DESIGN AND SIMULATION OF MILLIMETER WAVE FILTER FOR NEXT GENERATION (5G) RF FRONT-END TRANSCEIVER

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ABSTRACT

In RF Front-End is very important to provide a convenient interface between electromagnetic fields and (often digital) signal processing. For most telecommunications systems, this interface is bidirectional since it consists of both a transmitter and receiver front end. However, RF front end the gain is to convert the weak signals and frequency to convenient amplitude levels for further processing. This project aims to design and simulate a filter that can the millimeter wave at 28GHz for next generation (5G) RF Front-End Transceiver. The method used is substrate integrated waveguide (SIW) which that capable of the design of devices of low radiation, low insertion loss and high Q. In addition, the whole components are constructed by metallic-post in dielectric structure. The via hole of the SIW will be in between of the dielectric and made the via hole as a wall replacing the solid wall of the rectangular waveguide. CST Studio Suite software is used to design the filter. Once the simulation has done, the optimization carried by using parametric studies by changing the width and length of the t-shape metal and the distance of the pitch. The filter operating at frequency 28GHz with the return loss less than -10dB and wide bandwidth greater than 1GHz. Comparison of the filter performance is carried, in terms of filter parameters such as return loss, insertion loss, efficiency and bandwidth. Higher demand of device capacity and bandwidth will jamming the current frequency band spectrum, so this project can be implement to the industry as a 5G application as a millimeter wave filter RF Front-End Transceiver.

ABSTRAK

Dalam penghasilan RF Hadapan-Akhir adalah sangat penting untuk menyediakan antara muka yang mudah antara medan elektromagnet dan (sering digital) pemprosesan isyarat. Bagi kebanyakan sistem telekomunikasi, antara muka ini adalah dwiarah sejak ia terdiri daripada kedua-dua penghantar dan penerima akhir hadapan. Walau bagaimanapun, depan RF berakhir keuntungan adalah untuk menukar isyarat yang lemah dan kekerapan ke tahap amplitud mudah untuk proses selanjutnya. Projek ini bertujuan untuk mereka bentuk dan simulasi penapis yang boleh gelombang milimeter di 28GHz untuk generasi akan datang (5G) RF Hadapan-Akhir terima. Kaedah yang digunakan adalah substrat bersepadu pandu gelombang (SIW) yang yang mampu reka bentuk peranti radiasi rendah, kehilangan sisipan rendah dan Q yang tinggi. Selain itu, seluruh komponen yang dibina oleh logam-tiang dalam struktur dielektrik. Melalui lubang daripada SIW akan berada di antara dielektrik dan dibuat melalui lubang sebagai dinding menggantikan dinding pepejal pandu gelombang segi empat tepat. Perisian CST Studio Suite digunakan untuk mereka bentuk penapis. Sekali simulasi telah dilakukan, pengoptimuman yang dijalankan dengan menggunakan kajian parametrik dengan menukar lebar dan panjang logam t-bentuk dan jarak tengah antara dua tiang. Penapis yang beroperasi pada frekuensi 28GHz dengan kehilangan pulangan kurang daripada -10dB dan lebar jalur lebar lebih besar daripada 1GHz. Perbandingan prestasi penapis yang dijalankan, dari segi parameter penapis seperti kehilangan balasan, kehilangan sisipan, kecekapan dan jalur lebar. Kapasiti permintaan yang lebih tinggi dan lebar jalur peranti akan melebihi had pada frekuensi spektrum semasa, supaya projek ini boleh melaksanakan untuk industri sebagai penapis aplikasi 5G sebagai gelombang milimeter RF Hadapan-Akhir terima.

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CHAPTER 1

INTRODUCTION

This chapter will explain about the project briefing, problem statement, objective and scope of work.

1.1 Project Briefing

This project is focusing on the millimeter wave filter. The substrate integrated waveguide (SIW) is a minimal effort acknowledgment of the traditional waveguide synthesized in a dielectric substrate, where the side dividers are substituted by two parallel lines of via holes set so that there is no power leakage. A millimeter wave substrate integrated waveguide (SIW) filter is presented by using printed circuit-board technology. SIW filter is fabricated on substrate Rogers RT/Duroid 5880 [1]. SIW technology is the most popular and also the most developed platform as it is quite easy to “transplant” the existing and matured modelling and design techniques of the rectangular waveguide components into the SIW that is simply a synthesized rectangular waveguide [2].

