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Design A Wideband (25-40 GHz) Mm-Wave Microstrip Antenna for 5 g Applications

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Abstract: Millimeter wave is the spectrum between microwaves and infrared waves that are commonly known as extremely high frequencies, which is suitable for 5G networks. Features like antenna size, bandwidth, power consumption, traffic demand, and a high rate of data increase the need for such an antenna design. The aim of this research is to design a wideband Mm-Wave microstrip patch antenna for 5G application system. The design consists of edge-cut approach, an Inset-fed rectangular patch antenna with the partial ground. The proposed antenna can cover the 5G application from range (25 GHz – 40 GHz). The simulated result of bandwidth, return loss and VSWR shows the capability of the antenna that suits 5G Mm-Wave application systems. VSWR stands for voltage standing wave ratio is a measure of impedance matching of loads to the characteristic impedance of a transmission line or waveguide. This proved that proposed antenna can obtain wide bandwidth and high return loss by using four edge slots at the patch with partial ground. The Modified Inset-fed Microstrip Patch Antenna (MPA) demonstrates that this antenna is ideal for 5G Mm-Wave application.

Keywords: Microstrip Patch Antenna, Mm-Wave, 5G, Wideband, Bandwidth, Return Loss

1. Introduction

Satellite communication and wireless communication have advanced rapidly during the last few decades. World's communication depends on wireless links nowadays [1]. For 5G applications, bandwidth scarcity and millimeter wave frequency quality have grown to accommodate the increased traffic rate. The fundamental purpose of 5G technology is to boost transmission bit rates by utilising high-frequency bands and broad signal bandwidth, resulting in enhanced coverage with low battery usage and reasonable cost [2]. The 2015 World Radio Communication Conference identified the frequency allocation of 24 GHz to 86 GHz for future millimeter wave communication systems [3]. Because it is compact, light and integrated into the module circuit, microstrip antennas are crucial for supporting mobile terminals in wireless communication systems [4].

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Antenna systems are considered to be fundamental equipment for wireless technology, hence it's important to track their advancement. Modern antenna designs allow for the use of a single element in several systems. Microstrip patch antennas, as compared to conventional antennas, are primarily used in the development of new communication mechanisms because they have the advantages of being low profile and having simple or affordable production techniques. Antenna systems have been the subject of substantial research in the last four decades [4].

Current trends lean to the development of an antenna with wideband transmission and reception capabilities, as well as a high gain that can function across a wide frequency range. Thus, size reduction and bandwidth enhancement have become key design concerns for sensible applications of microstrip antennas [5]. But the major drawback of these antennas are have very narrow bandwidth characteristics that limits the frequency ranges over. The standard measurement bandwidth are 2.4 GHz and 5 GHz. The 2.4 GHz band has a longer range of coverage but sends data at a slower rate. The 5 GHz band has a smaller coverage area yet sends data at a quicker rate. Since higher frequencies cannot penetrate solid objects like walls and floors, the range in the 5 GHz band is limited. Higher frequencies, on the other hand, allow data to be sent more quickly than lower frequencies. Return loss is the measurement of the amount of light reflected back toward the source, it expressed in decibels (dB). A high return loss is beneficial since it leads to a smaller insertion loss. A good return loss that acceptable should be lower than -10 dB.

The objectives of this project are to study the concepts of microstrip patch antenna for 5G wireless communication system. To design a compact microstrip patch antenna and to simulate microstrip patch antenna for 5G application system.

The research work focused on the study of microstrip antenna which can be used for 5G application system that can support (5G, WLAN, Bluetooth, etc.). The MPA is designed within frequencies ranging from 25 GHz – 40 GHz that can operate 28 GHz and 38 GHz that use for Mm-Wave 5G systems. This project antenna has been designed and simulated using CST Microwave Studio is a specialist tool for the 3D EM simulation of high frequency components [6, 7, 8].

Table 1: Summarization of literature review comparison

Ref.	Project Title	F_c (GHz)	Area (mm^2)	BW (GHz)	Return loss (dB)
[9]	Millimeter Wave MicroStrip Patch Antenna for 5G Mobile Communication	38, 58	6 x 6	1.94, 2	-15.5, -12
[10]	Bandwidth Enhanced Rectangular Patch Antenna Using Partial Ground Plane Method for WLAN Applications	2.4	40 x 50	0.057	-41.38
[11]	A Design Rule for Inset-fed Rectangular Microstrip Patch Antenna	10	9 x 9	0.65	-23.5
[12]	Bandwidth Enhancement of an Inset-Fed Rectangular Patch Antenna using Partial Ground with Edge-cut Method	3	23 x 30	0.18	- 26.16

Table 1 shows that the past work researcher of designed the microstrip patch antenna. Microstrip patch antenna has been gaining great approach by researches as it has the capability of compactness and low-cost fabrication in communication devices. Future 5G application system will rely on Mm-Wave frequency antenna because wideband Mm-Wave microstrip antenna is less complex. Patch antenna are selected because of its simplicity of design [13, 14, 15, 16].

2. Methodology

There are 4 stages involved in this project. Figure 1 shows the flowchart of how the designed in CST works. This is major few steps needed to be followed in order to run the project smoothly.

