DESIGN AND DEVELOPMENT OF RADIAL LINE SLOT ARRAY ANTENNA AT 28.00 GHZ

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"I hereby declare that the work in this project is my own except for summaries and quotations which have been duly acknowledge."

Signature : ....

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Date : JUNE 2016

Dedicated to my respectful father, Azian Kamaruddin Bin Talha, to my beloved mother, Hazizah Binti Che' Ros and my family with friends for always there support and pray for me.

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ABSTRAK

Pada zaman sekarang ini, perkembangan teknologi tanpa wayar yang sejajar dengan arus perkembangan teknologi iaitu berkelajuan tinggi dan mempunyai sambungan yang pantas sangat diperlukan mengikut keperluan semasa ke semasa mengikut permintaan pengguna pada masa kini.. Kekerapan pusat pada julat frekuensi 28.00 GHz telah dipilih dimana reka bentuk dan binaan dilakukan untuk "*Radial Line Slot Array" (RLSA)* kerana terletak dalam kumpulan jalur Ka berdasarkan piawaian IEEE yang dimana julat frekuensi dari 26.50 GHz sehingga 40.00 GHz untuk rangkaian sistem 5G komunikasi mudah alih. Struktur antenna yang mudah dibina, kos rendah dan kecekapan yang tinggi adalah diantara kelebihan antenna *RLSA*. Antenna *RLSA* juga mampu meghasilkan tiga jenis pengutuban iaitu pengutuban lelurus, membulat dan membujur. Projek ini lebih berfokus pada antena RLSA yang dibina pada pengutuban lelurus dengan menggunakan "*Flame Retardant FR-4"* sebagai bahan substrat dan nilai ketulusan pada 1.13 yang merangkumi nilai substrat dan sengkang udara. Simulasi antenna *RLSA* yang dihasilkan dengan menggunakan perisian *Computer Simulator Technology (CST) Microwave Studio* telah digunakan untuk dapatkan perbandingan diantara nilai kearah corak sinaran dan kehilangan pulangan bagi simulasi dan diukur melalui percubaan di makmal. Kesimpulannya, antena *RLSA* pada julat frekuensi 28.00 GHz berpotensi untuk menghasilkan nilai keuntungan yang tinggi dimana menghasilkan lebih dari 20.00 dBi dan corak radiasi pada 28.00 GHz menunjukkan ketebalan bahan dan teknik alur angin pada h = 2.5 mm bagus untuk aplikasi titik ke titik sistem 5G komunikasi mudah alih.

ABSTRACT

Nowadays, the evolution of wireless technologies with high speed and fast connectivity are really needed because of demands by the users. The fifth generation (5G) cellular network was introduced where to meet these demands. The centre frequency of 28 GHz where chosen because it is located in the range of Ka band frequency based on IEEE standard which are from 26.50 GHz to 40.00 GHz for 5G mobile communication system by designed and developed for Radial Line Slot Array (RLSA). The RLSA is well known as a simple structure antenna, low cost and high efficiency. This RLSA antenna can produces of three polarizations which are linear, circular and elliptical polarized. This project is more focusing on the linear polarized of RLSA using "Flame Retardant" FR-4 as the substrate and 1.13 for permittivity value which is the summation of the value of substrate with the air gap. The Computer Simulator Technology (CST) Microwave Studio has be used as antenna simulator for doing simulation with carried out the result before start the next step of fabrication and measurement of the antenna. The specifications of the result between simulation and measurement must meet for the antenna on directivity; radiation pattern and return loss were noted as comparison between simulation and measurement in the lab. In conclusion, the RLSA antenna is achievable to provide high gain which is more than 20.00 dBi and radiation pattern at 28.00 GHz for cavity thickness with air gap technique of h = 2.5 mm shows the better for point to point communication and potentially can be operated on 5G mobile communication system.

