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A CPW-Fed Patch Antenna with DGS For Sub 6 GHz 5G Applications

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***Abstract*— This research paper outlines the development of a patch antenna using Coplanar Waveguide (CPW) feeding and Defected Ground Structure (DGS) for use in 5G applications operating below 6GHz. The antenna design was simulated using CST numerical analysis software and is intended to operate within a frequency spectrum 3.2GHz - 3.5GHz. Antenna involves a circular patch antenna with ring shaped slot modified with CPW feeding. The antenna is of compact size 45 mm × 45 mm × 0.035 mm and obtains a huge gain which is 6.05dBi and highest directivity of 7.0dB at 3.5GHz frequency. The antenna achieves a radiation efficiency of 88% and a VSWR of less than 2 across the sub 6GHz 5G frequency range. Thus, the intended antenna is a promising for SUB 6GHz 5G applications, offering a broad bandwidth, compact size, and stable radiation characteristics.**

Keywords—rectangular ring MPA, CPW fed, sub 6GHz 5G.

I. INTRODUCTION

Over the past 25 years, the wireless communications industry and mobile industry has evolved significantly, starting from analog to digital communication and finally, the 5th generation mobile network. The 5G is a technology standard for cellular communication which supports high data rates, low latency, high reliability and probably the next big thing for connectivity and smartphones [1]. Being the two different types of connectivity –the mm Wave and sub-6GHz. One of them is to apply sub-6GHz (n77~79 bands, 3.3~5.0GHz) in the existing mobile phones. Both of them are the key deployments yet offer vastly different benefits and drawbacks. Sub 6GHz 5G bands occur similar frequency ranges as previous generations, so they are not as much of a departure as mm 5G wave. This lower frequency signals retain the ability to better penetrate obstacles. Mobile networks will need spectrum capacity plans that are incorporated into a long-term vision of the future of the world as increased broad band and Internet of Things (IoT) data, analytics, and insight permeate every area of society [2].

“**Sub -6GHz 5G is essential for blanket coverage and bandwidth, while mm Wave offers high speed over shorter distances.”**

The history of sub-6GHz 5G technology dates back to 2015 when the Third Generation Partnership Project (3GPP) began developing the 5G standard. In 2017, The initial release of the 5G NR (New Radio) standard included the frequency bands operating below 6GHz, which are commonly referred to as Sub-6GHz spectrum. These frequencies comprise such as 600 MHz, 700 MHz, 4.9 GHz and 3.5 GHz.

Sub-6.5GHz 5G technology has several advantages over mm Wave 5G technology. Firstly, sub-6GHz 5G technology has a wider coverage area and can penetrate walls and other obstacles more efficiently. Secondly, it is more cost-effective to deploy than mm Wave 5G technology due to the need for fewer base stations. Lastly, sub-6GHz 5G technology has a lower latency, making it suitable for real-time applications...Sub-6GHz 5G technology is being widely deployed across the world. In the US, major telecommunication companies like AT&T, Verizon, and T-Mobile have deployed sub-6GHz 5G technology in several cities. In Europe, countries like the UK, Germany, and Spain have already deployed sub-6GHz 5G networks. In Asia, China, Japan, and South Korea are among the countries that have already deployed sub-6GHz 5G technology [3-6].

Sub-6GHz 5G technology has several applications in various sectors. In the healthcare sector, sub-6GHz 5G technology can be used for remote patient monitoring and telemedicine. In the transportation sector, sub-6GHz 5G technology can be used for vehicle-to-vehicle communication, enabling safer and more efficient transportation. In the industrial sector, sub-6GHz 5G technology can be used for machine-to-machine communication and real-time monitoring of equipment.

In conclusion, sub-6GHz 5G technology has a rich history and is currently being widely deployed across the world. Its advantages over mm Wave 5G technology, coupled with its numerous applications across various sectors, make it an essential component of the 5G ecosystem.

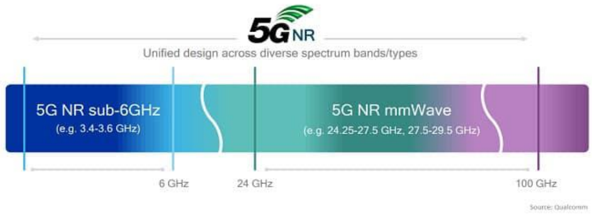


Fig 1. Sub- 6GHz Spectrum [3]

CPW modeling is a type of transmission line feeding technique used in radio frequency (RF) as well as microwave circuits. It is a popular method for feeding antennas, as well as for connecting RF and microwave circuits to other components in a system.