- Stage 1: Review previous MPA related Literature review.
- Stage 2: Design a microstrip patch antenna to be applicable with 5G application.
- Stage 3: Computer Simulation Technology (CST STUDIO SUITE 2018) is used to simulate the proposed antenna.
- Stage 4: Thesis report Writing

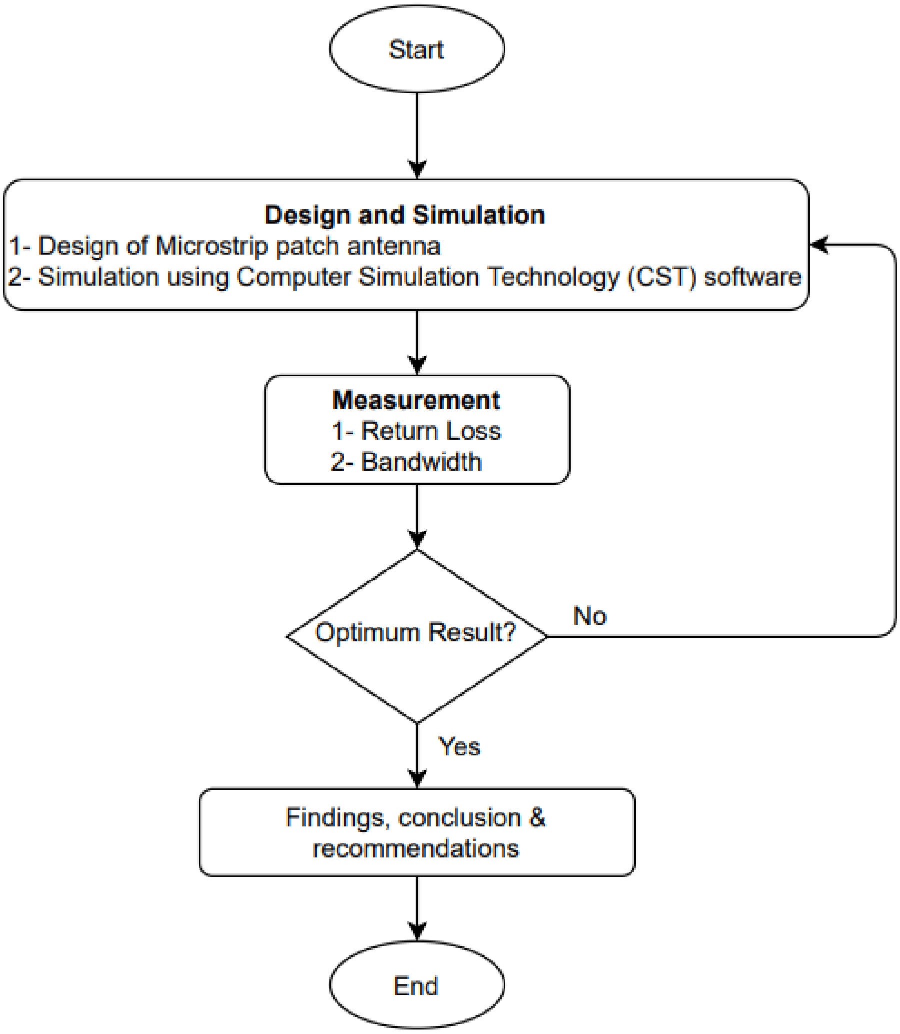

Figure 1: Flowchart of CST works [13]

2.1 Optimum Result MPA Design for 5G application system

The standard measurement bandwidth are 2.4 GHz for 4G and 5 GHz for 5G application system. The 2.4 GHz band has a longer range of coverage but sends data at a slower rate. The 5 GHz band has a smaller coverage area yet sends data at a quicker rate. Return loss is the measurement of the amount of light reflected back toward the source, it expressed in decibels (dB). A high return loss is beneficial since it leads to a smaller insertion loss. A good return loss that acceptable should be lower than -10 dB [14].

This patch antenna consists of partial ground and the edge-cut technique, an Inset-fed MPA. To achieve improved impedance matching, a re-designed form of ground and patch (combination of partial ground technique and slots at the four sides of the patch) was used. To achieve wide bandwidth with an inset feed technique that capable to generate effective impedance matching requirement. This antenna has the ability to cover both the 2.4 GHz / 5.5 GHz bands at the same time. This project model and simulate the MPA using CST Microwave Studio 2018. For the feeding line antenna, a 50 Ω CPW line has been designed by studies the various design parameter on characteristic line impedance.