1.2 Problem Statement

The main problem in RF Front-End is gain (to change over the generally weak signals to advantageous sufficiency levels for further handling) and frequency conversion (to change over signals to helpful frequencies for further processing). In the get way, choosing the desired channel among (numerous) different channels, and extricating the data that is connected through modulation to the radio flag, is normally done in the IF signal processing circuits. In the transmit way, regulating the data to be transmitted onto a radio flag is regularly additionally done in the IF circuits [3]. Other problem is high traffic spectrum, congested capacity and fully utilize. Increasing the number of tension of wireless communication frequency resources, requires an upgraded as developing modern microwave and millimeter wave components. With these problems could give a bad communication frequency and transmission. Jamming of sending data or signal could happened too. To solve the problem is by choosing the millimeter wave which have a high speed, high bandwidth and high capacity. By applying the millimeter wave could give a better frequency and transmission. So that, 28GHz is chosen as candidate. Next, focus on rectangular waveguide filter to be modified as SIW. Because of rectangular too bulky and costly, need to be modified to a low cost and easy to integrate.

1.3 Objective

The objective of this project is to design a millimeter wave filter that utilize substrate integrated waveguide band pass filter operates at 28GHz. This filter design is able to achieve a low insertion loss and good selectivity because of the Q factor of SIW is high, as result it will produce high performance filters. Measurement data also take part for obtained a good performance.

1.4 Scope of Work

This project will focus on the design, simulate, analysis, and measurement of substrate integrated waveguide band pass filter between 28GHz RF Front-End Wireless Backhaul. Other goal is about by improving the current usage of coverage which is LTE to the Next Generation (5G). The filter will be design by using a CST Suite Studio 2016 software. The type of filter will be designed that is substrate integrated waveguide. After complete design process, the next procedure is to do by simulation and measurement. Then, the result will be compared with the measurement result and the actual results. Other S-parameter such as return loss level, insertion loss, and structure will also be focus at as to know performance of filter design.

1.5 Organization of Thesis

In chapter 2, present the researched journals that were reviewed about the filter design at varies frequency. After choosing the desired journals by changing the exact frequency which is at 28GHz, comparison was carried among them. An addition this chapter covers a detail theory about a filter and its parameters that determine its performance.

In chapter 3, will explain about the method and flow of designing for this project from the beginning until the end of the project.

In chapter 4, briefly explain the result of the filter design for millimeter wave filter RF Front-End Transceiver that are obtained through simulation. The simulation result of the filter was obtained using CST Studio Suite 2016.

Lastly in chapter 5, will conclude and discuss about overall of the project.

CHAPTER 2

LITERATURE REVIEW

This chapter present the researched journals that were reviewed about the filter design at varies frequency. After choosing the desired journals by changing the exact frequency which is at 28GHz, comparison was carried among them. An addition this chapter covers a detail theory about a filter and its parameters that determine its performance.

2.1 Critical Literature Review

The literature review was performed on a journal to collect related information and facts that can be used in the design process of this project

Design process; research was carried out by performing a review of the literature in several journals related to research the topic of millimeter wave filter. Table 1.1 summarize the sample literature reviewed journals.

2.1.1 Summarize Journals

Using a general mode-matching technique, gives 3.4 dB insertion loss and 17 dB return loss over the whole passband at near 24 GHz (K-band) with 440-MHz bandwidth (1.8%) [4].

Mode-matching techniques (MMTs) are employed to facilitate the design of planar SIW circuits as well as surface mounted waveguide (SMW) components. Active component integration and antenna design employ commercially available field solvers [5].

Novel compact millimeter wave bandpass microstrip filter using a three-mode resonator with two shunt stepped impedance open stubs. The simulated insertion loss S 21 is less than 1.2dB, and the return loss is greater than -17.3dB in the passband. Moreover, the attenuation below -20dB is from 42 to 90GHz [6].

Tapered fin-line transition is designed for dielectric substrate having a relative permittivity higher than 4. Measurement results of a back-to-back transition show excellent performance in a bandwidth of 6% (33-35 GHz) with less than 1 dB of insertion loss and a return loss of better than 15 dB [7].

Using irises inside a rectangular hollow waveguide we can design wide bandwidth filter to cover the whole 40-60 GHz frequency range [8].

A millimeter wave wideband bandpass filter is proposed and designed by using novel slotted substrate integrated waveguide (SIW) units. The unit consists of two pairs of same size dumbbell slots etched on both the top and bottom metal planes of the SIW. The slots act as shunt resonators, which reduce the filter size and produce transmission zeros simultaneously. A five-order bandpass with a center frequency of 32.5 GHz and a 3dB fractional bandwidth of 34.6% is developed, and it is small in size, and low loss with a measured insertion loss of 1.54 dB at the center frequency [9].

A novel tunable band gap filter for use in the microwave and millimeter wave domain is presented. The device is based on the use of liquid crystal in resonant cells. Simulations are presented showing the tunable range and bandgap bandwidth [10].

