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Deign of Millimeter-Wave Antennas for 5G

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Abstract: The evolution of 5G is became a common in this decade and characteristic of 5G provide high speed and low latency provoke the demand of development of millimeter wave antenna. This project is to design a compact millimeter-wave antenna for 5G at 28GHz using CST Studio Suite and validation of simulated result using fabrication and measurements. The double side FR-4 with thickness of 1.6 mm and dielectric constant of 4.7, copper with thickness 0.035mm is used and microstrip feed line is used as feeding technique to the antenna. The CST Studio Suite used in simulation and obtain reflection coefficient of -45.11 dB, 1.011 VSMR, gain of 5.472 dBi and directivity of 6.694 dBi at 28 GHz. The measured result obtains 27.776 GHz with -19.18 dB using VNA.

Keywords: Microstrip patch antenna, mm-wave, 5G, FR-4

1. Introduction

The 5G technology has now become a focusing developing point due to its higher data rates' capacity following the evolution of the universal telecommunication system [1]. The Five generations have benefit of faster data rate, density connection higher and low latency [2]. The emerging 5G technology will have demand on antenna with beam forming capability of the radiation pattern to perform spatial scanning that requires reasonable trade-off between technology design and commercial criteria such as low cost, small size, radiation efficiency, antenna gain on the millimeter wave bands [3]. The millimeter wave spectrum has the advantage of providing 5G services that have high-data rates and low latency over the entire band [1]. Besides, it has unexploited spectrum to fulfill the fifth generation need [4]. 5G have been allocated with several frequency bands including 28 and 38 GHz as most popular. The millimeter-wave spectrum is sensitive to atmospheric attenuation due to small wavelength, this could down grade the experience of 5G. This situation could be overcome by using antennas with high gain level to reduce the atmospheric conditional effects [1]. The 28 GHz is particular defined form Ka band as frequencies range 26.5 – 40 GHz with an available bandwidth of 1GHz and now low-cost antenna are being researched and developed [2]. The low-profile antenna is required as cost, size, weight ease of installation, performance and aerodynamic profile are important. Basically, microstrip that have characteristic of compact size, lightweight, easy process of fabrication and wide bandwidth which the most common used shape is rectangular and circular. The size of the patch antenna would depend in the substrate dielectric constant as higher substrate dielectric constant leads to smaller size of antenna patch [5]. The antennas have important role in Wireless communication for different application. There are different bands are used in 5G, one of them is 28 GHz. This

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create new challenges in designing the antennas to move to these millimeters wave. There are many challenges of using millimeter wave frequency which include propagation loss shadowing, sensitivity to blockage, large scale attenuation of human bodies and materials and atmospheric absorption. In order to overcome these challenges, a high gain directional beam forming antenna which it can overcome the path loss at millimeter wave frequency. The microstrip patch basically have four part which is patch, ground, substrate ad feeding part. The advantage of the microstrip patch it has small size, low profile and lightweight conformable to planar and non-planar surface [6]. The objectives of this project are to design a compact antenna for 5G. To simulate the designed rectangular patch antenna using CST software tools and to validate the simulated results by fabrication and measurements. The research work focused in the design of rectangular microstrip patch for millimeter-wave antenna. The antenna focusing on the operating frequency of 28 GHz. This proposed antenna is design and simulated using CST Studio Suite and fabricated out later for validation of the simulation result by fabrication and measurements.

2. Materials and Method

This methodology includes 5 steps. Fig. 1 shows the flowchart of the project which followed during the process to make sure the project in the track.

Step 1: Literature review of previous study on millimeter-wave microstrip patch antenna on 28GHz.

Step 2: Design of microstrip patch antenna to operate on 28GHz.

Step 3: Computer Simulation Technology (CST STUDIO SUITE 2019) is used to simulate the proposed antenna.