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CHAPTER 1

INTRODUCTION

1.1 Project back ground

A technology emerging to fifth generation (5G) is currently new wireless technologies communication networks that are consist of first generation (1G), second generation (2G), third generation (3G) and fourth generation (4G). Where, the combinations of analog voice communication using frequency modulation, digital techniques and time-division multiple access (TDMA) or code-division multiple access (CDMA), Internet Protocol (IP) architecture and Orthogonal Frequency Division Multiplexing (OFDM) for downlink and Single-Carrier Frequency Division Multiple Access (SC-FDMA) for uplink. The peak speed requirements of 5G is better than 4G or also called Long Term Evolution (LTE) which can go fast as in very short time that passengers pass through multiple cells using train at speed greater than 250 km/h for frequent handover [1]. Its takes less than six (6) seconds pass between two base stations for a mobile phones and at least six (6) seconds between different base stations [1].

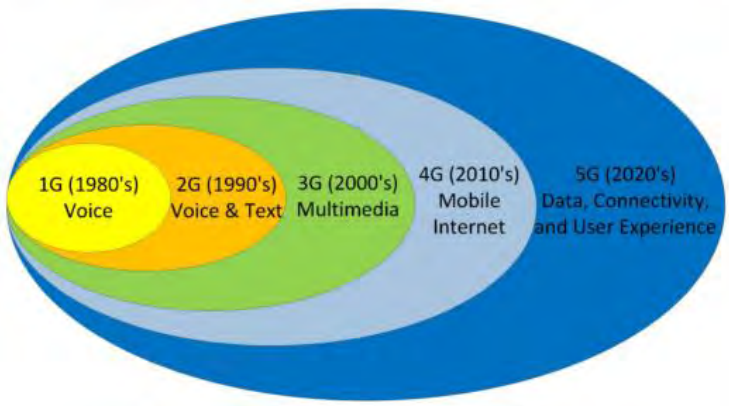

Figure 1.1: Development of service types over wireless mobile generations [2]

The fastness speed rather than before, can have great services when in a crowd, ubiquitous things communicating, super real time with reliable connections and get an amazingly best experience to follows are the key targeted 'Mobile and wireless communications Enablers for the Twenty-twenty Information Society'(METIS) need to be referred for 5G [2]. This is because demand from the customers and businesses that willing pay to get the better services to stay connected with internet. They will be increased 1000 time in year 2020 more than the current volume mobile traffic [3].

Samsung had launch their Internet of Things (IOT) that makes operation systems and new modern application such MagicInfo, Knox that can operate as mobile device and Smart Signage [4]. The 5G mobile communications systems was invented because to provide wide bandwidth that can used new frequency band to avoid the overflow of traffic volume [3]. In the frequency range of 10.00 GHz – 40.00 GHz was used mmWave band for Giga Korea (GK-5G) mobile communication system [3]. The patch array antenna was used for mmWave band for GK-5G because it can withstand large path loss result from multi-beams.

The Quality of Services (QoS), energy efficiency, data rate, latency and capacity were defined all needs for 5G wireless communication systems [5]. Increasing number of users will affected the data roaming and it makes the interruption, so used high frequency to get wider bandwidth with many frequency band insides. Concepts 5G emerging common features evolving for future.

1.2 Problem statement

The fifth generation (5G) applications were built because to fulfil the demand from the users which are nowadays towards to businesses and technologies areas. The high speed of data transmission with bigger bandwidth, high directivity can be getting by the user if he/she is far away from the antenna and high efficiency to reduce the losses of the signal. The operating frequency at 28.00 GHz was produced to increase the directivity of antenna with more than 20.00 dBi gain. The Radial Line Slot Array antenna is good characteristics such as reduces the cost of production, low profile, ease of installation and simple structure. Besides that, this type of antenna also produces smaller side lobe level in terms of production of signal and radiation with high directivity and gain. To overcome this problems the concept of slot for array antenna is applied.

1.3 Objective

The purpose of this project is to design and development of Radial Line Slot Array (RLSA) Antenna at 28.00 GHz as the following:

i. To achieve high directivity characteristics this had more than 20 dBi gain.

iii. To achieve less than -10.00 dB return loss

1.4 Antenna design specification

Referring to the literature review in the chapter 2 as below so can be specification references. This specification will be the main references must be followed to develop the prototype of the antenna.

