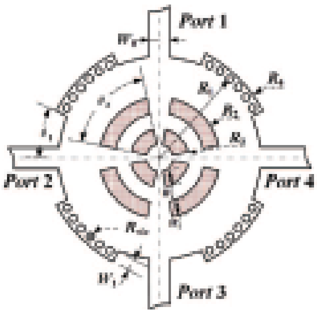


Figure 2.7.2.1: Crossover proposed for SIW

Figure 2.7.2.2: Mode 1 and mode 2 distribution on h-field

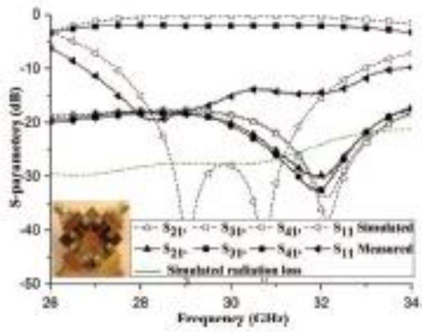


Figure 2.7.2.3: Measured and simulated response frequencies and suggested crossover

The journal tells about an ultracompact wideband crossover with slotted SIW structure is proposed and designed. It consists of a rotating SIW junction with eight fan-shaped slots that are symmetrically engraved to the inset feed mechanism surface. The shaped fan is used to control the circular SIW cavity resonator's two degenerate modes to achieve wideband operation. The experimental findings indicated the insertion loss estimated is greater than 18dB and the return loss greater than 14dB, which can be accomplished over the 16.7% bandwidth. The dielectric constant is 2.2, 0.254 mm thick. The proposed crossover energy loss comes primarily from the substrate and SMA connections, the estimated integration loss is 2 ± 0.1dB. The discrepancy between measurement and simulation is caused mainly by errors in manufacture. It achieves the comparable bandwidth and significant size reduction of about 91%.

2.7.3 Millimeter-Wave Ultra-Wideband (UWB) Bandpass Filter (BPF) Using Microstrip Parallel Coupled Lines [19]

This article explains and indicates that the lightweight millimeter-wave bandpass filter for automotive radars was designed to meet the FCC requirements, the filters are designed to pick the UWB spectrum (22-29GHz). The filter consists of two parallel-coupled line segments, which are quarter-wavelength long at an average frequency of around 25.5 GHz. In order to improve filter efficiency by allowing the filter to display a new transmission zero across each part of the passband, a shunt ring resonator and an open-circuited shunt impedance stub are installed between the coupled microstrip sections in the centre. The configuration of the filter is made using the RT / Durroid 6002 substrate, and the EM simulation and test are used to validate the design. The filter configuration is produced and tested effectively, and a very strong agreement is reached between the simulated and calculated performance. In order to meet the FCC requirements for automotive radar systems, the filter is configured to pick the UWB spectrum (22- 29GHz). The filter is designed to have a fractional bandwidth of around 22% to achieve this. At a frequency of around 25.5 GHz with mid-band. The filter is applied with RT / duroid 6002 substrate for an effective 2.94 dielectric constant, the thickness of the 0.127 mm, and a 0.0012 tangent loss. The magnitudes of losses from insertion and return are shown in Fig. 2.6.3.3.The measured insertion loss at midband frequency is less than 3.7. The measured yield loss over the entire bandpass is better than 12 dB. The flicker displayed 3 poles within the bandpass and two zeros at the ends of the bandpass.

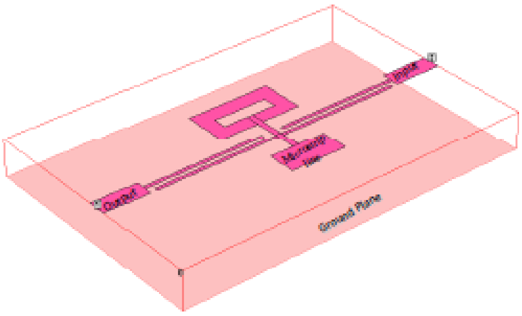


Figure 2.7.3.1: Bandpass proposed UWB millimeter wave on microstrip substratum

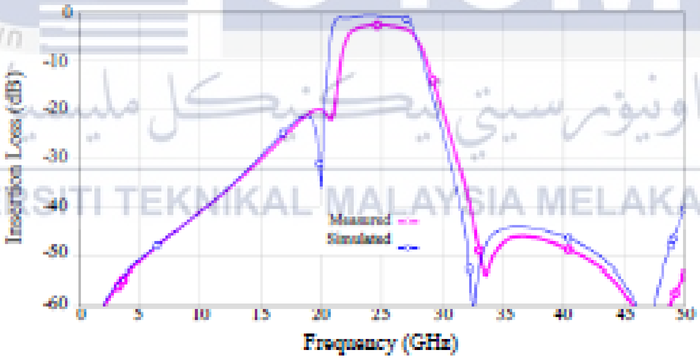


Figure 2.7.3.2.: The proposed UWB BPF compares simulated and measured losses at insertion

2.7.4 Demonstration of 28GHz Band Pass Filter toward 5G Using Ultra Low Loss and High Accuracy Through Quartz Vias [20]

The electrical conductivity of artificial fused quartz and the high precision of quartz glass by forming technique (TQV) have been demonstrated. Synthetic fused quartz metallization technology is often addressed and is also a key technique for the effective use of materials A 28 GHz Integrated WaveGuide (SIW) Band Pass filter is shown and defined. The effects of its measurement well supported the simulation result and demonstrated an incredibly large output. SIW equipment was constructed using finite element method b (THE FEM). Dielectric constant is AQ material parameters Of 3,785 and a Tangent deficit of 0.0002. The AQ was 0.4 mm in thickness. Approved 100 µm tqv diameter. We select 400 µm as a pitch-based SIW. The bandwidth of the measured SIW-BPF was about 2 GHz (27.2 GHz~29.2 GHz) due to loss of 1.2dB and 7.14 percent fractional band length below insertion. Further analysis will be needed to measure the device's output itself, since all systems are measured characteristics using SIW-to-CB-CPW.

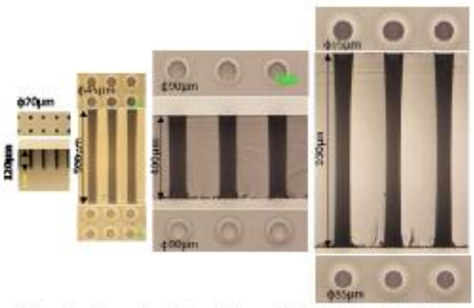


Figure 2.7.4.1: Through via and blind via formed

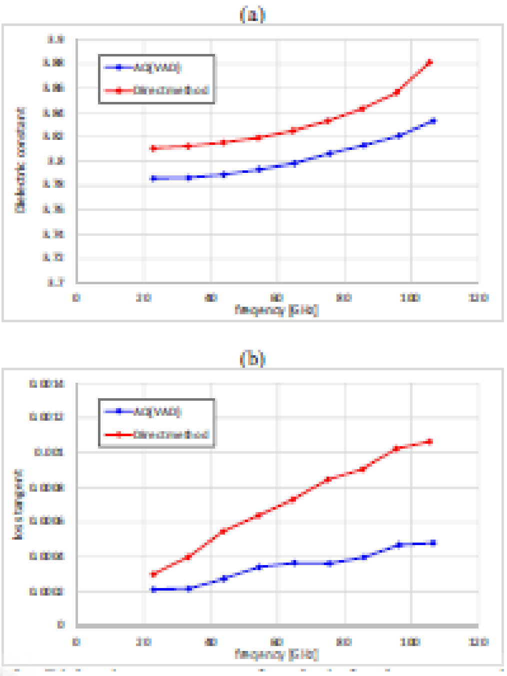


Figure 2.7.4.2: Dielectrical analysis via VAD and direct process of the synthetic fused quartz materials: (a) dielectric constant, (b) tangent loss

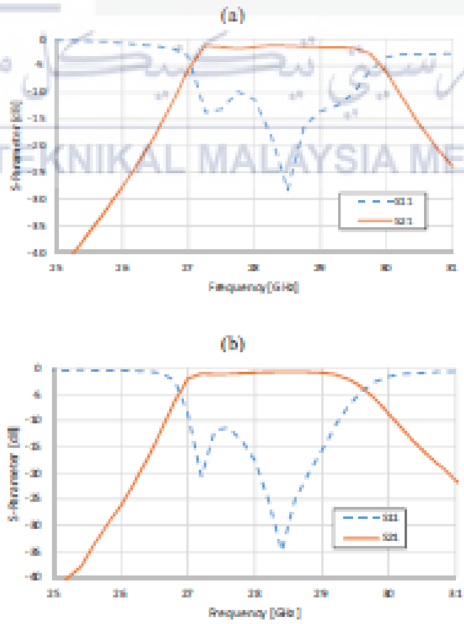


Figure 2.7.4.3: SIW-BPF Interfaces Transition:

(a) Model S-parameters (b) The S-parameters estimated

2.7.5 Design of an Ultra-Wideband Bandpass Filter for Millimeter Wave Applications [21]

This book explains Ultra-Wideband Bandpass (UWB BPF) filter designs with 3 different structures; using a double shunt ring resonator, a resonant frequency resonator, and a microstrip resonator located in the center of two parallel paired microstrip parts. The 22-29 GHz frequency spectrum is used as a mid-range to satisfy the specifications of the FCC and 25.5GHz. Full simulations of the proposed designs are performed using HFSS V13 software using RT Duroid 6002 as a 2.94 substrate constant dielectric surface. Both designs are built on the same substratum with an identical 5.8mm*2.8 mm substrate area and a thickness of 0.127 mm. This extracts a large fractional bandwidth of almost 40%, a high selectivity of up to 82dB, particularly in the case of a double square patch resonator model.