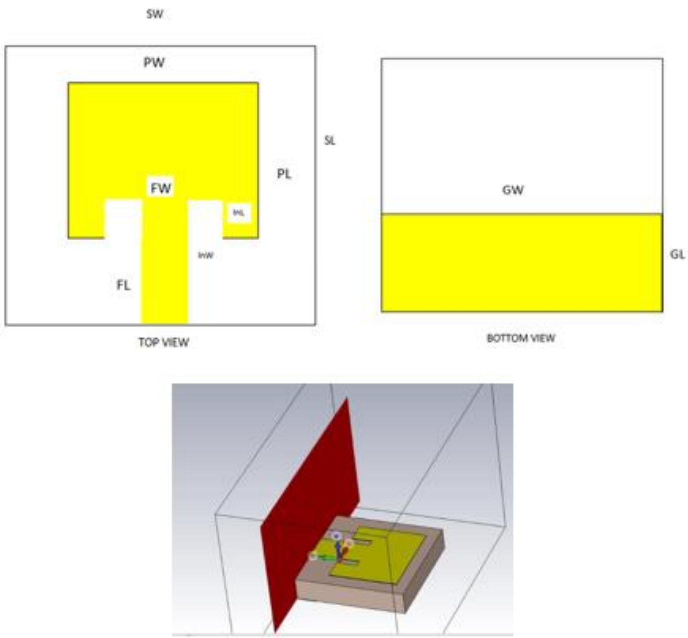

Figure 2: Configuration parameter of inset-fed MPA

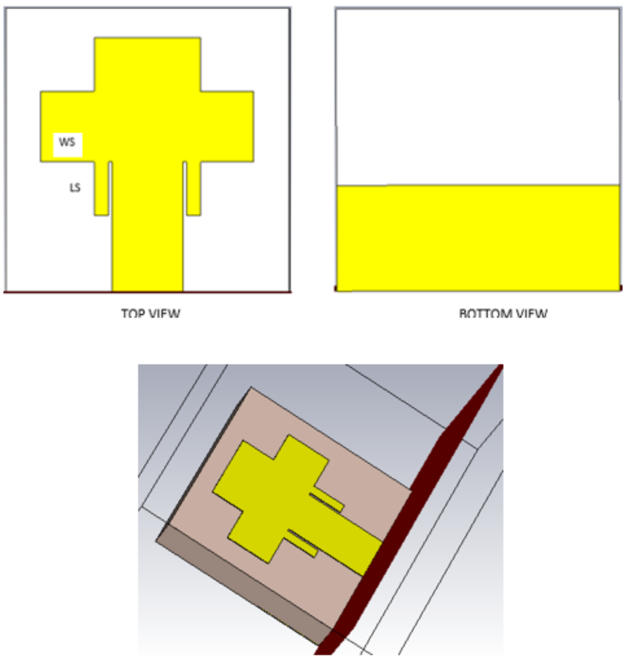

Figure 3: Configuration parameter of inset-fed MPA

Table 2 shows the configuration of inset fed MPA with partial ground and modified inset fed MPA with improved version of ground and patch. The difference modified inset fed MPA from inset fed

MPA are this model has additional parameter which is width of slot and length of slot (four edge cut slots). Both antenna design have different width of inset and length of inset.

Table 2: Parameter of the Inset-fed MPA and modified Inset-fed MPA

Parameters	Inset-fed MPA (mm)	Modified Inset-fed MPA (mm)	Description
SW	8	8	Width of substrate FR-4
SL	8	8	Length of Substrate FR-4
SH	1.6	1.6	Height of substrate FR-4
Mt	0.035	0.035	Height of copper
GW	8	8	Width of Ground
GL	3	3	Length of Ground
PW	6	6	Width of Patch
PL	5	5	Length of Patch
FW	2	2	Width of feed line
FL	2.15	2.15	Length of feed line
InW	0.5	0.1	Width of Inset
InL	1.5	1.5	Length of Inset
WS	-	1.5	Width of Slot
LS	-	1.5	Length of Slot
ε_r	-	4.3	Dielectric Constant

3. Results and Discussion

This process discuss the simulation results obtained in this project. The proposed antenna is capable to operate at 2 frequency band ranging from 25 GHz – 40 GHz that can perform at 28 GHz and 38 GHz. The partial ground is chosen because it offers wide range of operating frequency bands. The simulation result has been measured and analyzed.

Table 3: Characteristic parameters and simulation result of both proposed antennas

Antenna	Frequency (GHz)	Return Loss (dB)	VSWR (GHz)	Bandwidth (GHz)	Directivity (dBi)	Gain (dB)
Inset-fed MPA	28	- 12	1.9299	2.09	7.812	7.18
	38	- 42.05	1.3457	5.97	7.195	7.2
Modified Inset-fed MPA	28	- 15.88	1.3729	15.7	5.472	- 0.56
	38	- 29.20	1.1594	15.7	7.069	- 0.949

The simulation result for both proposed antenna has been presented. According to the Table 3, the Inset-fed MPA acquired the highest return loss which is -42.05 dB at 38 GHz. At 28 GHz, it achieved acceptable return loss at -12 dB. The bandwidth at 28 GHz didn't achieve desired result. At 38 GHz the bandwidth achieved the aim of this study which is above 5 GHz for 5G system. As for Modified Inset-fed MPA, both frequencies achieved above acceptable result. The bandwidth for both Modified Inset-fed MPA frequency achieved a tremendous result which is 15.7 GHz. The VSWR of Modified Inset-fed MPA smaller than Inset-fed MPA. Also, four edges slots of the patch demonstrated that it achieved wide bandwidth. This simulation result shows that Modified Inset-fed MPA has better performance than Inset-fed MPA which is return loss, VSWR and bandwidth that is a good argument for 5G Mm-Wave application systems.

Figure 4 shows that the green line is effect 'S' varies which is S11, as the frequency becomes higher, the return loss decrease. At 28 GHz, the simulated result didn't achieve desired result which the bandwidth is 2.09 GHz with return loss at -12.57 dB. But at 38 GHz, the simulated result has a bandwidth of 5.97 GHz and return loss -42.05 dB, which is second to none return loss result.