Step 4: Fabrication of proposed antenna

Step 5: Validate the simulated results by measurements

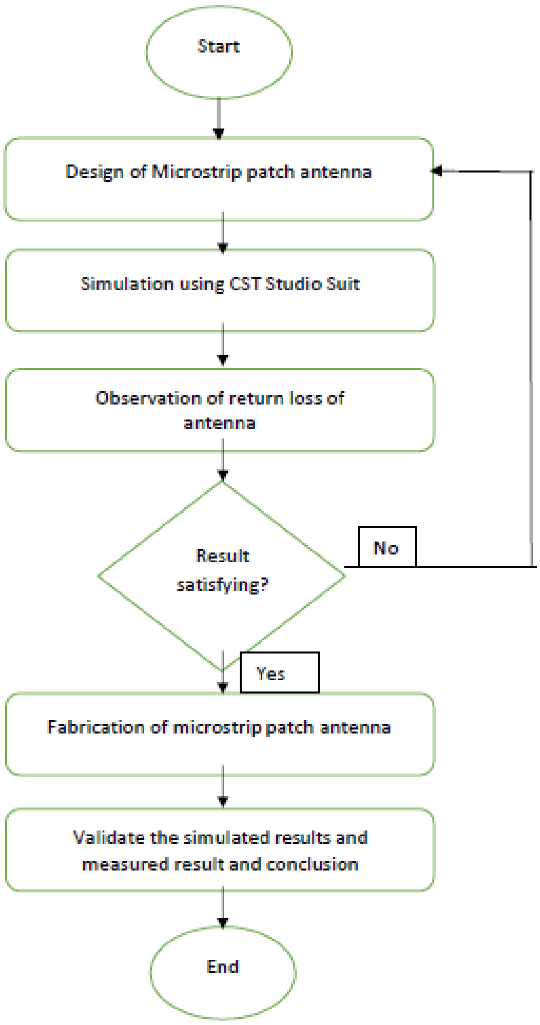


Fig. 1 - Project flowchart

Table 1 - Summarization of literature review comparison

Ref.	Project Title	Fc (GHz)	Area (mm^2)	BW (GHz)	Return loss (dB)
[7]	Design and analysis of a 28GHz Microstrip Patch Antenna for 5G Communication System	28	8.5 x 8.5	1.046	-38.87
[8]	High Directive Wideband Microstrip Patch Antenna for 5G Mobile Phone	28	6 x 6	0.057	-21.16
[9]	Compact Slotted Microstrip Antenna for 5G Applications Operating at 28 GHz	28	7 x 7	2.62	-27.79

Table 1 illustrates that the previous work done by researcher in designing the microstrip patch antenna. The microstrip patch antenna is being used because it has advantages of compact size and low cost. The 28GHz mm-wave antennas has advantages of faster transfer data rate in 5G.

2.1 Antenna Design Specification

The antenna designed needed to meet requirement of 28 GHz which is one of the most prominent frequency band, small size and high gain characteristic [10-15]. The designed antenna based on rectangular microstrip patch antenna and using double side FR-4 substrate with 1.6 mm thickness and dielectric constant of 4.7, copper with thickness of 0.035mm. The CST Studio Suite has been used to simulate the proposed antenna. The proposed antenna undergoes parameter study until get a satisfy result as show in Fig. 2. The Fig. 3 shows the structure of the proposed antenna. After the simulation, the antenna fabricated out to validate the simulated result by measurements using VNA.

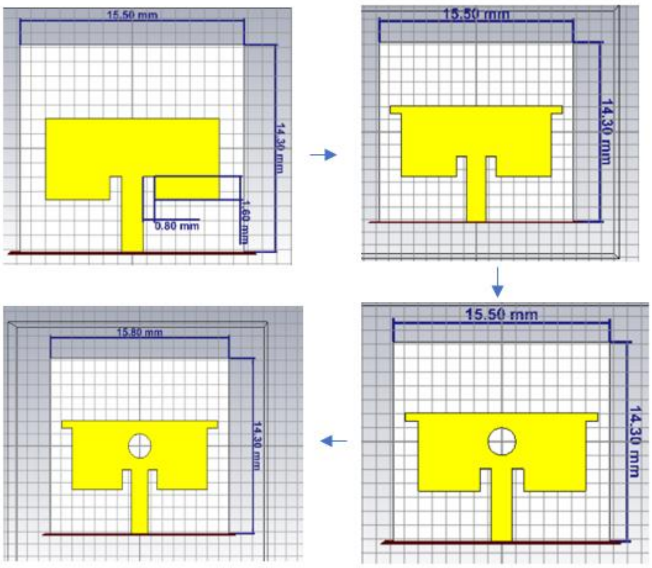


Fig. 2 - Parameter study

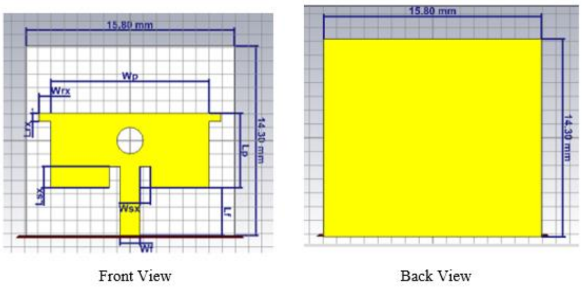


Fig. 3 - Proposed microstrip patch antenna

Table 2 shows the parameter of the proposed microstrip patch antenna. The proposed antenna has slot, inset and circle hole based on rectangular patch antenna.