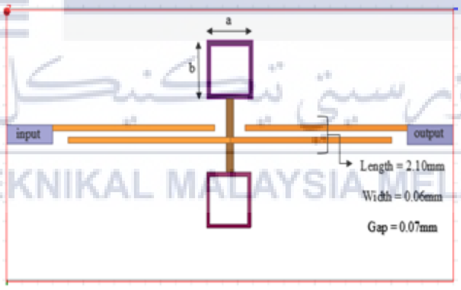


Figure 2.7.5.1: Circuit model with dual, identical shunt ring resonator

Parameters	Specifications
Width of shunt ring resonator (a)	0.60mm
Length of shunt ring resonator (b)	0.60mm

Table 2: Parameter for the shunt ring resonator

All filter parameters are analyzed in Figure 2.7.5.1 and comparative analysis is performed. These designs are more successful than conventional designs. Both designs are performed on an RT / Durroid 6002 substrate with 2.94 dielectric constant and 0.0012 tangent loss. Simulation is done with HFSS V13 software with a 25.5GHz center frequency. The results of the proposed model using dual identical shunt ring resonators are shown in Figure 2.6.5.2.

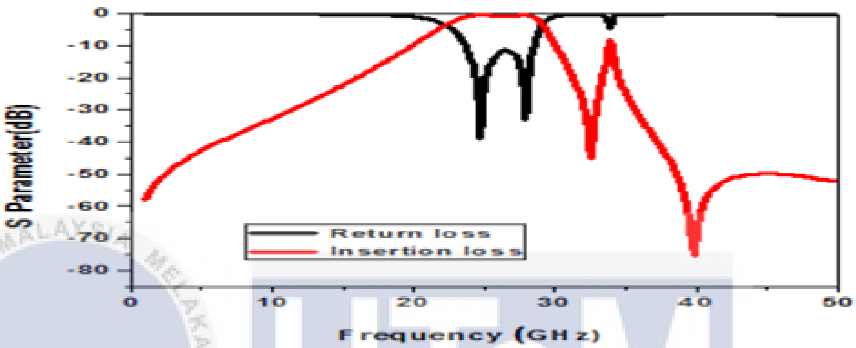


Figure 2.7.5.2: Two identical resonators

The dual-identical shunt ring resonator configuration results in a return loss of approximately 14dB at a mid-frequency of 25.5GHz, increasing to 37dB at 24.7GHz. The resultant integration losses are closer to 0.4dB, which is almost equal to that of the insulation coefficient, although the coefficient of reflection is directly related to the return loss.

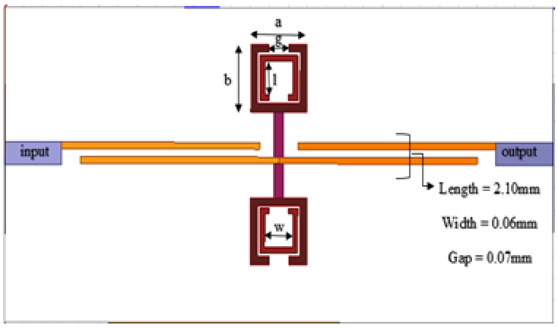


Figure 2.7.5.3: Suggested circuit layout with double equal split ring resonator

Including SRR increases the coupling effect of the filter in the presence of an electromagnetic field due to its high magnetic susceptibility properties. Other advantages of SRR are low radiation loss, high Q factor and small size due to quasi-static sub-wavelength resonance measurement.. Relative to the size with increased filter parameters, the SRR decreases the occupancy of the substrate. Table 2 shows the specifications for the proposed model with identical dual SRR.

Parameters	Specifications
Width of outer core of SRR (a)	0.60mm
Length of outer core of SRR (b)	0.60mm
Width of inner core of SRR (w)	0.40mm
Length of inner core of SRR (l)	0.40mm
Gap between cores of SRR (g)	0.20mm

Table 3: Parameter for the outer core SRR

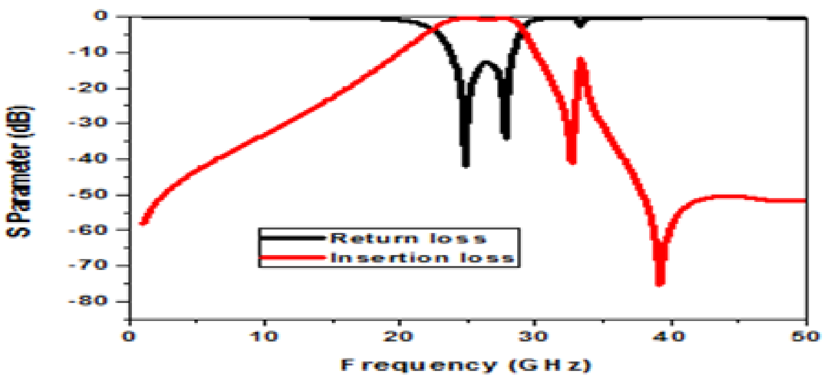


Figure 2.7.5.3: S-parameters proposed for the filter with a dual split ring resonator

The return loss of this design concept is approximately 16dB at centre frequency , i.e. 25.5GHz extending to 46dB at 24.8GHz, and the center frequency loss of insertion is 0.39dB. Of filter designs at the center frequency, the values of the return loss and reflex coefficient as well as the insertion loss and insulation values are the same. The fractional bandwidth of this system is approximately 28 percent with a high selectivity for 41dB close to 32GHz. The ability to prevent false signals is characterized by selectivity.

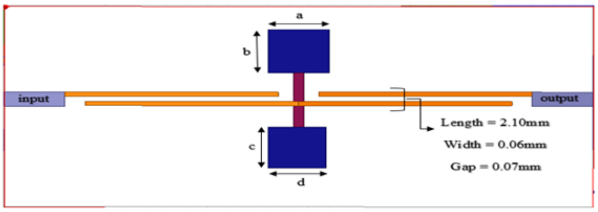


Figure 2.7.5.5: Proposed circuit model with resonator with double square ring

Parameters	Specifications
Width of the upper square patch(a)	0.60mm
length of the upper square patch(b)	0.60mm
Width of the lower square patch (c)	0.57mm
Length of the lower square patch(d)	0.57mm

Table 4: Parameter of the upper square patch

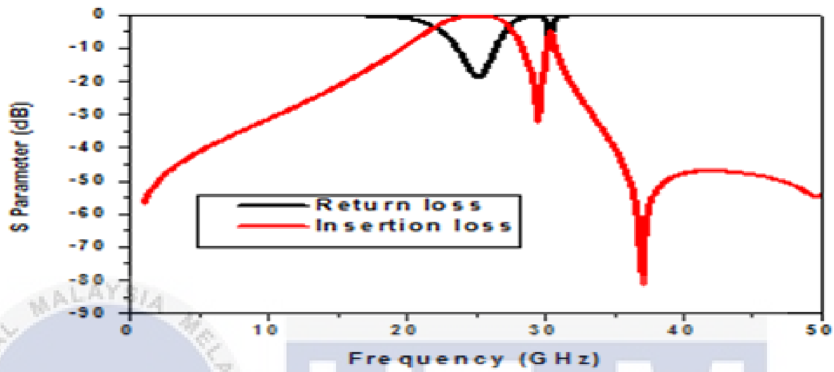


Figure 2.7.5.6: Proposed circuit model with resonator for double square ring

The rate of return loss and reflect is almost equal and hits nearly 45dB on 25.9GHz. The lack of insertion is also not affected as S (2 , 1) shows a low value of almost 0.3dB. Designs with higher return loss results in an increased loss of insertion, but this design provides the desired results with a small size and ease of manufacture. The radiation efficiency is around 28%.

2.7.6 Microstrip Crossover for Millimeter-wave Applications (22)

Using 2.94 permittivity, 30 mm thickness, 0,0012 tangent dielectric loss. The concept is shown in Figure 2.7.6.1. The length of the transmission line is 5.9 mm, the crossover dimensions are 32 GHz. Its bandwidth is 1.5 GHz. Aircrafts can be studied by reducing to four forms of single-port configuration, each symmetry plan by magnetic or electrical boundary or by strange excitation of the planes of each symmetry.

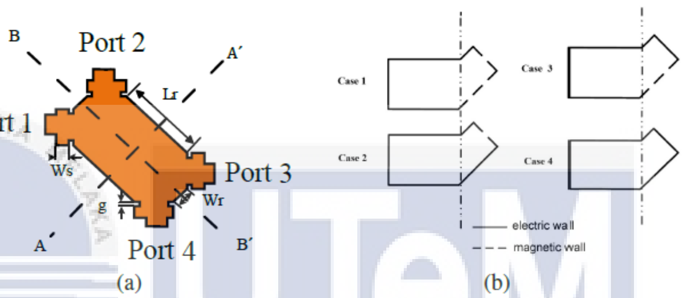


Figure 2.7.6.1: (a) Crossover planned. Lr is 3 mm, Wr is 0.72 mm, g is 0.15 mm, Ws = 0.42 mm, (b) Crossover boundry.