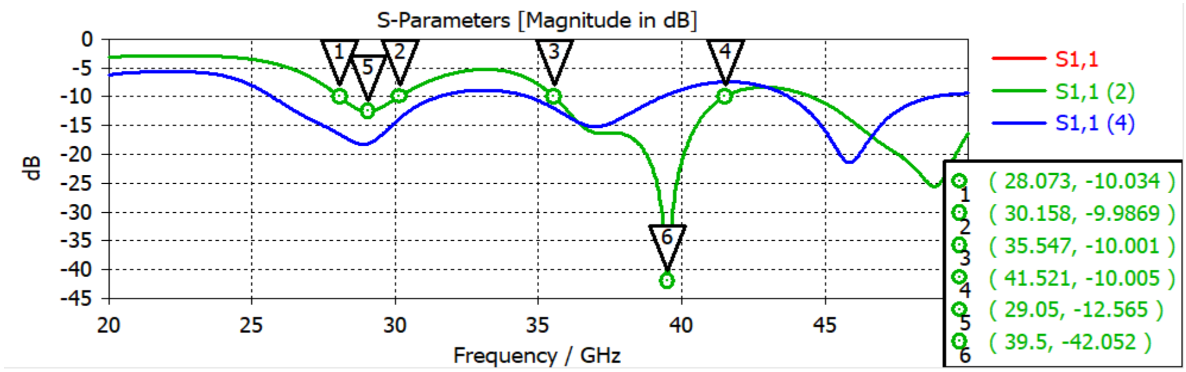

Figure 4: Effect S variation of Inset-fed MPA on return loss

Figure 5 shows that the effect 'S' varies, as the frequency gradually increase, the return loss decrease. The return loss is -15.88 dB at 28 GHz, while the return loss is -22.84 dB at 38 GHz. The best return loss result is -29.20 dB. Both simulated bandwidth is 15.7 GHz, this modified antenna covers 2.4/5.5 GHz bands.

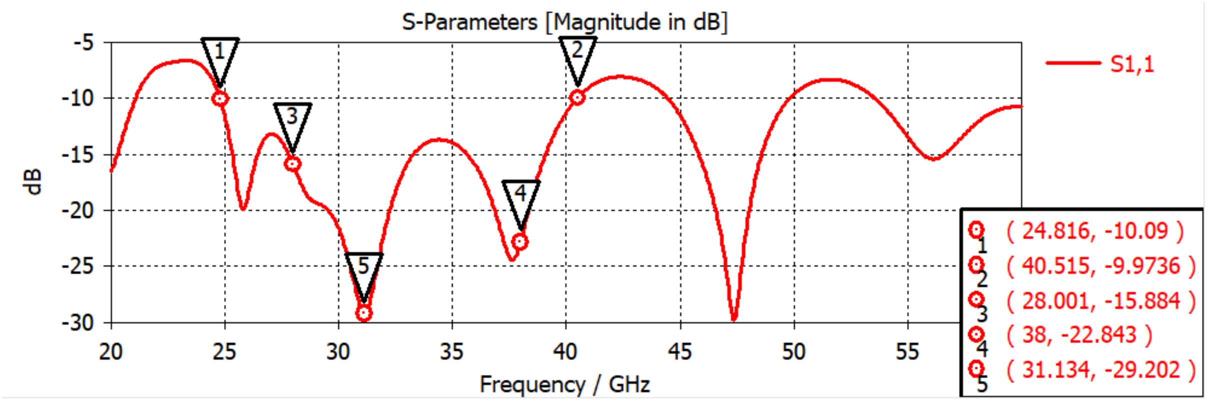

Figure 5: Effect S variation of modified Inset-fed MPA on return loss

From Figure 6 and Figure 7, the green indicator shows that VSWR is 1.9299 and 1.3457, when resonant frequency at 28GHz and 38 GHz respectively. The performance of the antenna increase when the value of VSWR is smaller. VSWR ideal range should 1 – 2 to demonstrate good performance [1].