Table 1.1: Parameter of the prototype

Parameter	**Value**
Centre frequency	28.00 GHz
Cavity thickness	2.500 mm and 3.200 mm
Radius of antenna	60.000 mm
No of slots	228
Thickness of radiating surface (copper)	0.035 mm
Thickness of ground (copper)	0.035 mm
Relative permittivity of FR4 with air gap technique	1.13

Table 1.2: The ETSI (European Telecommunication Standard Institute)

Dielectric substrate	FR-4
VSWR	< 2: 1
Reflection coefficient	< -10.00 dB
Gain	> 22.00 dBi
Bandwidth	> 1.00 GHz
Front to back lobe ratio	> 25.00 dB
Side lobe ratio	17.0 dB at 15^{o}

1.5 Organization of report

There are five (5) chapters in this project and the outline as the following:

Chapter 1, consists of the introduction parts which are consists of project background, the problem statement, objectives of the project and the scope of this project.

Chapter 2, consists of literature review of the project which is discussed about the specific title of the project that was done by the previous researcher which is related to the title of the project.

Chapter 3, consists of methodology part that discussed on how the project flows, design and simulated by using CST Microwave Studio. It is also shown how the antenna is fabricated.

Chapter 4, consists of results and discussion obtained based on the objectives of this project. The results in terms of return loss (RL), bandwidth, gain or efficiency and directivity for Radial Line Slot Array antenna is discussed in detail.

Chapter 5, consists of explanation regarding the conclusion and recommendation for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The works from other researchers had been explained into this chapter that are related to the design and development of this project which is "Design and Development of Radial Line Slot Array Antenna at 28.00 GHz". This project is successfully developed by continuously do the literature review until completed this antenna design. By doing comparison with several types of antennas had been developed at 28.00 GHz.

2.2 Antenna design specification at 28 GHz

Antenna is very commonly used for mobile applications and other applications. Most probably, the more number of available spectrums the higher the number of frequency that needed. Referring to the MCMC requirements, the Local Multipoint Communication Systems (LMCS) in Malaysia had been fixed as the Standard Radio System Plan (SRSP) states for the utilization of the frequency band between 24.25 GHz to 27.00 GHz; 27.00 GHz to 29.50 GHz; and 31.00 GHz to 31.30 GHz. The point-to-point or point-to-multipoint radio systems are fixed with consisted of local multipoint distribution central/hub stations with the associated local multipoint terminal stations. In some other countries Local Multipoint Distribution Systems (LMDS) is having same means with LMCS. These were used for one-way or two-way broadband point-to-point or point-to-multipoint radio communications services to businesses and households. The broadband data, internet access, video teleconferencing and other interactive multimedia are examples of two-way LMCS services. The LMCS and fixed satellite services are located from frequency band 27.5 GHz until 29.5 GHz.

Table 2.1: Frequency Band 27.5 - 29.5 GHz Allotted for LMCS from MCMC **[6]**

Frequency Range (Lower Band) GHz	**Bandwidth MHz**	**Frequency Range (Upper Band) GHz**	**Bandwidth MHz**
27.549 - 27.661	112	28.557 – 28.669	112
27.661 – 27.773	112	28.669 – 28.781	112
27.773 – 27.885	112	28.781 – 28.893	112
27.885 – 27.997	112	28.893 – 29.005	112
27.997 – 28.109	112	29.005 – 29.117	112
28.109 – 28.221	112	29.117 – 29.229	112
28.221 – 28.333	112	29.229 – 29.341	112
28.333 – 28.445	112	29.341 – 29.453	112

2.2.1 Double Ridged Horn Antenna

The horn antenna can operates at several bands which operating at 5.30 GHz – 6.30 GHz; 11.02 GHz – 11.80 GHz; 16.50 GHz – 18.00 GHz; 22.80 GHz – 23.70 GHz; and 28.00 GHz – 29.14 GHz because of the horn antenna or also known as tapered part. It is proved which is suitable for RADAR systems and EMC applications with those ranges of frequency. This researcher was proven by doing parameter studies on the length with nine sections with each of the length 2.41 mm and the result shown the smaller the waveguide obtained the linear flare of the main horn antenna [7].The techniques were used to improve the return loss and the impedance matching. This antenna can approach to beam steering a high intensity towards narrow beam.