Table 2 - Parameter of the rectangular microstrip patch antenna

Parameters	Dimension (mm)	Description
Ws	15.8	Width of substrate FR-4
Ls	14.3	Length of Substrate FR-4
WG	15.8	Width of Ground
LG	14.3	Length of Ground
Wp	8	Width of Patch
Lp	3	Length of Patch
Wf	6	Width of Feed
Lf	5	Length of Feed
Wsx	2	Width of Inset
Lsx	2.15	Length of Inset
WRX	0.5	Width of Slot
LRX	1.5	Length of Slot
-	1.0	Radius of Circle

3. Results and Discussion

The simulation results obtained in this project showed in this part. The millimeter-wave antennas having operating frequency at 28 GHz for 5G. The microstrip patch is used because of its compact size and low lost characteristic [11]. The result obtained using CST Studio Suite.

Table 3 - Characteristic parameters and simulation result of proposed antennas

Antenna	Frequency (GHz)	Return Loss (dB)	VSWR (GHz)	Bandwidth (GHz)	Directivity (dBi)	Gain(dBi)
Proposed antenna	28	-45.115	1.011	2.895	6.694	5.472

The proposed antenna able to transmit or receive electromagnetic wave at 28GHz showed in the simulation. The frequency of the operating frequency highly depends on the length of patch. A smaller length would produce a higher frequency. The simulation result obtains return loss of -45.11dB, 6.694dBi directivity and 5.472dBi. At 28 GHz it achieves a return loss of -45.11dB which is consider a good return loss value as a lower return loss value indicate a higher proportion of radio waves accepted against the radio waves rejected. The VSWR obtained is 1.011 indicate a good impedance matching, VSWR smaller than two is acceptable. The gain of the antenna is 5.472 dBi to minimize the attenuation. The radiation pattern shows the antenna is a directional antenna with directivity of 6.694dBi and having rounded and wider pattern against the obstacles.

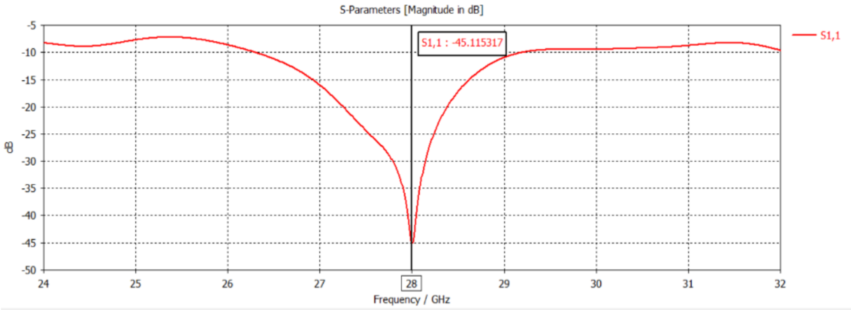


Fig. 4 - The S-parameter value

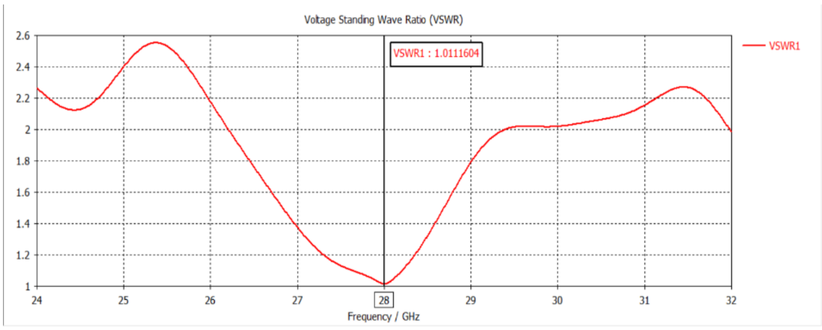
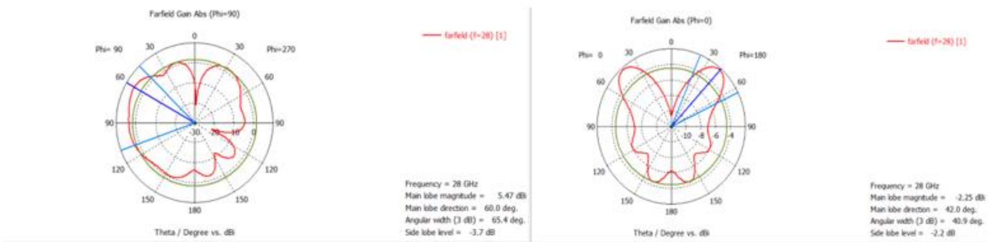