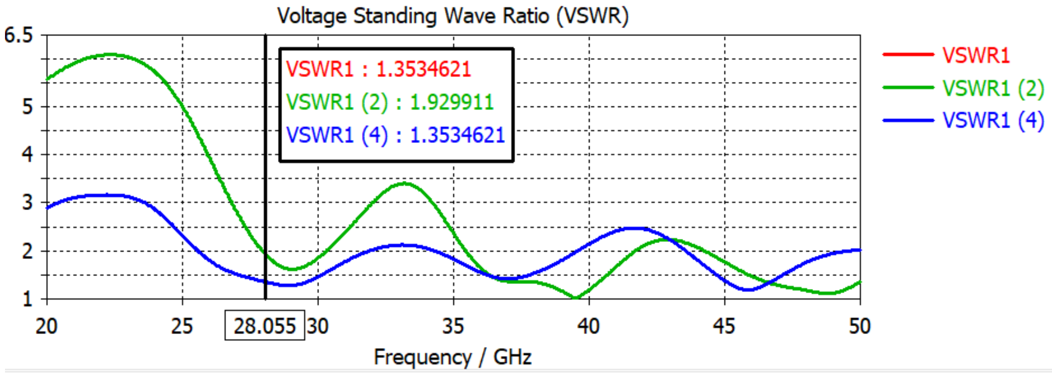

Figure 6: VSWR of Inset-fed MPA at 28 GHz

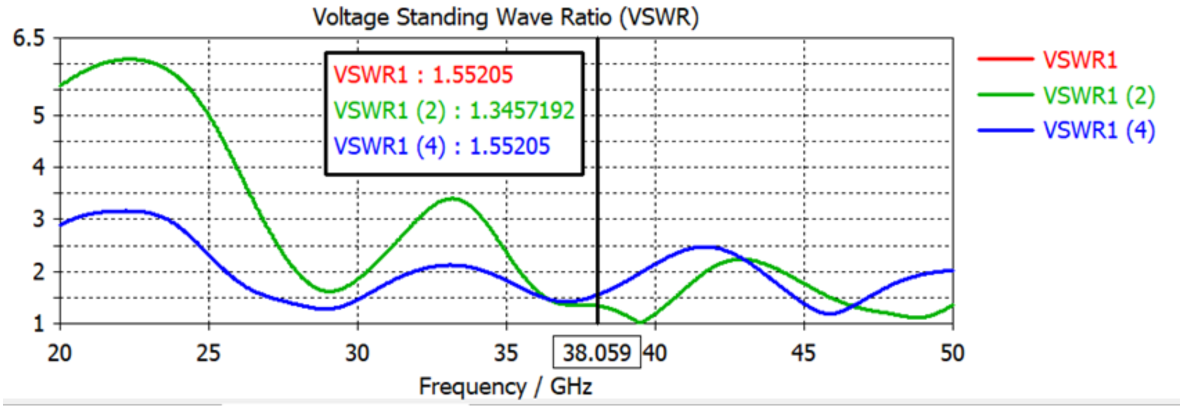

Figure 7: VSWR of Inset-fed MPA at 38 GHz

From Figure 8 and Figure 9, the red indicator shows the resonant frequency at 28GHz and 38 GHz, the VSWR is 1.3729 and 1.1594 respectively. This demonstrated that modified Inset-fed MPA is better performance according to the simulated result.

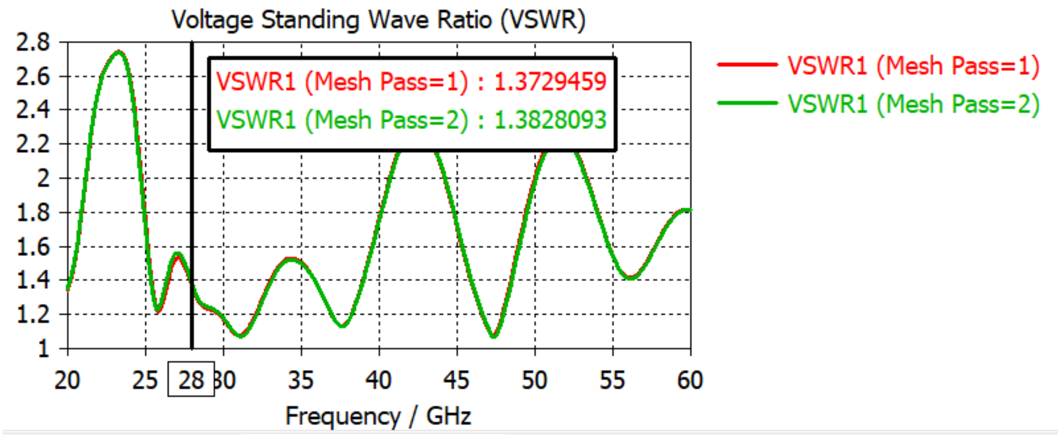

Figure 8: VSWR of modified Inset-fed MPA at 28 GHz

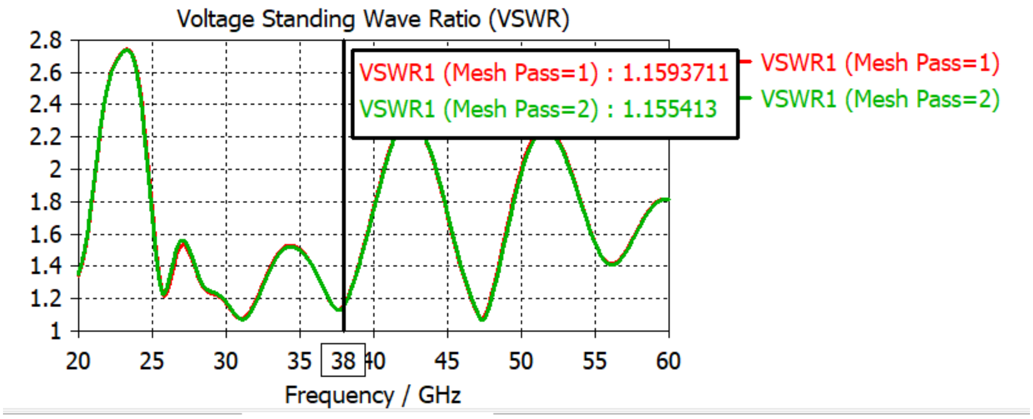

Figure 9: VSWR of modified Inset-fed MPA at 38 GHz

According to Figure 10 and Figure 12, the Inset-fed MPA acquired a directivity of 7.81 dBi at 28 GHz and 7.19 dBi at 38 GHz respectively. The red colour in the pattern of radiation represent the amount of radiation intensity from directivity plot. Also, from the Figure 11 the main lobe directed at an angle of 121 degree with gain 7.18 dB and having angular beam width of 103.4 degree. As for Figure 13, the main lobe directed at an angle of 94 degree with gain 7.2 dB and having angular beam width of 74 degree.