Table 1.1: Summarize Journals

Journal	Application	Method	Improvement
[4]	K-band at 26.5GHz	Mode-matching technique (MMTs)	The expected result achieved for return loss and cross polarization
[5]	Microstrip filter at 42GHz to 90GHz	Three-mode resonator (two shunt stepped impedance open stub)	Enhance the insertion loss, attenuation and return loss
[6]	W-band at 90GHz to 98GHz	SIW Chebyshev filter inductive cross-shaped metal	Good achieved of BW at central frequency, low pass band insertion loss and a high stop band insertion loss
[7]	SIW at 33GHz to 35GHz	Antipodal fin-line	Reduce of insertion loss and a better of return loss. BW is 6%
[8]	Wide pass-band at 40GHz to 60GHz	Irises rectangular waveguide	Enhance the insertion loss and return loss
[9]	Wideband bandpass at 20GHz to 40GHz	Novel slotted SIW	Reduce filter size and produce transmission zeros. Achieved good BW
[10]	Microstrip at 40GHz to 80GHz	Novel tunable band gap filter	Different parameters as tunable. Achieved for BW, return loss and insertion loss

2.2 Filter Theory

A filter is a device or process that evacuates some undesirable parts or elements from a signal. Filtering is a class of signal processing, the characterizing feature of filters being the total or fractional suppression of some part of the signal. At the end of the day is expelling a few frequencies and not others with a specific end goal to suppress interfering signals and lessen background noise.

2.3 Filter Properties

There are many of basic properties that are used to describe the performance of the filter. There are including insertion loss, return loss and bandwidth.

2.3.1 Insertion Loss

Insertion loss is defined as a ratio of the signal level in a test configuration without the filter installed (|V1|) to the signal level with the filter installed (|V2|). This ratio is described in dB by the following equation (2.1);

$$IL(dB) = log_{10}\frac{|V_1|^2}{|V_2|^2} = 20log_{10}\frac{|V_1|}{|V_2|} \quad (2.1)$$

Where;

IL = Insertion loss

($|V_1|$) = without the filter installed

($|V_2|$) = with the filter installed

$|V_2| < |V_1|$ IL is positive and measures how much smaller the signal is after adding the filter.

In case the two measurements ports use the same reference impedance, the insertion loss (IL) is defined as equation (2.2);

$$IL = 10log_{10}\frac{|S_{21}|^2}{1-|S_{11}|^2} \quad (2.2)$$

2.3.2 Return Loss

Return loss is an advantageous approach to portray the input and output signal sources. Return misfortune can be characterized in dB as in the following equation (2.3);

$$RL\ (dB) = -20log_{10}|\Gamma| \qquad (2.3)$$

Where;

RL = Return loss

Γ = Reflection coefficient

2.3.3 Bandwidth

Bandwidth is the difference between the upper and lower frequencies. In other words, range of frequency that the filter specification may require that within the filter passband. The 3dB bandwidth of an electronic filter is the part of the system"s frequency response that lies within 3dB of the response at its peak, which if the filter may operate is at or near its centre frequency.

The bandwidth can be the scope of frequencies on either side of the centre frequency where the filter qualities like maximum and minimum gain and input impedance which have obtained at the centre frequency.

2.4 Rectangular Waveguide

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

A rectangular waveguide supports TM and TE modes but not TEM waves because of unique voltage since there is only one conductor in a rectangular waveguide. The material with permittivity and permeability were fills within the conductor. Moreover, a rectangular waveguide cannot proliferate beneath some specific frequency. The recurrence was known as cut-off frequency.

In most of communication system, metallic waveguide plays essential part in satellite communication framework and are regularly utilized between high power amplifier and transmitting antenna to acquire great coordinating. In this way, waveguide filters in millimeter band have been utilized as a part of numerous applications than stripline filters. There are some factors why waveguide is a good candidate compared to stripline because of their low loss, high quality factor, and high power capability [11]. There are some disadvantages which is its too bulky and costly.

Waveguide may be designed in many ways of methods until the substrate integrated waveguide were used to get a better performance and low cost of filter. It is one of the most popular filter for the production of low radiation loss, low insertion loss and high Q [4]. Figure 1 shown the 3-Dimensional of waveguide.