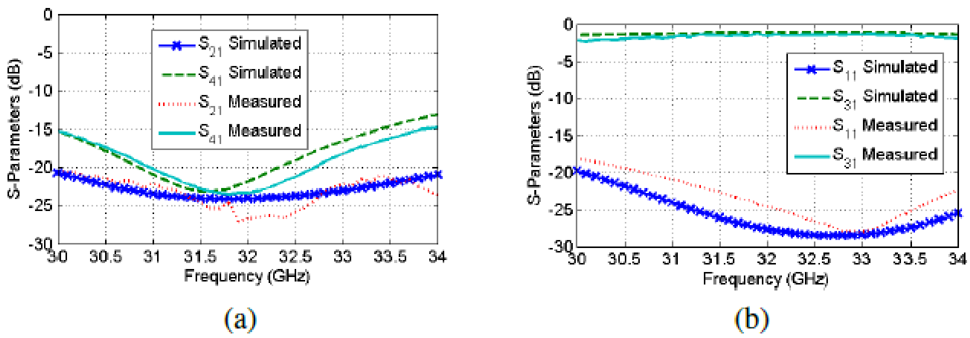


Figure 2.7.6.1: (a) Measured and predicted crossover (S21) and (S41), (b) Simulated and calculated crossover (S11) and (S31)

This letter creates a new lightweight low-loss crossover using microstrip technology and comprised of four port couplings. A full-wave analysis of an analogous circuit is presented and an experimental test is carried out. The results of the measurements showed a very good correlation with the simulated component. For sufficient performance, insulation and coupling is less than 20 dB. The insertion loss is less than 0.7 dB and the insulation bandwidth is 5 %. Circuits can be used to exit other millimeter wave systems, such as radars, and crossover microstripe junctions designed to be really good and suitable for compact development.

2.7.7 Design of substrate integrated waveguide fifth order band pass filter [23]

One of the really commonly used filter design type is the rectangular structures that promote the optimization process by which the number of parameters we use. Based on the band-pass filter design process. We used rectangular waveguides to determine the parameters G of the inverter impedance corresponding to the discontinuity of the waveguide. After a parametric analysis of the two factors, the most optimal use was made of them in the project result. A symmetrical X-band based SIW . The Bandpass filter is built as shown in the figure below. It is a Chebyshev 5th order bandpass filter with a 0.1dB ripple of 0.8 mm thick substrate content, 4.3 permittivity.

Figure 2.7.7.1: Fifth order SIW filter with irises

The initial CST-MWS model is calculated and an optimization technique for the entire filter is carried out. The results of the S-parameter simulation for the proposed SIW filter as shown in Fig 2.6.7.2 show good selective filter performance with Lar=40dB rejection level. The filter bandwidth is about 13 percent, with a return loss of almost 40 dB at 11.2 GHz Decent selective efficiency from 10 GHz to 11.4 GHz as shown below.

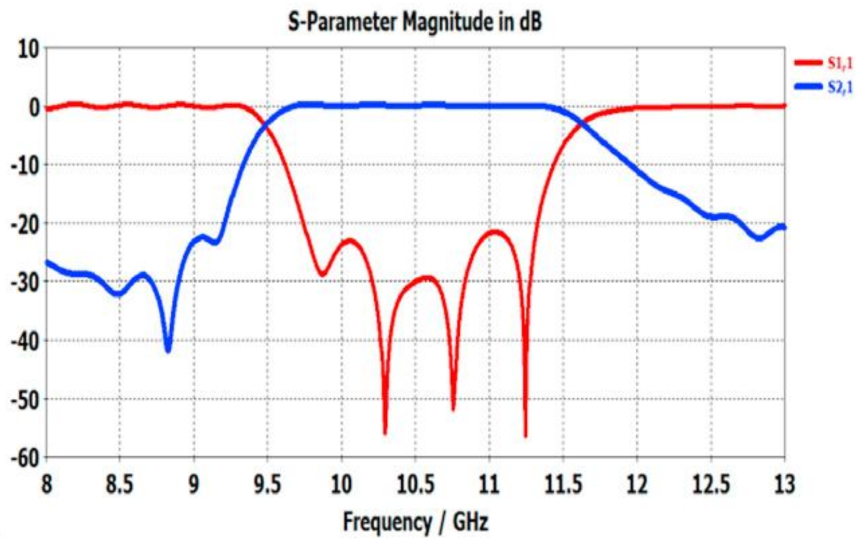


Figure 2.7.7.2: WG Fifth order filter s irise parameters

2.7.8 Integrated Transition of Coplanar to Rectangular Waveguides [24]

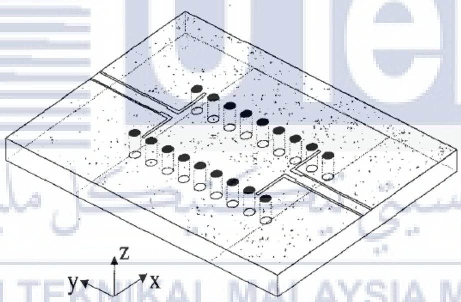


Figure 2.7.8.1: Schematic view of the designed rectangular wave guide and coplanar wave guide mounted on the same substrate.

The integrated waveguide represents a good solution between a rectangular air-filled waveguide and a microstripe line. The microstripe is too thin to design quality Factor components in the millimeter-wave spectrum. For eg, the unloaded Q factor is 42 at 28 GHz, a 50 Q line built for a 0.254 mm thick dielectric with an allowivity of 2.33 (tan6=0.001) and 0.0254 mm copper cladding. This is a very easy change to design. The length of each bend slot (L) on the CPW is approximately h/4, and the short circuit ends. The electrical fields on these positions, minimum at the end and average at the other end of the quarter wavelength line, relate very well to the propagation of the TELO field in.

A transition within the spectrum of LMDS frequencies is planned, programmed and tested to validate the proposed definition. The arrangement consists of two reverse-to-reverse transformations and an integral 10 mm waveguideDielectric thickness may be boosted in order to avoid the amount of the conductor in relation to the rectangular waveguide design. Measured findings are right in the agreement of the simulated tests for our production transformation study. Suitable for millimeter-wave frequencies for circuit construction. The active circuits MIC and MMIC could be used to integrate passive waveguide components for commercial production. Figure below shows our simulated and measured results containing 2 transitions and a 10 mm rectangular waveguide. More than 7 per cent of the bandwidth obtained here €or a return loss of 15dB between 27.5 and 29.5 GHz. The measured loss of insertion in the whole band is better than 3.2dB.

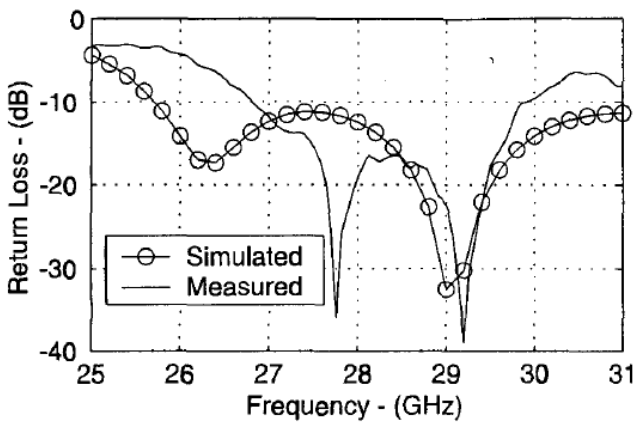


Figure 2.7.8.2: Simulated and measured transitions of two-way results separated by integrated 10 mm waveguide

CHAPTER 3

Methodology

The procedure used to design this filter is described in this chapter. This chapter described every technique and steps that were used. The filter is designed using the ADS software after calculation for the waveguide parameters has been done. In the software the final design has been simulated. Therefore the methodology has to be organized to ensure that this project runs efficiently.

3.1 Introduction

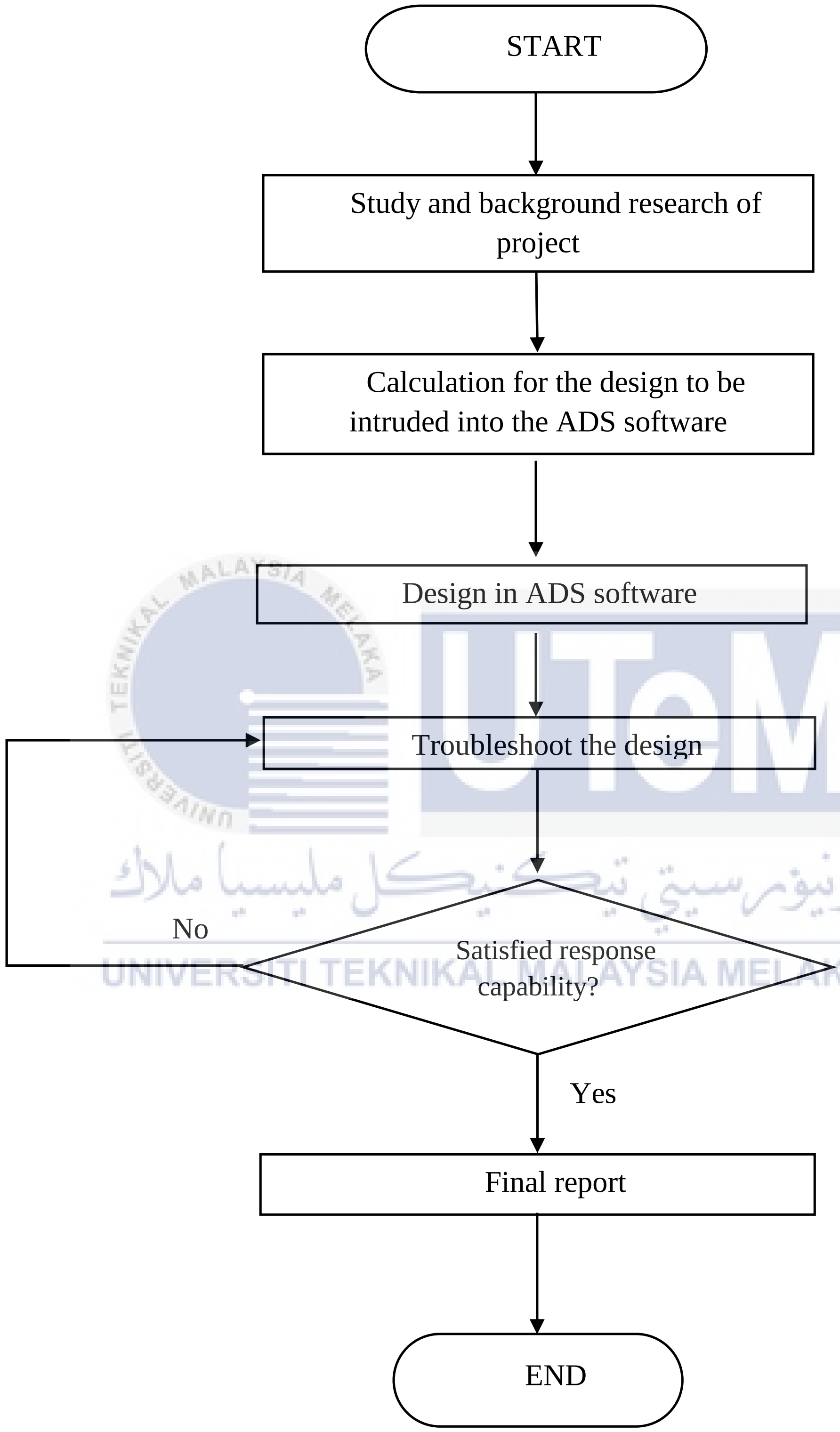
This chapter will address all policies, strategies and approaches to accomplish the goals of this initiative. The methodology will therefore explain more about each step of the project to ensure that the project is able to work and run smoothly without major errors.