In a CPW feeding structure, a conductor is placed on a relative permittivity containing a ground base having opposite plane of the PEC. The signal conductor contains mostly made wider than the ground conductor, which creates a intrinsic impedance for the CPW. The wave impedance of a transmission line is determined by the dimensions of the signal conductor, the thickness of the PEC, and the distance besides signal and ground conductors. The CPW feeding technique offers several advantages, such as low loss, good impedance matching, and the ability to integrate passive components into the same structure. It also provides a wide bandwidth, which makes it suitable for high-frequency applications.

CPW feeding can be used in a variety of applications, including antennas, filters, power dividers, and mixers. It is commonly used in microwave circuits, as well as in high-speed digital circuits, where the coplanar structure provides a low inductance and capacitance.

DGS is a technique used in the modelling of microwave and RF circuits to maximize their performance. It involves introducing a pattern of holes or slots into the ground plane of the circuit board, which effectively creates a series of resonant structures that can suppress unwanted frequencies and reduce crosstalk between different parts of the circuit.
The basic principle of DGS is to create a resonant circuit by removing a small section of the ground plane, which effectively creates a slot antenna. The slot antenna then resonates at a particular frequency, which can be tuned by adjusting the size and shape of the slot. By carefully designing the DGS pattern, it is possible to create a band stop filter that can suppress unwanted frequencies in the
Circuit. DGS can be used in a variety of microwave and RF circuits, including filters, couplers, and antennas. It is particularly useful in high-speed digital circuits, where crosstalk between different traces can cause signal integrity problems. By incorporating DGS into the ground plane, it is possible to reduce crosstalk and Boost the circuit's overall performance [7].

Therefore, in this document DGS with CPW for the paper presents an analysis of wireless uses for 5G operating below 6GHz, specifically at a frequency of 3.5 GHz. The software used in this work is CST Replication. The frequency range below 6GHz, also known as Sub-6GHz, is considered a mid-frequency range that spans from 1GHz to 6GHz. This range is ideal for facilitating optimal conditions for the transmission of 5G millimetre-wave communication. This involves incorporating filtering capabilities into the antenna's radiation pattern, while maintaining high gain, superior isolation and FTBR is being investigated as a potential option for 5G applications.

II LITERATURE SURVEY

In current scenario, there has been an increasing interest in circular patch antennas with a ring-shaped slot in the patch. The ring-shaped slot creates a resonant structure that can improve the antenna's bandwidth and radiation efficiency. The slot also reduces the antenna's cross-polarization levels, making it ideal for circularly polarized signals. The combination of a CPW feed and a CPA with a ring like structure slot can result in a compact and efficient antenna system which is applied in a huge range of working principle, having SC and WLAN. These systems offer several advantages over traditional antenna systems, including better radiation patterns, increased bandwidth, and reduced cross-polarization levels.

Analysis of its CPW-fed CPA with DGS for 5G uses by S. Mandal et al. (2020): Current paper defines the formation and analyzed of a CPW-fed CPA with a DGS for 5G applications. The antenna operates at 3.5 GHz and provides a bandwidth. DGS gets introduced to increase the performance by reducing its mutual coupling in ground along with patch fed in antenna.[8-10]

I. ANTENNA DESIGN AND GEOMETRICAL DETAILS

The intended CPW fed circular patch antenna with ring shaped slot is printed by using Perfect Electric Conductor (PEC) substrate of height 0.035mm. The substrate dimensions are 45mm × 45mm × 0.035mm.