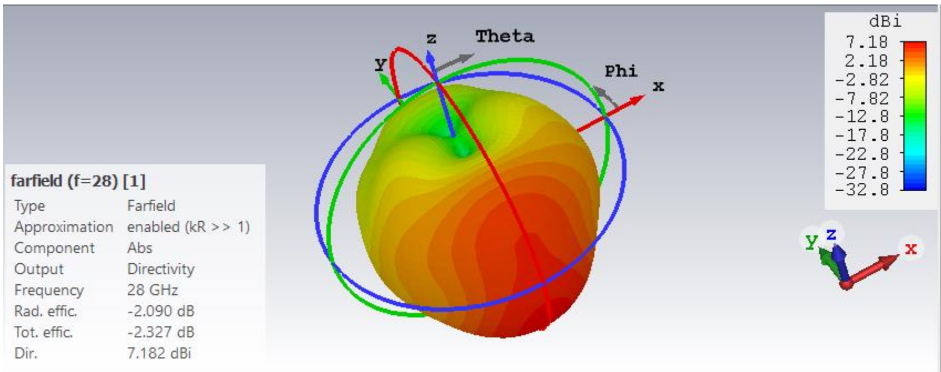

Figure 10: Directivity (3D) view of Inset-fed MPA at 28 GHz

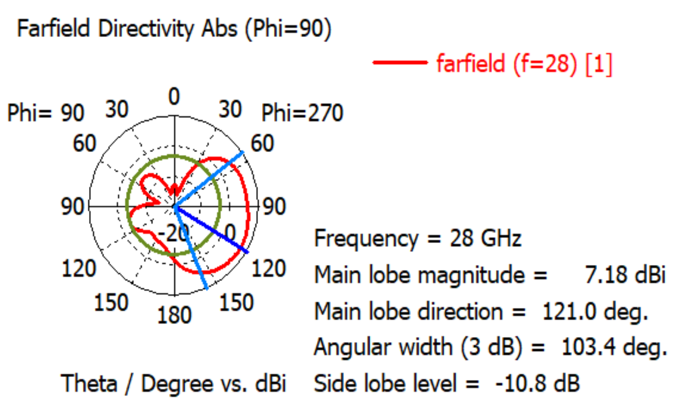

Figure 11: Pattern of Radiation Inset-fed MPA at 28 GHz

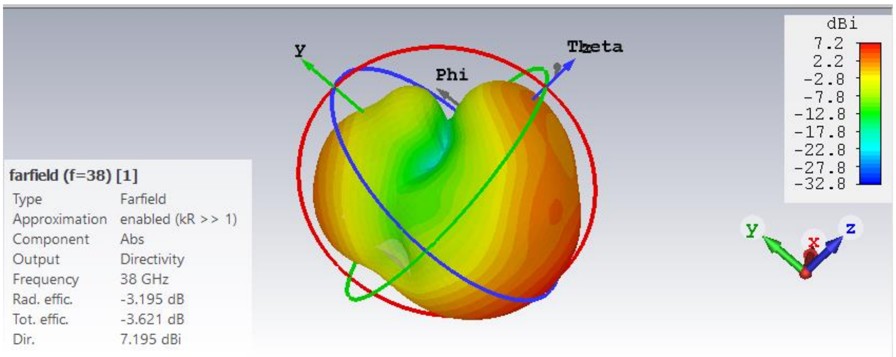

Figure 12: Directivity (3D) view Inset-fed MPA at 38 GHz

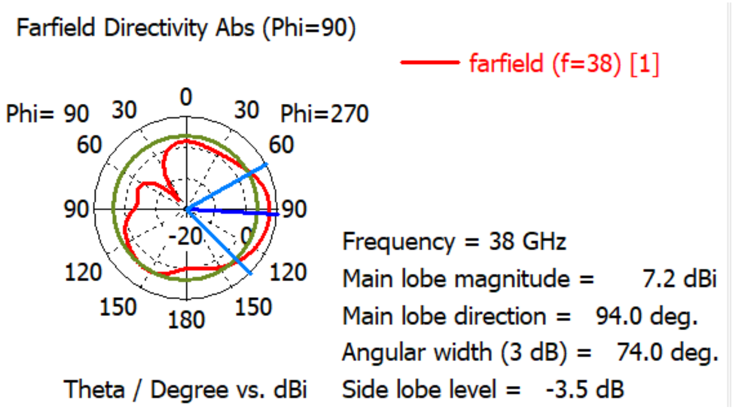

Figure 13: Pattern of Radiation Inset-fed MPA at 38 GHz

According to Figure 14 and Figure 16, the Modified Inset-fed MPA achieved a directivity of 5.47 dBi at 28 GHz and 7.07 dBi at 38 GHz respectively. From Figure 15, the main lobe directed at angle of 82 degree with gain -0.56 dB and having angular beam width 298.4 degree. As for Figure 17, the main lobe directed at angle of 108 degree with gain -0.949 dB and having angular beam width of 275 degree.