3.2 Methodology Process

In order to complete this section, the methodology for this project must have a sequence of events in written form. The chronology of this project approach involves determining the right project description, reading article, preceding related project work, project preparation, program setup, simulation testing, performance monitoring and reporting. Both of these chronologies are important to ensure the secure and successful execution of the project process. It's also to make sure this project is on the right track and stay on the right track, otherwise. The title we choose must be relevant to and related to the project.

Research must be conducted through books, journals, and other items having similarities to the previous project in order to establish and identify the operation of the project. In order to avoid errors, project planning had to be carried out during the project process. The technology used for this project must therefore be optimized to determine and execute the software. The features and outcome of the project can be helped ensure by simulating a simulation to identify the output and, if a problem arises, by easy troubleshooting.

3.3 Flowchart of the project



The plan for the final year is an essential part of your journey. This can be challenging, particularly for those with a lack of direction. Some are usually unsure about the whole study process, considering the condition of beginners. The most challenging aspect of undertaking a final year thesis is to decide the research field. Many students are simply overwhelmed by the number set of possibilities available. At this early stage, it is quite necessary for people to consult each and every possible person, both friends and professors, for advice. Conduct a thorough enquiry before reaching a conclusion and never turn back from recommendation. However, you must ensure the final action is in your hands.

A thorough analysis of the literature seems more than sufficient here. This not only discusses past instances of your project concepts, and moreover encapsulates, analyses, compares and contrasts, and creates a connection between various research papers, paperback novels and other reliable sites that may relate to the proposed project. By providing a literature review, you tell your evaluation panelists that you've not neglected the basic steps of your research. Don't negotiate on this step. A rich review of the findings gives your paper the advantage.

This is where the technical implementation is taking place, the body of your project. Students are shaken quite often at this point. Make sure you 're running your development challenges so that your project is well constructed. Pay attention to all the details and try to minimize your mistakes and be self - assured about what you do. There would be some trials and errors at first, but make absolutely sure you don't give up. If the criteria is met, move to the next phase of computation before transferring the hollow rectangular waveguide to ADS Software. After implementation, testing and adjustment, it is time to complete the project. This stage is critical and it dictates if the project is a grave injustice. Inability to do so will result in your project not being treated fairly. Take the reasonable conclusion on the basis of the results and gain an overview of the process.

Data analysis is required whenever the simulations in ADS software is efficient. Data analysis is a method of analyzing, updating, turning and modeling data for the purpose of finding valuable knowledge, informing judgment and improving decision-making. Data diverse techniques under a variety aspects and methods, encompassing different techniques under a number of ways, and is used in different fields of business, study and political theory. Investigation that relies heavily on dependent variable, relevant to business information. Data analysis can be performed into descriptive and inferential statistics, exploratory data analysis (EDA) and reliability and validity data analysis (CDA) for statistical purposes. EDA includes the investigation of new data functionality, while CDA concentrates on the verification or falsification of known theories. Finally, the end of the project would be the preparation of the thesis.

3.4 Design parameter.

This is a very easy process to plan. Upon those slots, the electromagnetic fields are negligible at the end and highest from the other end, watching the TE10 well from the quarter wavelength line waveguide flow pattern apart from if for the slot, the rectangular waveguide electromagnetic current is in the x-y plane and the x-z axis.

3.4.1 Design and proposed Filter

To validate the depending on the purpose, the transition operating upon this standard waveguide WR-34, with an operating frequency range from 22 GHz to 33 GHz, is selected. The overall measurement is 7.9 mm × 5.4 mm. The layout of the filter and the simulation of the parameters is carried out by using Advance Design System (2011) software on RT / Duroid 5880 with a dielectric constant, supply = 2.2 and a tangent loss of 0.0009 @ 10 GHz. The entire circuit has a thickness of 0.254 mm. Final dimensions referring to figure 3.4.2.1 – figure 3.4.2.3. Two novel-slotted units are etched with both the above and below metal planes of the SIW channel to create a bandpass. As mentioned above, the cut-off frequency at the lower end can be calculated by the SIW width W, and the cut-off frequency at the downside and the transmitting zero location can be calculated.

It is difficult to design SIW BPF using via-hole magnetic pairing windows, because it is too small to be produced at such a high rate. The etching of certain special form slots on the up or down part metal planes of SIW is widely used in several journal articles for the development of microwave band-pass filters. DGSs is a well-known way to build and implement low-pass filters. This paper proposes a novel resonance structure for millimeter-wave elements. As shown in Figure 3.4.1(a) two are sets of dumbbell slots of the same size engraved on top and bottom of the SIW metal cavity planes with a 90-degree axis rotation. The notched unit on the top plane contains of multiple longitudinal units Figure 4.2.1(b) indicates the dumbbells and the slotted unit is engraved on the bottom side.

The approximate circuit dimensions are used for even more optimization in the full-wave EM simulator. The fine-tuned circuit dimension gained from the EM simulation software in ADS software are L=7.9 mm, W=5.4 mm, P=1 mm, D=0.5 mm, d=0.19 mm, W_g=4.44 mm, W_0=0.782 mm, W_2=0.46 mm, W_4=0.54 mm, W_1=g1=0.68 mm, W_3=g3=0.56 mm, g_2=g4=0.34 mm.

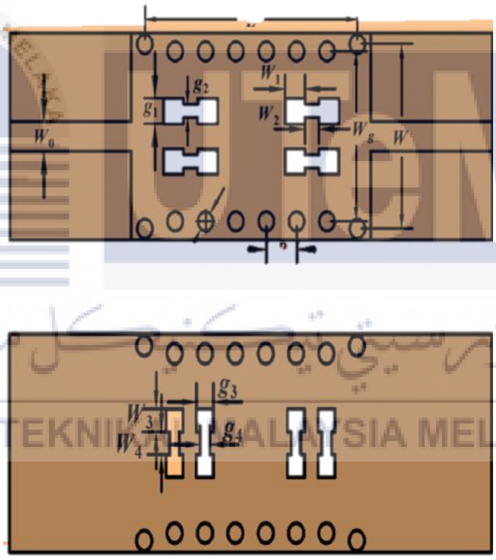


Figure 3.4.1: (a) Estimated circuit dimensions design of the proposed BPF. The filter's top view

(b) The bottom layout of the filter

The proposed SIW was constructed guided by definite formula below:

I. The following two conditions, which are required for SIW design:

$$d < \frac{\lambda_g}{5} \quad (3.1)$$

Where:

d = via hole diameter

λ_g = wavelength

$$s \leq 2d \quad (3.2)$$

Where:

s = distance between the vias

d = diameter of the via hole

II. Guided wavelength

$$\lambda_g = \frac{2\pi}{\sqrt{\frac{\varepsilon_R(2\pi f)^2}{c^2} - (\frac{\pi}{\alpha})^2}} \quad (3.3)$$

Where:

ε = relative dielectric constant

c = speed of electromagnetic wave

F= resonant frequency

α = width of waveguide

III. First resonant frequency mode of SIW cavity

$$f = \frac{c}{2\pi\sqrt{\varepsilon_R\,\mu_R}}\sqrt{(\frac{\pi}{W_{eff}})^2 + (\frac{\pi}{I_{eff}})^2} \quad (3.4)$$

Where:

ε = relative dielectric constant

c = speed of electromagnetic wave

μ_R = permeability of free space

$$W_{eff} = W - \frac{d^2}{0.95s} \quad (3.5)$$

$$I_{eff} = I - \frac{d^2}{0.95s} \quad (3.6)$$

Where:

I= length of single SIW cavity

W = width of a single SIW cavity

s = distance between the vias

d = via hole diameter

3.4.2 Filter layout in Advance Design System (ADS)

The simulation is generated in ADS software and the bandpass filter is tuned to obtain the results.