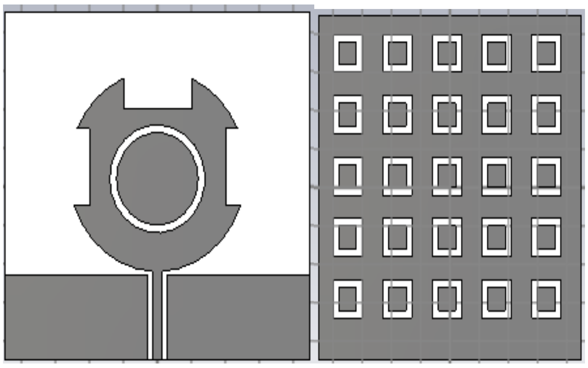
The formula for calculating radius given 26mm is defined as:

$$a = \frac{F}{\left[1 + \frac{2h}{\pi \varepsilon_r F}\left[l_n\left[\frac{\pi F}{2h}\right] + 1.7726\right]\right]^{1/2}}$$

Its inserting technique implied is CPW feeding (Coplanar Waveguide feeding), due to its low loss wide bandwidth and easy integration. The main feed line is 4mm wide and with defected ground structure of 30mm x 40mm dimensions with circular patch in between with radius of 26mm. Also slots are made on side and upper side to give it a circular shape . The current modelling parameters for the Revised antenna is deliberated given expression and measurements for the current work specifications are shown below in the given below.

TABLE 1 Dimensions for the intended design

Name	Value
x	90
y	90
t	0.035
h	1.6
r1	26
r2	0
xc	0
yc	4
xf	3
yl	-15
k	5
l	13
c	4
rad 1	14
rad 2	12



(a) (b)

Fig. 2. (a) front view of designed antenna &

(b) back view with DGS.

II. RESULT AND DISCUSSION

The intended assignment of CPW-fed circular MPA is constructed and formed by CST Studio Suite simulation software. The simulated graphical results like RL, VSWR, gain, directivity, RE, TE and radiation pattern for the assigned project is shown below.

A. Return Loss (RL)

RL defined as measurement of the amount of energy reflected back from a transmission line or system compared to the amount of energy initially sent into the system. The specified term refers to the measurement of the reflected wave's power compared to the incident wave's power, expressed in decibels (dB), which is known as the reflection coefficient (RC). The graphical plot of RC with respect to frequency is given. The graph generated from the experiment indicates that the proposed antenna exhibits resonance at three distinct frequencies, specifically 3.13 GHz, 3.5 GHz, and 3.81 GHz, accompanied by corresponding return loss values of -10.078 dB, -20.316 dB, and -10.069 dB. Furthermore, the antenna's resonant frequency bandwidth spans from 1 GHz to 5 GHz.

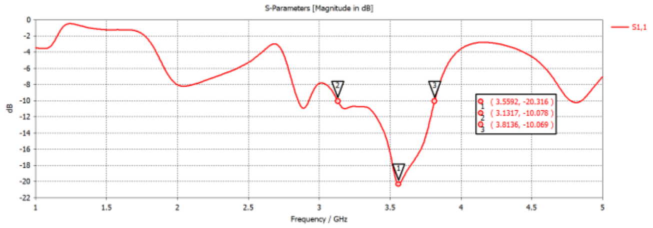


Fig 3. S11 scattered plot graph.

B. Voltage Standing Wave Ratio (VSWR)

VSWR can be implied the ratio of the highest voltage to the lowest voltage with a transmission line, which presents when a wave is reflected due to an impedance mismatch. The range of VSWR must lie between the values 1 to 2, for an efficient performance. The VSWR at resonant frequency of 3.5GHz is 0.5. The VSWR plot is provided after simulation is as follows:

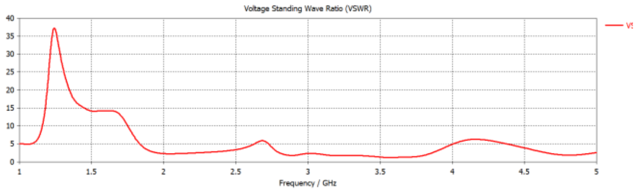


Fig. 4. VSWR plot

C. Gain and Directivity

Gain and directivity are both concepts related to the performance of antennas. Gain refers to the measure of an antenna's ability to amplify an incoming signal in a specific direction compared to a reference antenna. It is usually expressed dB and also calculated by the ratio of the radiating power by an antenna in a particular direction to the power that would be radiated by a hypothetical isotropic radiator (a theoretical antenna that radiates equally in all directions) with the same input power. Directivity, on the other hand, is a measure of how directional an antenna is in transmitting or receiving signals. It is the ability of an antenna to focus its energy in a particular direction while rejecting signals from other directions. Directivity can be expressed in dB and is known as the ratio of the intensity radiated in the direction of maximum radiation to the average intensity radiated in all particular directions. The intended design obtains the maximum gain of 6.05 and the maximum directivity 7dB at 3.5GHz frequency respectively. Since the obtained gain is positive we can say the intended antenna is working and can be used .