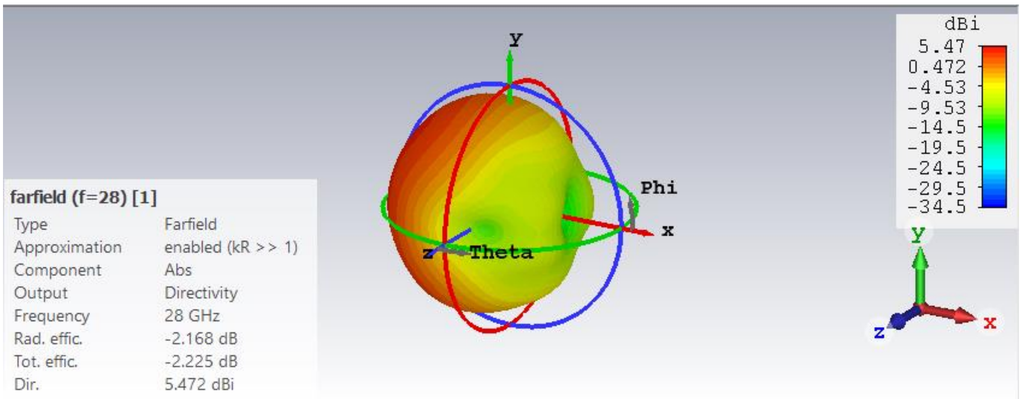

Figure 14: Directivity (3D) view Modified Inset-fed MPA at 28 GHz

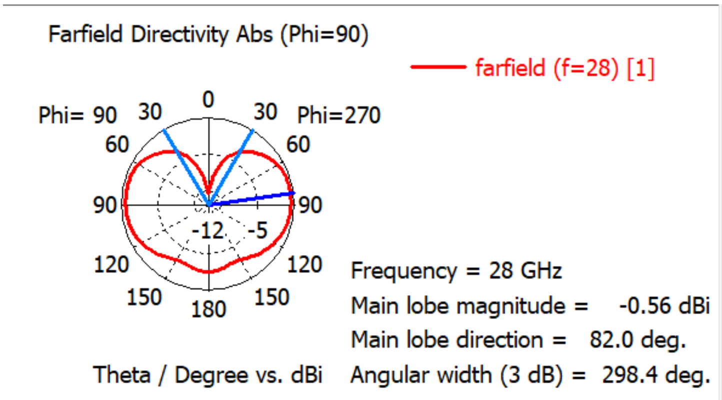

Figure 15: Pattern of Radiation Modified Inset-fed MPA at 28 GHz

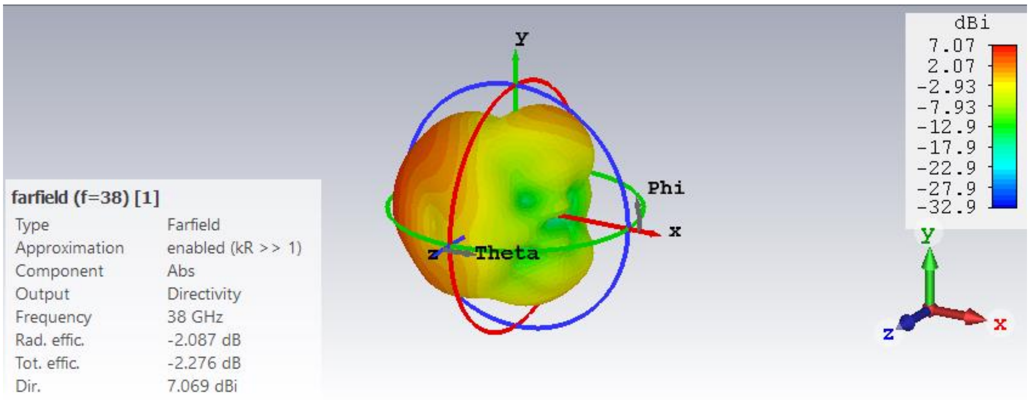

Figure 16: Directivity (3D) view Modified Inset-fed MPA at 38 GHz

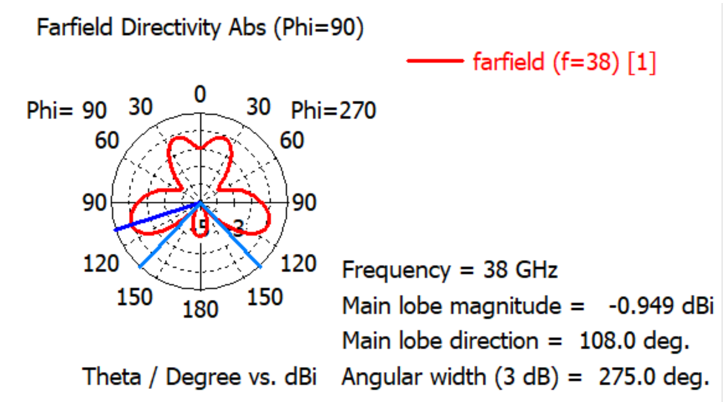

Figure 17: Pattern of Radiation Modified Inset-fed MPA at 38 GHz

4. Conclusion

Patch antenna are selected because of its simplicity of design. The most effective method to defect the ground by reducing the patch size. Next, reducing the size of the ground plane can enhances the bandwidth rose to 30.00 % with a good return loss (implying improved impedance matching). Next, the inset cut in the patch role is to match the impedance of the feed line to the patch. The patch resulted a 125.00 % increase in bandwidth when the patch is made using partial ground technique and four edges slots.