2.2.2 Microstrip Antenna Array

Maximum PAE and compact RF-front end because of omitting interconnecting elements between amplifier and antenna had been used as the technique. The directivity that can be achieved by this antenna is 11.80 dBi gains with the E-plane is 25.00 dB; H-plane is 26.00 dB and side lobe level is 6.50 dB. This antenna is good for broadband application that can be used for increase the capacity of user because it can produce the power output at almost 28.00 dBm

2.2.3 Planar Array Antenna

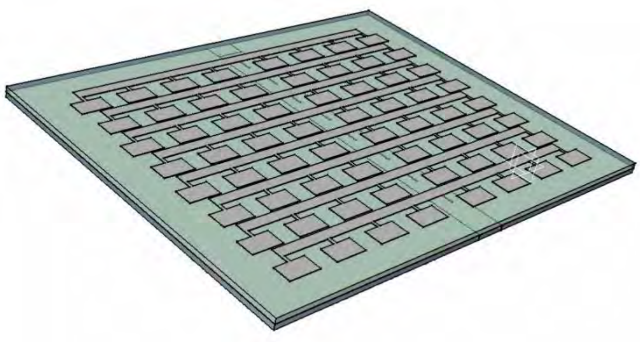

Figure 2.1: The 64 Element Array Antennas

This microstrip and array antennas are widely used for commercialize application because it eases of installation, low cost and low profile. The coplanar feed network and slotted integrated waveguide (SIW) as combination both can improves the efficiency of the antenna [8]. The description for this antenna is 8x8 uniform array by using material of substrate at permittivity 2.2 as the result the gain for each of the patch can gave the directivity around 8.16 dBi gain and the overall directivity is 24.40 dBi gain with efficiency is 87%. The return loss of the antenna at -10.00 dB is at bandwidth 1.00 GHz. The omnidirectional of radiation pattern is produces. The disadvantages are increases losses of microstrip line and unwanted radiation produces from power distributing circuit.

2.2.4 Dipole Array for Millimetre Wave Mobile

The researcher used the techniques changes to decrease the range outdoor wireless and size of the antenna, increase gain and enables beam steering where beam steerable collinear dipole array will produced a fan beam for these applications. As a result, peak gain for each antenna is 3.00 dBi while the combination the directivity is 7.00 dBi gain and it still not effective antenna because it is only focuses towards integrated mobile applications. The advantages of this antenna design are can have higher frequency and smaller wavelength.

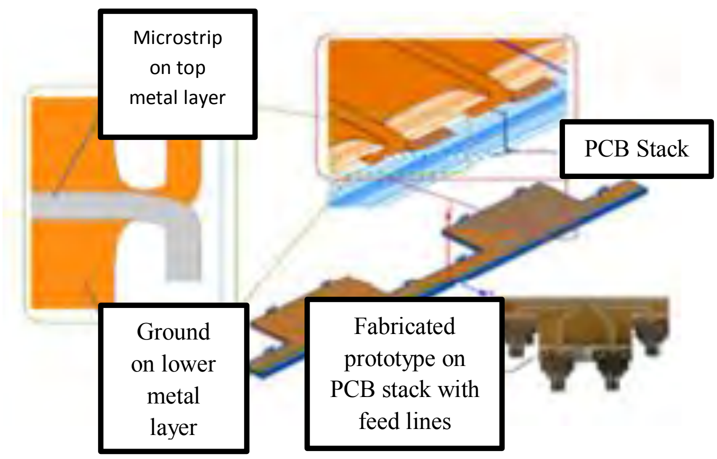

Figure 2.2: Dipole Array Antenna

2.2.5 Millimetre-Wave Open Ended SIW Antenna

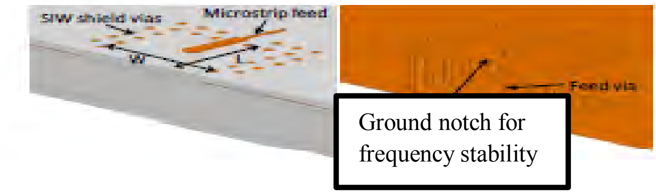

Figure 2.3: Geometry of proposed antenna

Refer to the reference, antenna is developed with using microstrip patch antenna because ease of installation by using PCB. The PCB edge tolerance give compassionate to the V-shaped notches that need applied by cut the top and bottom walls of the SIW [9].