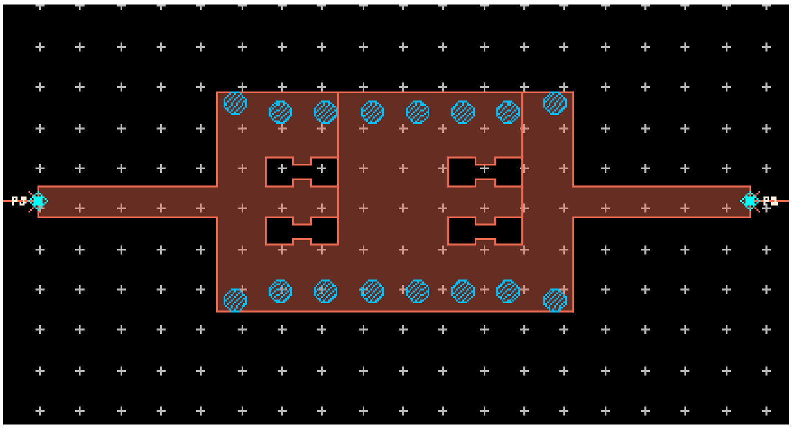


Figure 3.4.2.1: SIW top layout in ADS software

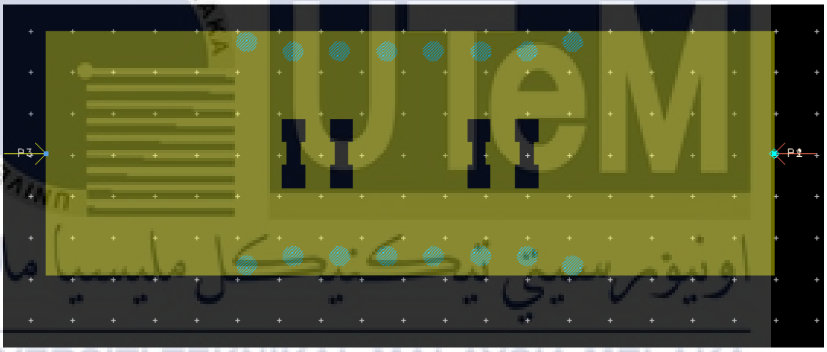


Figure 3.4.2.2: SIW bottom layout in ADS software

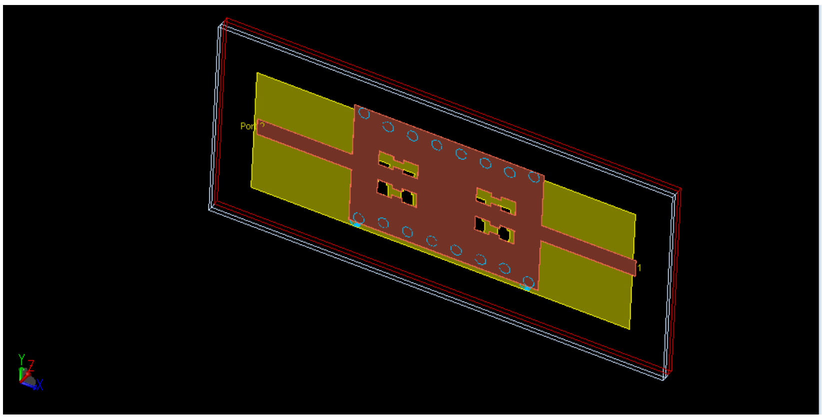


Figure 3.4.2.3: 3D preview for the SIW cavity

3.4.3 Patch and slot

Copper thickness is 0.254 mm at the top and bottom. The proposed WB BPF SIW consists of eight as a total hole and four dumbbell shape at the top and the bottom of the layer. There are four dumbbell shape slots at the top of the copper, and eight via SIW hole. Rogers 5880 substrate lies between top and bottom copper.

3.4.4 Substrate

The substratum used in this proposed design filter is Rogers 5880 which has a 2.2 dielectric constant and a 0.254 mm thickness. The Rogers 5880 substrate on the ADS software library used for this project is shown in Figure 3.4.4.

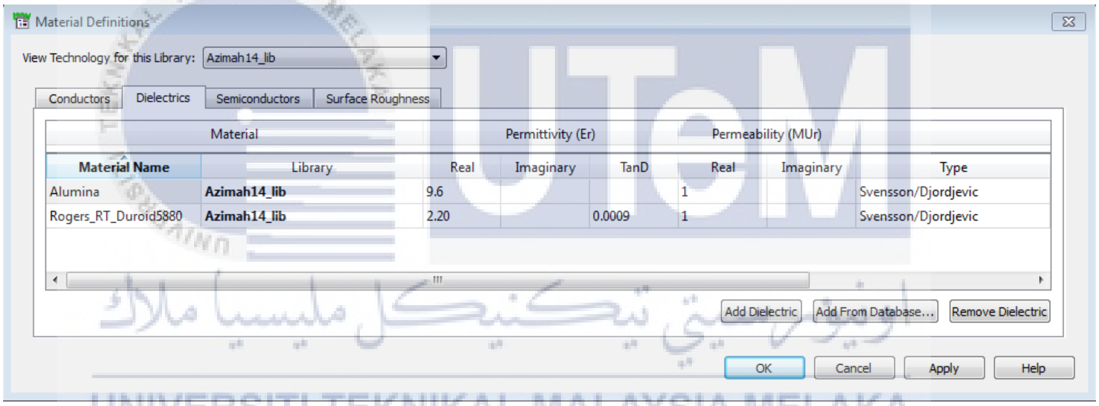


Figure 3.4.4: Rogers 5880 substrate in ADS software library

Chapter 4

RESULTS AND DISCUSSION

The study of wideband bandpass filter using slotted SIW resonator is discussed in this chapter. Ultimately, they explain the data derived from the simulations.

4.1 Introduction

This chapter presents the simulation result obtained by using Advance Design System (ADS) software for the bandpass filter from the SIW. The type of filter is identifiable from the result. Other than that, return loss S_{11}(dB), insertion loss S_{21}(dB), upper cut-off frequency, F_U(GHz), lower cut-off frequency, F_L(GHz), center frequency ,F_c (GHz) and fractional bandwidth can be achieved.

The outcome will be focused on:

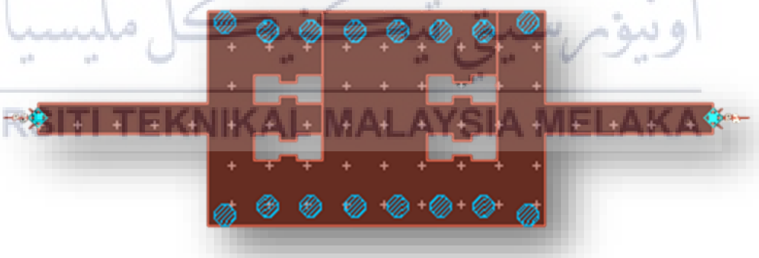
i. Return loss (S_{11})

ii. Insertion loss (S_{21})

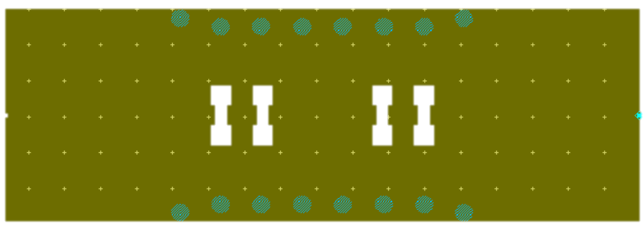
iii. Bandwidth

iv. Center of frequency

4.2 Proposed design



4.2.1: Top layer of the proposed slotted SIW



4.2.2: bottom layer of the proposed slotted SIW

4.2.1 Frequency response

Figure 4.2 shows the frequency response and the value of the high cut-off frequency, lower cut off frequency, center frequency, return loss ,insertion loss obtained in simulation by using software ADS. The lower cut off frequency is 21.71GHz, the high cut off frequency is 33.21GHz and the center frequency is 27.5GHz, which is approximate to 28GHz. The return loss is smaller than -10dB which was -18.174dB and the insertion loss is -1.323dB.

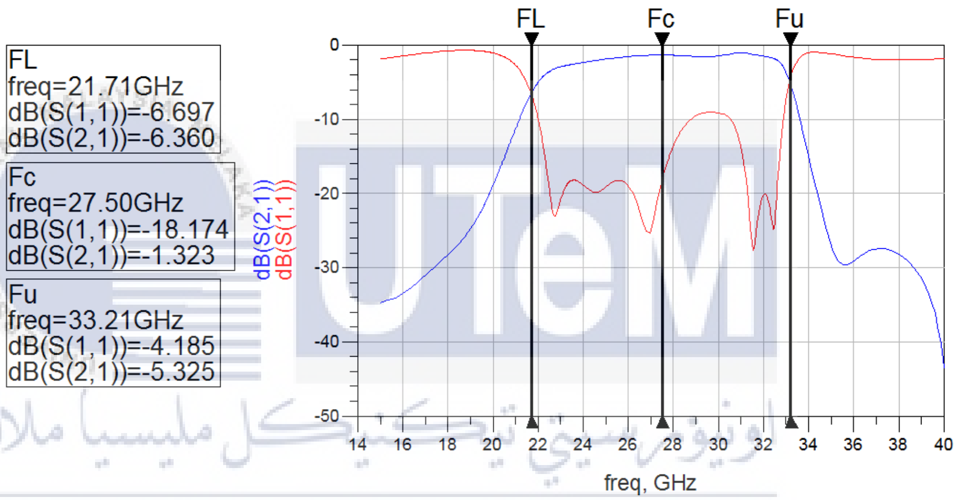


Figure 4.2.2.1: Frequency response of proposed SIW

4.2.2 Bandpass filter

From the result, it show that it is a bandpass filter by referring to the insertion loss S (2, 1). Figure 4.2 show the frequency response of a bandpass filter.