Fig. 5 - The VSWR value



H-plane E-plane

Fig. 6 - The 2D radiation pattern

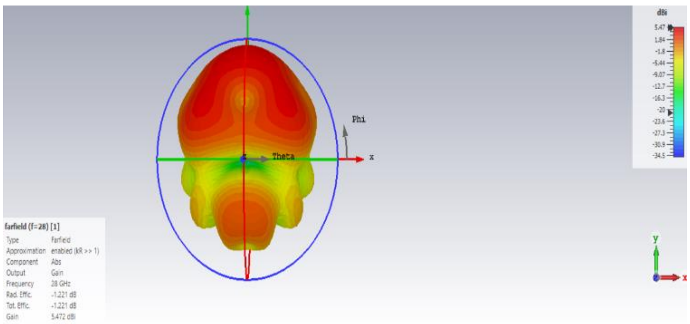


Fig. 7 - The 3D radiation pattern

3.1 Validation of Simulated Result by Fabrication and Simulation

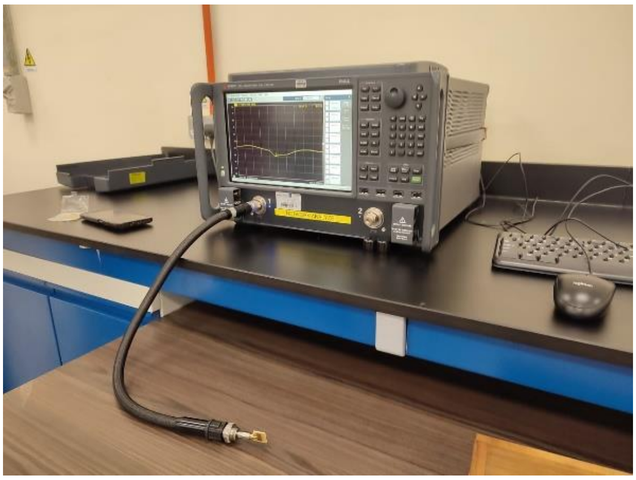


Fig. 8 - The measurement of proposed antenna using VNA

Fig. 9 - The Measured S-parameter result

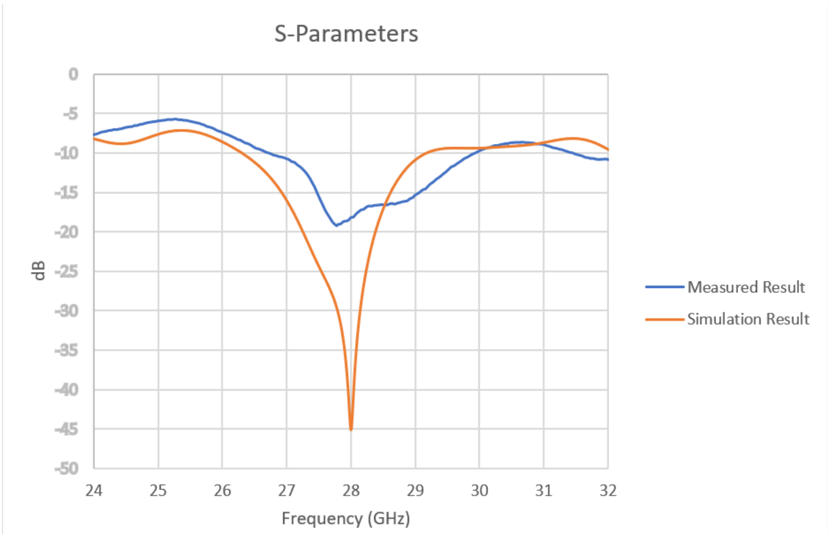


Fig. 10 - Comparison of simulation and measurement results

The proposed antenna is fabricated using etching machine and measurement is done using Vector Network Analyzer for obtained the S-parameter value. The S-parameter obtained resonant frequency at 27.776 GHz with reflection coefficient of -19.18dB as showed in Fig. 9. The comparison of simulation result and measured results in showed in Fig. 10. The deviation in value from 28 GHz with -45.11 dB to 27.776GHz with -19.18 is may due to insertion loss in feeding line during soldering process and cutting of FR-4 substrate is not precise.

4. Conclusion

As a conclusion, the proposed antenna able to operate at 28GHz showed in the simulation. This antenna would be useful in implementation of 5G technology at millimeter wave level. The design of the antenna is using rectangular microstrip patch antenna as the base model when developing to achieve a compact antenna. The antenna using double side FR 4 substrate with 1.6mm and dielectric constant of 4.7 during process design and simulation. The simulation result gets 45.11dB return loss value, VSMR with 1.011, gain of 5.472dBi and directivity of 6.694dBi. Beside microstrip patch antenna be more easily to fabricated out using PCB board. The fabricated antenna be measured by VNA get 27.776 GHz with return loss -19.18 dB. The measured result of the fabricated antenna is deviate from simulation result cause by technical problem during the fabrication process such as the cutting of the dimension of antenna is not precise and the soldering process of SMA connector on the antenna causing insertion loss in the impedance matching. Hence, all the project objective is achieved.

Acknowledgement

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