As the result mention in the articles, the antenna with V-notches is much more having stable performance rather than the antenna without the V-notches. The measurement bandwidth of the antenna features at centre frequency at 28.00 GHz is 3.90 GHz.

2.2.6 Antipodal Linearly Tapered Slot Antenna

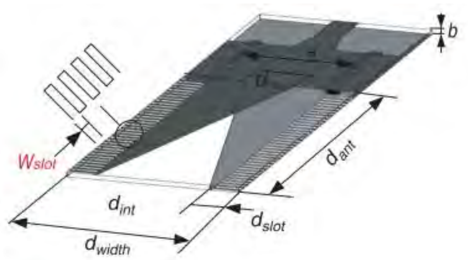

Figure 2.4: Corrugated antipodal LTSA feed by SIW structure and microstrip to SIW transition

This antenna design is very compact TSAs. The small spacing between antenna elements is used as techniques. Suppress higher modes mostly done by the horn antennas which are also called corrugations design. With the main goals for this article is to improve the radiation pattern at 28.00 GHz.

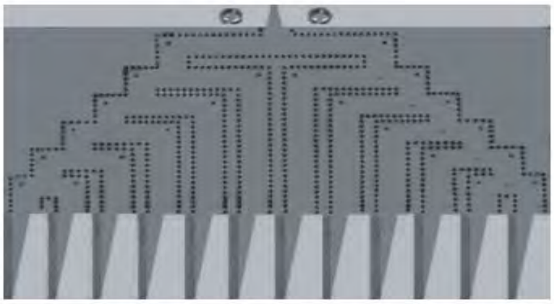

Figure 2.5 : The 1x12 Antipodal LTSA array antenna feed by quasi triangular power divider

The serial network or corporate feed network shown as above figure is to provide the right or left hand side ports of individual dividers signal power. The different value of a^2 is used for separate space for 10 elements equally by 0.5 λo. As a result, the decrease the value of a^2 it gives effect on the side lobe level to suppressed at 20 dB with increases in directivity. The Figure 2.5 shows the main lobe achieve 19.25 dBi with a 3.00 dB beam width of 10^o and 18.86 dB difference between main and side lobes at 16^o. This antenna is complicated to develop.

2.2.7 SIW Coupler for Tapered Slot Antennas

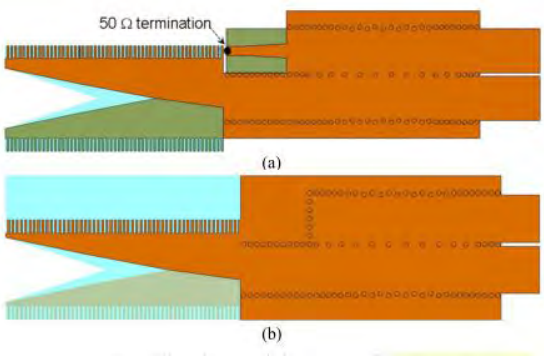

Figure 2.6: Antipodal Linearly tapered Slot Antenna with Substrate Integrated Waveguide Coupler: (a) Isolated coupler port terminated and (b) Shorted [10]

This type of antenna was widely used for limit the output power of transmitters and couple into gain circuit that limit the power delivered to drive the gain of receiving amplifier. Both antennas were used for adaptive ATSA-SIW receiver systems. For the figure 8(a) is for four-ports coupler that required all ports be matched depend on the performance and need inserted 50Ω load that makes fabrication process be complicated when in array applications. Coupler for uneven power divider was approach in second figure 8(b). The even slot cannot be matched simultaneously.

The return loss and isolated was shown 34.00 dB for frequency 18.00 GHz and 27.30 GHz of 20.00 dB SIW couple performances. The 28.00 GHz can be achieved by narrowing the SIW guides with increased coupling value from 18.00 GHz and 21.00 GHz. It actually eases fabrication and simple PCB process of ATSA coupler.

As the result can obtained from the figure above shown that the odd coupler design can produce simultaneously the measurement compared to the even coupler