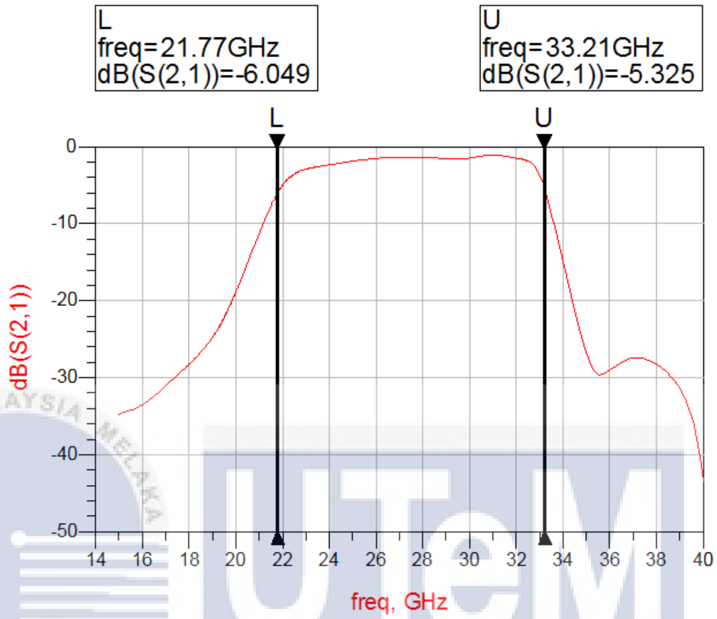


Figure 4.2.2.2: Insertion loss S (2, 1) of proposed SIW BPF

The bandpass filter is a device that excludes anything below and above the frequencies while passing a certain band of frequencies. The upper cutofffrequency value and the lower cutoff frequency shall be taken at -3dB. Through this filter, it excludes from the bandpass frequencies below 21.77GHz and above 33.21GHz, thus allowing betweenthe two resonance frequency. The top the cut-off frequency and the reduced cut-off frequency are taken at -3 dB response by follow the formula below,

$$\frac{P_{OUT}}{P_{IN}} \geq 0.5$$

$$10 \log \frac{P_{out}}{P_{in}}$$

$$10 \log 0.5 = -.3\text{dB} \qquad (4.1)$$

By referring to the equation (4.1), the Pout / Pin ratio should be greater than the 0.5. See below. It converts 0.5 to decibel (dB) by using the formula above, and gets -3dB.

4.2.3 Center of frequency, f_c

The frequency of the center is a frequency between the lower frequency of the cutoff and upper frequency of cut-off. The lower cut-off frequency (f_L) value is 21.77GHz whilst the upper cut-off frequency (f_U) value is 33.21GHz. The center frequency can be calculated with the equation (2.2). The operating frequencies value is 27.5GHz, which is roughly near 28GHz.

4.2.4 Return Loss (RL)

The general definition of the return loss is the ratio of the transmission to the incident signal on the system input circuit. The return loss value should be smaller than -10 dB. This indicates that 90% of the input power is supplied to the system and fewer than 10% of the reflected electricity. Figure 4.2.3 shows that the return loss of the SIW bandpass filter from frequency 21.77GHz to 33.21GHz is lower than -10 dB. There are four resonance frequency, which are 22.73GHz, 26.96GHz, 31.52GHz and 32.44GHz.

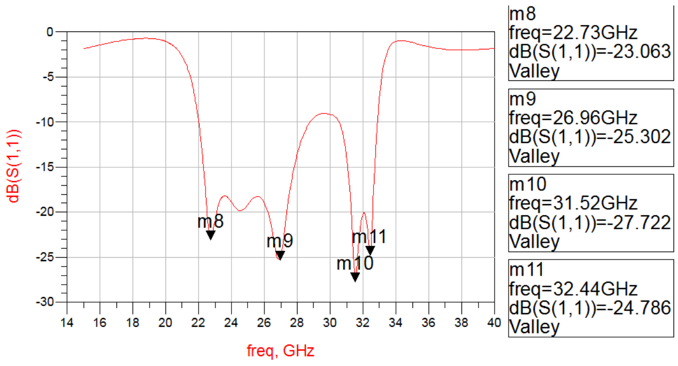


Figure 4.2.4: Frequency response show the value of return loss S (1, 1) is smaller than -10 dB of proposed SIW BPF.

4.2.5 Insertion Loss

The lack of induction is a signal strength ratio at the input and output ports of a closed switch. A good insertion loss value is greater than -3 dB which will be closer to 0dB. Figure 4.2.5 shows the insertion loss for the filter is larger than -2.905 dB.

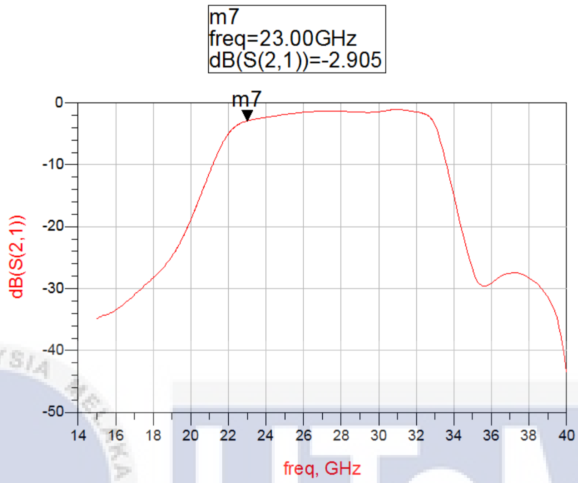


Figure 4.2.5: Insertion loss value S (2,1) is greater than -2.905 dB of SIW BPF proposed

4.2.6 Bandwidth and fractional bandwidth

The frequency value between upper cut-off and lower cut-off frequencies in a continuous frequency bands are called bandwidths. The lower cut-off frequency (f_L) value is 21.77GHz whilst the upper cut-off frequency (f_U) value is 33.21GHz. The bandwidth can be calculated with the use of equation (2.1).

For the proposed SIW BPF the bandwidth value is 11.5GHz. The device's bandwidth divided by its center frequency is called fractional bandwidth. The higher the percentage value, the wider the bandwidth. The formula to get the fractional bandwidth is stated in equation (2.3). The value of the fractional bandwidth is 41.81%.

It is therefore a wideband bandpass filter as it is larger than 20% and smaller than 50% as stated in Table 1.

4.3 Parametric study

4.3.1 Substrate Integrated Waveguide (SIW)

Figure below shows the layout for the SIW without any dumbbell slot on the top and the bottom of this substrate.

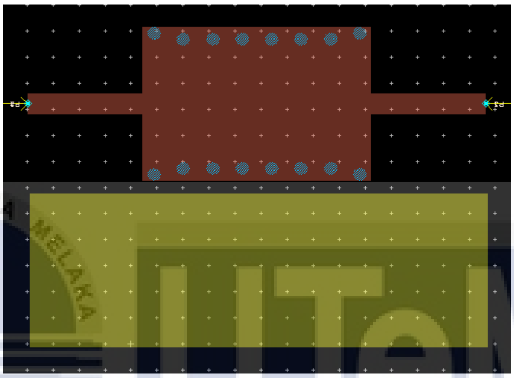


Figure 4.3.1.1: Substrate with zero number of dumbbell slot.

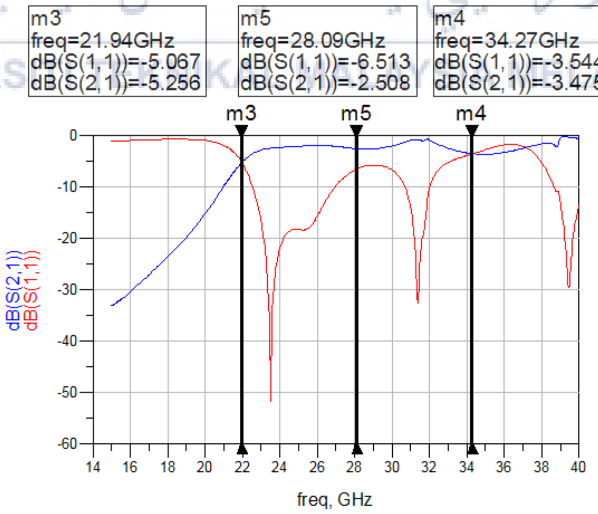


Figure 4.3.1.2: Simulated results for zero dumbbell slot

For the value of m3, the lower cut-off frequency is 21.94GHz and the value of upper cut off frequency, m4 is 34.27GHz which is not in the range 22GHz to 33GHz. The bandwidth is 12.33GHz and the return loss is bigger than the -10dB.

4.3.2 Dumbbell slots etched on the top of the substrate

In order to study the effect of dumbbell slot etched at the top of the copper of the substrate, two design is used.

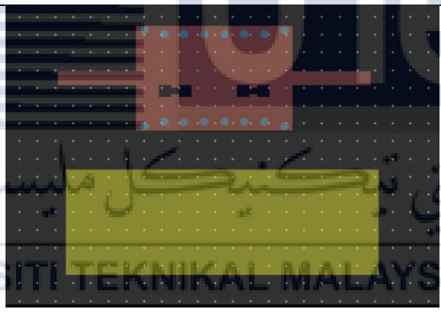
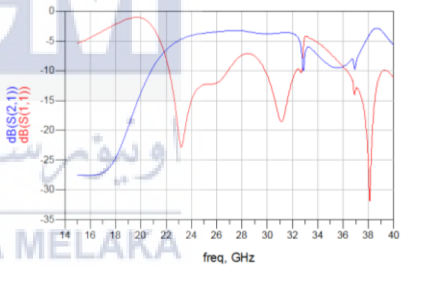
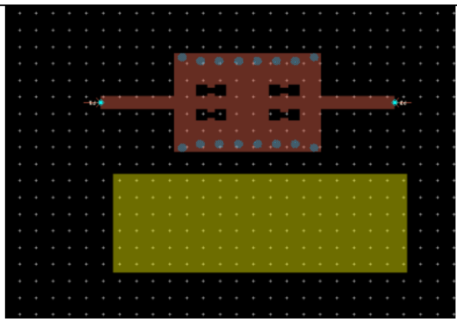
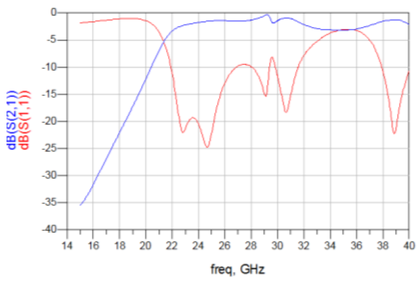
Number of dumbbell slot etched on the top	Number of dumbbell slot etched on the bottom	SIW BPF design	Frequency response
2	0		
4	0		

Table 5: Comparison of dumbbell slots etched on the top of the substrate and frequency response.