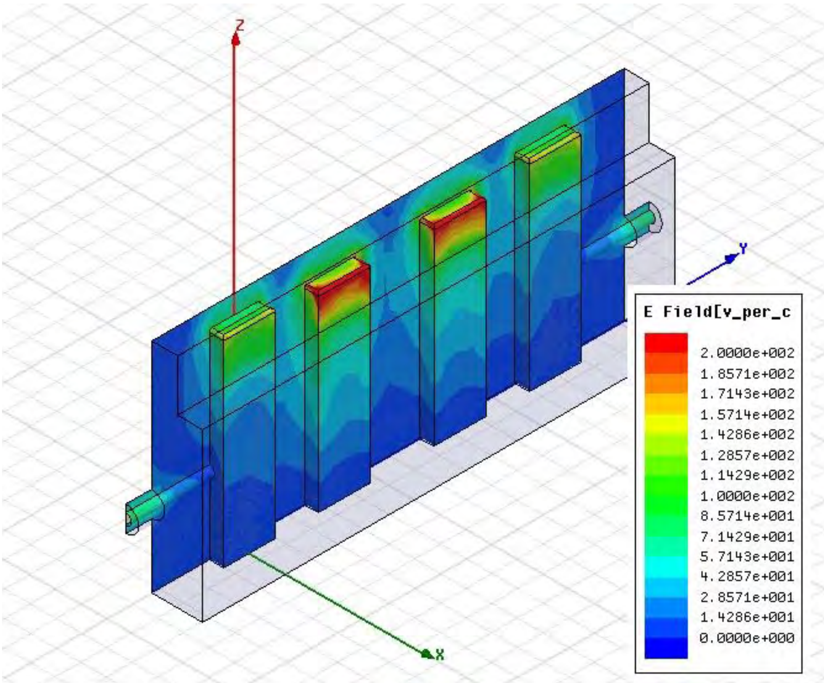

Figure 1: 3-Dimensional of waveguide

2.5 Substrate Integrated Waveguide

Substrate Integrated Waveguide (SIW) is a development in recent years, dynamic gadgets and detached segments can be coordinated high-productivity, and the measure of microwave and millimeter wave framework is diminished effectively. Besides, its mass-producible, elite and high return microwave. At millimeter wave frequencies, specifically, circuit-building squares including antenna components are firmly identified with each other through electromagnetic couplings and interconnect.

At present, the SIW method has a wide range in many microwave gadgets application, such as filters, power dividers, directional couplers, antennas, oscillators, power amplifiers, power selective surfaces and etc. This shown that SIW is a good technique to obtain better performance and at the same time may reduce the cost of material. The field distribution in an SIW is similar to that in a conventional metallic waveguide [12].

Substrate integrated waveguide in its fundamental shape comprises of 4 sections (dielectric substrate, diameter and pitch) as appeared in Figure 2. Where L is the length of SIW cavity, W is the width of SIW cavity, h is the dielectric substrate thickness and ε_r substrate relative permittivity.

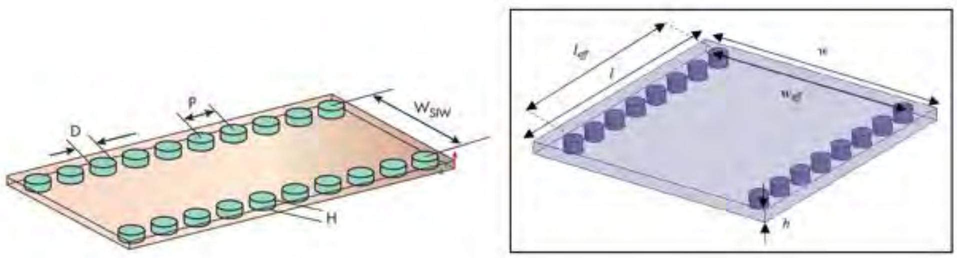

Figure 2: Basic structure of SIW [4]

2.5.1 Dielectric Substrate

Between the top and bottom metal planes of substrate it is the dielectric layer. There are a great deal of substrate material and particulars to look over as indicated by the receiving filter necessity. The most two elements determining dielectric substrate will be substrate height (0.003 λo ≤ h 0.05 λo) and dielectric constant (2.2 ≤ ε_r ≤ 12).

Substrates that are thick with low dielectric constant are preferable for enhancing efficiency, bandwidth and radiation in space. On the other hand substrates that are preferable for microwave circuits should be thin with high dielectric constant.

2.5.2 Diameter and Pitch

Diameter and pitch otherwise called distance between focal point to focal point of via hole appeared in Figure 3.

With a specific end goal to limit the leakage loss between nearby hole, pitch should be kept as little as could be expected under the circumstances.

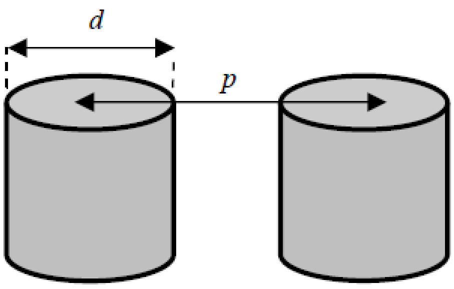

Figure 3: Diameter and Pitch [4]