In this paper, the microstrip patch antenna concept is used for 5G Mm-Wave application systems. The microstrip patch antenna able to operate at dual frequency at 28 GHz and 38 GHz. Both bands can be utilised in 5G communication bandwidth at 2.4 GHz and 5 GHz. From the simulated result, Inset-Fed MPA and Modified Inset-Fed MPA gives return loss -42.05 dB and -29.20 dB at 38 GHz respectively. Although the bandwidth Inset-fed MPA obtain at 38 GHz is 5.97 GHz, but at 28 GHz the antenna didn't achieved the target bandwidth. As for Modified Inset-Fed MPA, both frequency 28 GHz and 38 GHz achieved second to none bandwidth which is 15.7 dB. This proves that the antenna can obtain wide bandwidth by using four edge slots at the patch with partial ground. The Modified Inset-Fed MPA has an outstanding performance based on return loss, bandwidth and VSWR. The proposed Modified Inset-Fed MPA demonstrates that this antenna is ideal for 5G Mm-Wave application systems.

Acknowledgement

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References

[1] Richa. (JULY 2013). Design, Fabrications and Performance Analysis of Microstrip Patch Antenna for Wireless Applications. *Electronic and Communication Engineering Department Thapar University*, 1.

[2] Benjebbour, A. S. (2016). 5G Radio Access Technology. *NTT*, 17(4).

[3] Iskandar Fitri, A. A. (n.d.). ―A New Gridded Parasitic Patch Stacked Microstrip Antenna for Enhanced Wide Bandwidth in 60 GHz Band. *IEEE Transaction on Antennas and*, 2017.

[4] Abdullahi SB Mohammed, S. K. (OCTOBER 2019). A Review Of Microstrip Patch Antenna Design At. *INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH* , VOLUME 8, ISSUE 10.

[5] Iskandar Fitri, A. A. (n.d.). ―A New Gridded Parasitic Patch Stacked Microstrip Antenna for Enhanced Wide Bandwidth in 60 GHz Band. *IEEE Transaction on Antennas and*, 2017.

[6] Najib, AL-Fadhali, Huda Majid, and Rosli Omar. "Multiband frequency reconfigurable substrate integrated waveguide antenna using copper strip for cognitive radio applicable to internet of things application." *Telecommunication Systems* 76.3 (2021): 345-358.

[7] Najib, AL-Fadhali, et al. "Wideband millimeter-wave substrate integrated waveguide cavity-backed antenna for satellites communications." *Bulletin of Electrical Engineering and Informatics* 9.5 (2020): 1933-1940.

[8] AL-Fadhali, A. N. M., et al. "A compact ultrawideband (42-54 GHz) mm-wave substrate integrated waveguide (SIW) cavity slot antenna for of future wireless communications." *Int. J. Innov. Technol. Explor. Eng.(IJITEE)* 8.9 (2019): 548-552.

[9] Imran, D. F. (2018). Millimeter wave microstrip patch antenna for 5G mobile communication.

[10] Suhana Rashid, C. K. (2015). "Bandwidth Enhanced Rectangular Patch Antenna Using Partial Ground Plane Method For WLAN Applications". *Putrajaya Campus: The 3rd National Graduate Conference.*

[11] M A M, A. I. Sayeed." A Design Rule for Inset-fed Rectangular Microstrip Patch Antenna" Department of Electrical Engineering and Computer Science North South University, 2010

[12] Charles U.N. Oluwafemi A., Oboyerulu E.A. "Bandwidth Enhancement of An Inset-Fed Rectangular Patch Antenna using Partial Ground with Edge-cut Method". International Journal of Electromagnetics and Applications, (2017).

[13] Yi. C. W. (2017). Frequency Reconfigurable Slotted Loop Antenna for Mobile Device.

[14] AL-Fadhali, Najib, et al. "Substrate integrated waveguide cavity backed frequency reconfigurable antenna for cognitive radio applies to internet of things applications." *International Journal of RF and Microwave Computer-Aided Engineering* 30.1 (2020): e22020.

[15] AL-Fadhali, Najib Mohammed Ahmed, et al. "Frequency reconfigurable substrate integrated waveguide (SIW) cavity F-shaped slot antenna." *Indonesian Journal of Electrical Engineering and Informatics (IJEEI)* 7.1 (2019): 135-142.

[16] Najib, AL-Fadhali, et al. "Ultra-wideband (50–60 GHz) mm-wave substrate integrated waveguide (SIW) antenna for 5G applications." *2019 IEEE 10th control and system graduate research colloquium (ICSGRC)*. IEEE, 2019.