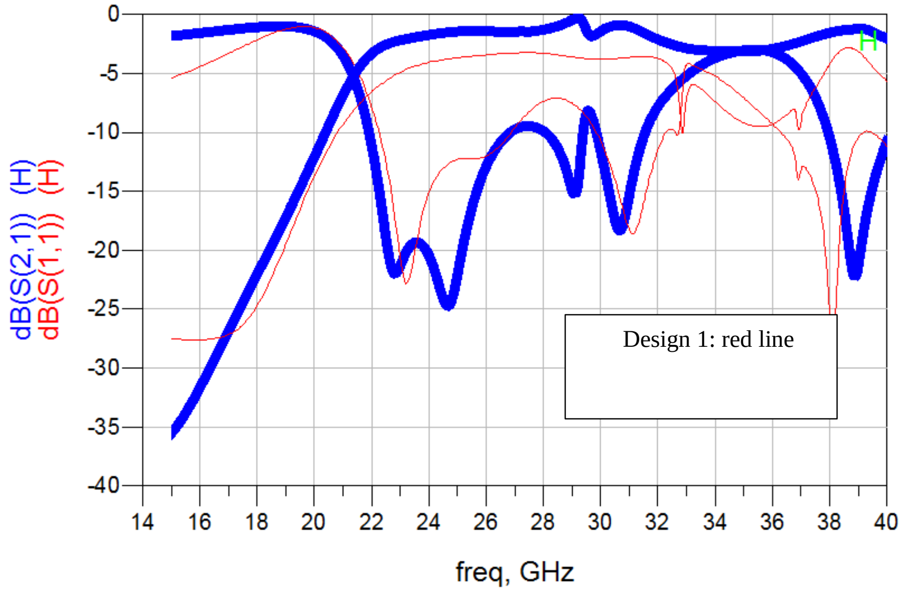


Figure 4.3.2.1: Frequency response for design 1 and 2 to study the effect of dumbbell slots etched on the top of the substrate.

From the figure above, the first design with 2 dumbbell slot, the bandwidth is 10.95GHz with two resonance frequency. The lower cut off frequency is 21.84GHz and the upper cut off frequency is 32.79GHz with the return loss -6.901 dB and -8.719 dB. For the second design with four dumbbell slot, the bandwidth is 13.45 GHz with two resonance frequency at 21.34GHz and 34.79GHz. The value of return loss is -5.336 dB and -3.147 dB. Both of the design has return loss is bigger than -10dB.

4.3.3 Dumbbell slot etched on the bottom of the substrate

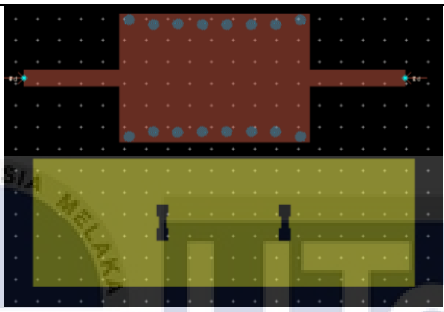
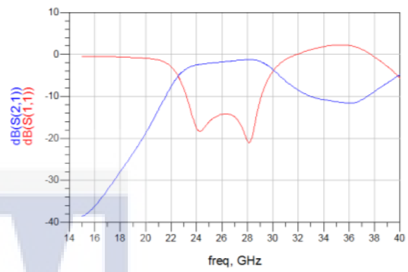
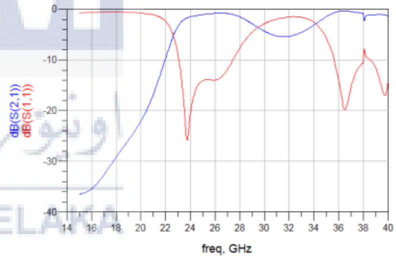
Number of dumbbell slots etched on the top	Number of dumbbell slots etched on the bottom	SIW BPF design	Frequency response
0	2		
0	4		

Table 6: Comparison of dumbbell slots etched on the bottom of the substrate and frequency response.

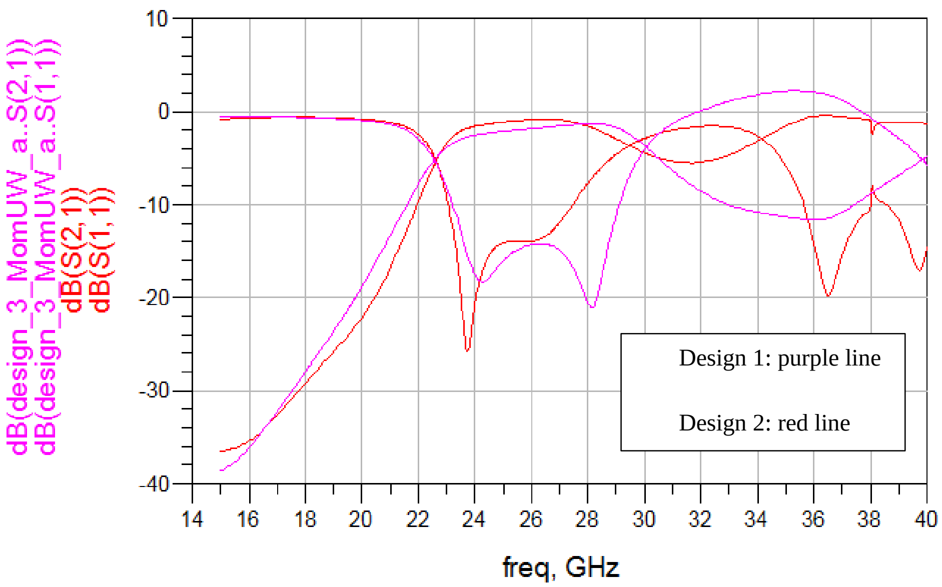


Figure 4.3.3: Frequency response for design 1 and 2 to study the effect of dumbbell slots etched on the bottom of the substrate.

From the graph above, for the first design, the bandwidth is 7.52GHz with two resonance frequency and return loss of -14.194dB. The value of insertion loss is good for a filter which was -1.698dB and the cut off frequency was 26.37GHz. Meanwhile for the second design, the insertion loss was very small -0.846dB with the return loss of -13.957dB. It provided the center frequency of 29.42GHz that is not in the frequency range between 26GHz to 28GHz.

4.3.4 The position of the dumbbell slots etched on the top and bottom of the substrate

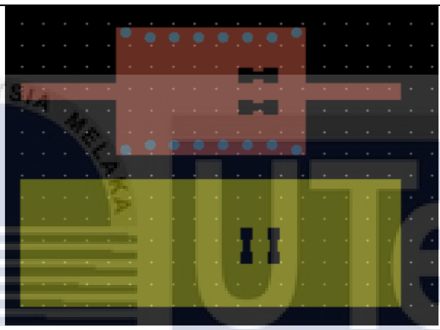
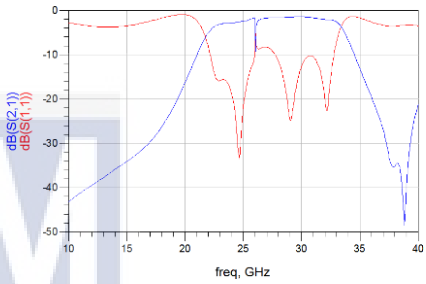
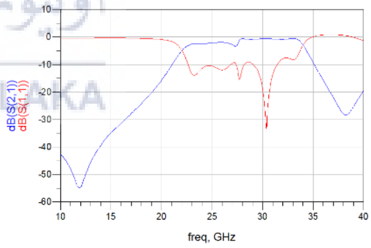
<table>
<tr><th>Number of dumbbell slots etched on the top</th><th>Number of dumbbell slots etched on the bottom</th><th>SIW BPF design</th><th>Frequency response</th></tr>
<tr><td>2 on the left side</td><td>2 on the left side</td><td></td><td>
</td></tr>
<tr><td>2 on the right side</td><td>2 on the right side</td><td></td><td>
</td></tr>
</table>

Table 7: Comparison of dumbbell slots etched on the bottom and top ofthe substrate and frequency response.

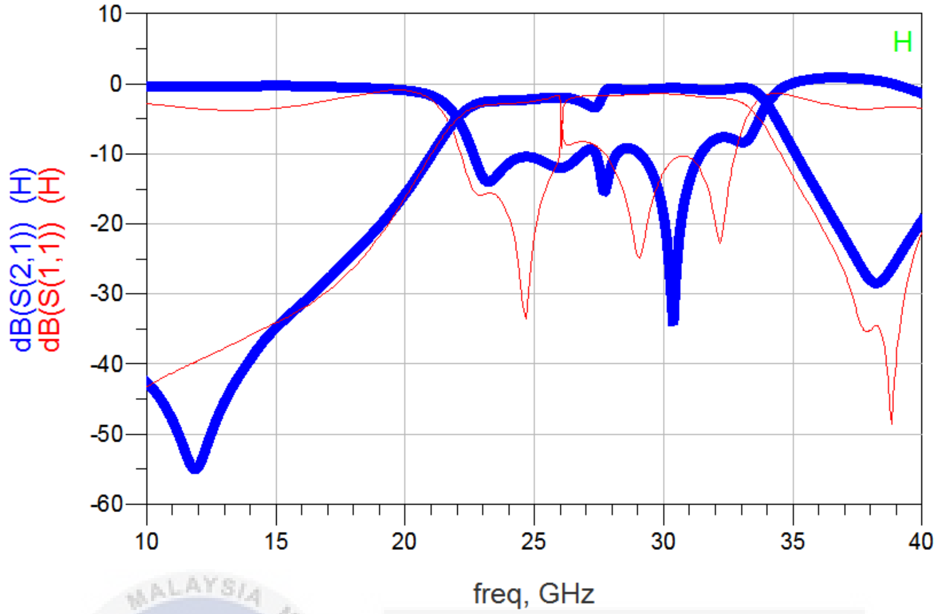


Figure 4.3.4: Frequency response of the position of the dumbbell slots etched on the top and bottom of the substrate

To study the relationship between the right and left position of the dumbbell slot figure above shows the frequency response having drop of frequency approaching 27GHz for design 1. For design 2, it have slightly drop off frequency near to 28GHz and continue to rise again and cut at the 33.96GHz. Both frequency response indicate that the value of return loss is bigger than -10dB. Which is not suit to our desire.

4.3.5 Different position dumbbell etched on the top and number of dumbbell on the bottom.

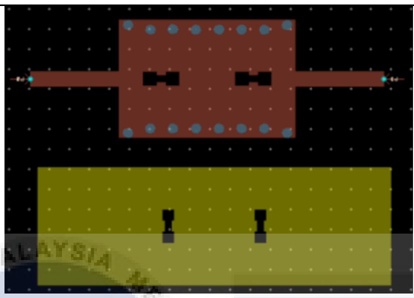
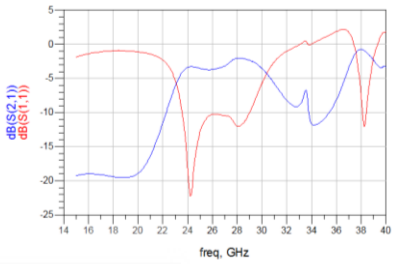
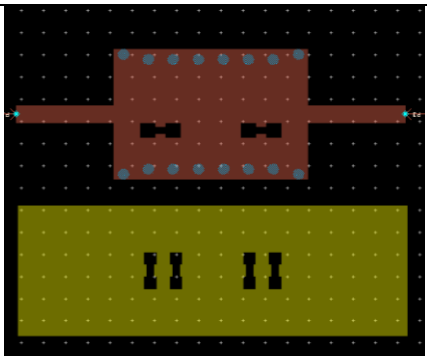
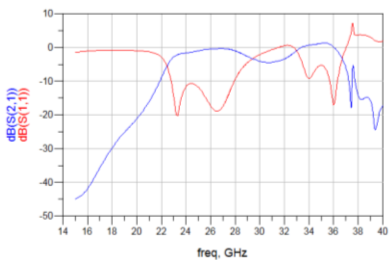
Number of dumbbell slots etched on the top	Number of dumbbell slot etched on the bottom	SIW BPF design	Frequency response
2 in the middle	1 on the right 1 on the left		
2 at the top side	1 on the right and 1 on the left side		
2 at the bottom side	2 on right and 2 on left		

Table 8: Comparison of the dumbbell slots etched on the bottom and top of the substrate and frequency response.

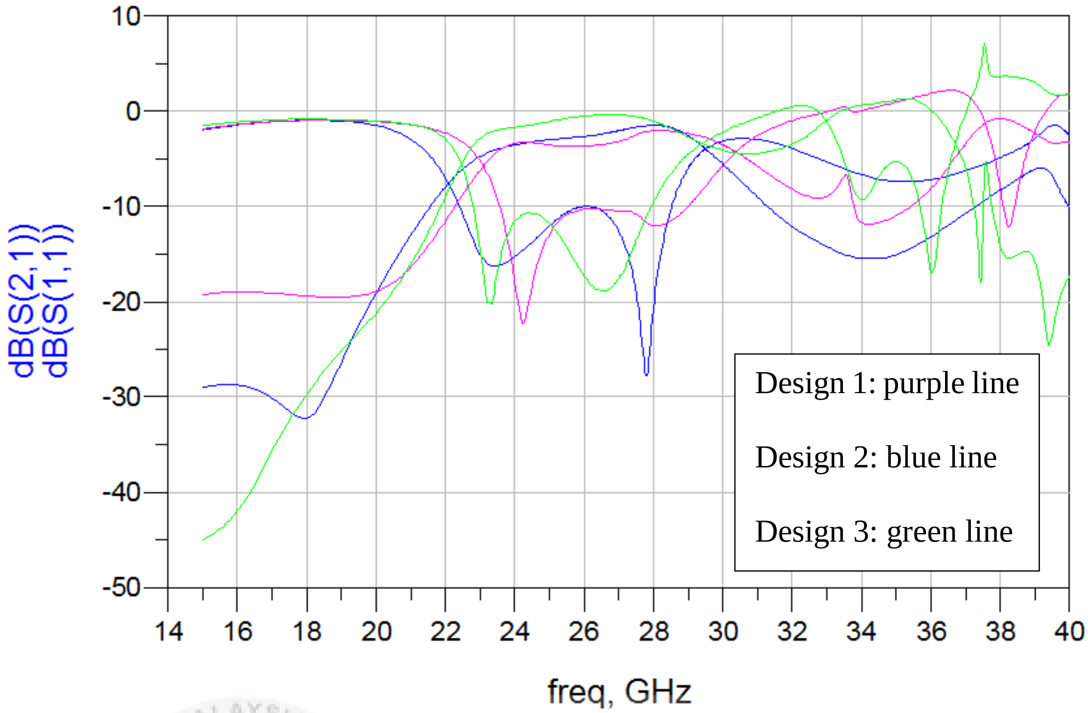


Figure 4.3.5: Frequency response for design 1,2 and 3 to study the effect of dumbbell slots etched on the top and bottom of the substrate.

By referring to figure above, design 1 cut at 23.12GHz on the lower frequency and 30.36GHz at the upper cut off frequency with the bandwidth of 7.24GHz. in design 2, the resonance frequency are 22.03GHz and 29.45GHz with 7.42GHz as its bandwidth. The two resonance frequency for design 3 were 22.42GHz and 29.32GHz with the bandwidth of 6.9GHz. All three design having cut off frequency of 26.75GHz, 25.75GHz and 25.55GHz which is further away from 28Ghz. The value of the return loss also does not achieve the objective as it is bigger than -10dB.

4.4 Summary

The frequency response generated as shown in Figure 4.2.3 showing the frequency of the bandpass filter. Distance beginning from 21.71GHz to 33.21GHz rendering 11.5 GHz bandwidth. The simulation results of the S parameters also indicate that the filter has lower and upper stop band insertion loss measurements of-10dB at 21.77GHz and 33.21GHz. The return loss better which the measurement were -6.697dB and -4.185dB. The architecture filter functions between 26/28Ghz with a return loss amount of more than 15db for the entire passband and a fractional bandwidth of 41.81% using the presented SIW resonator bandpass filter. A filter that advantages from low loss of insertion, compact size, high efficiency and excellent success outside the unit. The filter therefore also seems to be attractive for use in 5G applications.

Chapter 5

Conclusion and future works

5.1 Conclusion

A realistic design tool, independent of the filter type / construction, robust equal ripple filter optimization is a simple and intuitive alternative to synthesis design and a key component for port tuning complex EM based filter models. EM tools keep maturing and adding capabilities / speed, making it practical to use them in a loop for optimization. This technique was used to tackle the challenge of highly sensitive mm-wave filter designs.

In this paper, we proposed a wide-band pass filter using novel-slotted units etched on SIW metal cavity planes. The SIW cavity has also been used to develop a high-pass filter, the cut-off frequency of which can be adjusted by the width of the cavity, W and the proposed slotted units, which can be set to g2 and W3, are used to produce the cutoff frequency at the overhead and the transmission zeros. Finally, a wideband pass filter is built for 27.5GHz and a fractional bandwidth of 41.81 %.

5.2 Future works

The thesis had a time limit. The theory about filters is very broad and profound. Along the text the reader was able to figure out how complicated the criteria can be. The next step is to develop tolerance analysis with the aim of performance prediction of the filter knowing the tolerances of dielectric materials and the limitations of fabrication. Then the filter will be produced either alone or with the antenna to be analyzed. Both are fascinating events. Once it is manufactured, testing is required and comparison is made between theoretical analysis and measurements. Finally, deployment and calculations will be taken on a commercial computer.

Another point here would be filter miniaturisation. To minimize still more design without loosing results, new strategies based on learning and papers from past years can be implemented. Lastly, an experiment will be carried out to determine the actual transmit and power received. This is very important for application of the filter.

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APPENDICES

Project Planning																																							
List the main activities for the proposed project. Specify the time period required for each activity.																																							
	PSM 1																								PSM 2														
	2019																2020																						
Main activity	Sep			Oct				Nov					Dec				Jan			Feb					Mar				Apr				May				Jun		
	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Literature review		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																	
Design Of Wideband Bandpass filter using Slotted SIW										X	X	X	X	X	X	X				X	X	X																	
Material deposition on side-polished formation																							X	X	X	X													
Data Analysis																												X	X	X	X								
Thesis writing					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							
Thesis Submission																																		X	X				