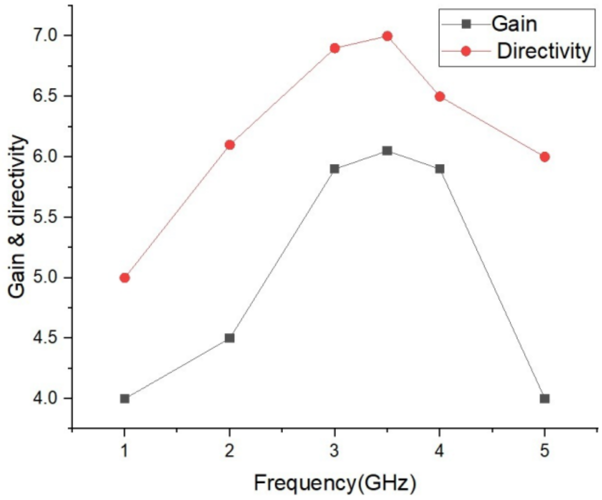


Fig. 5. Intended antenna gain and directivity plot representation.

D. Radiation and Total Efficiency (RE, TE)

Radiation refers to the process of energy transfer through the emission of electromagnetic waves or particles, such as photons or alpha particles. This process occurs naturally in many phenomena, such as sunlight, radioactive decay, and X-ray. TE refers rate of useful output to the overall energy input of a system. In other words, it measures how much of the input energy is actually converted into a useful output. Total efficiency takes into account all losses due to factors such as friction, heat transfer, and radiation. From the obtained graph simulation, we can conclude that for 3.5 GHz RE is 68% respectively.

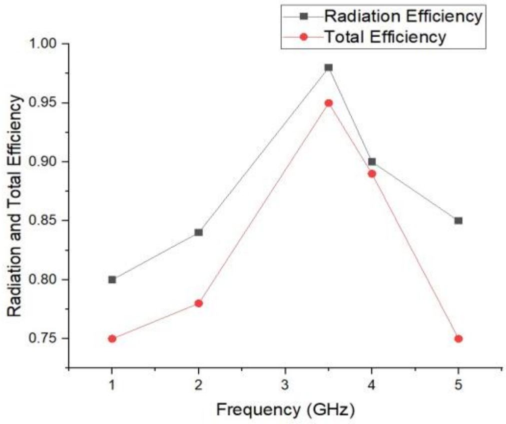


Fig 6 Radiation and Total Efficiency Plot

E. *Radiation Pattern (RP)*

RP displays the electromagnetic field's relative intensity and orientation, emitted by the antenna, in various directions. This is shown as a function of either the angle or distance from the antenna. The anticipated far-field radiation pattern for the resonant frequencies, with phi equal to 90 degrees, is illustrated in the figure below. The radiation patterns exhibit stability and are omnidirectional.

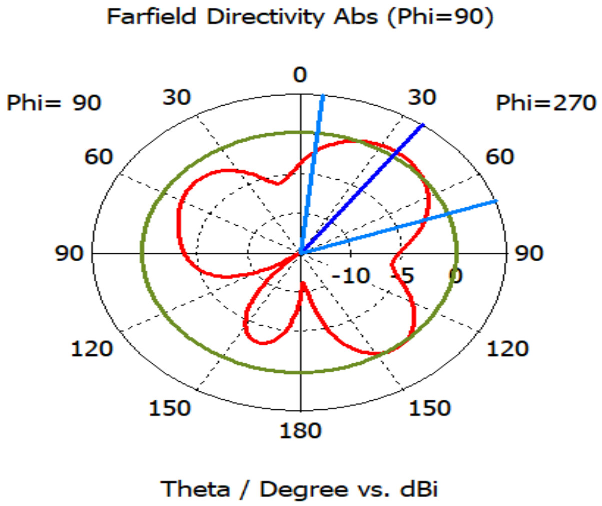


Fig. 7.RP of given expected antenna

III. CONCLUSION

A design of CPW-fed circular MPA is formed for the Sub-6GHz 5G for different uses. The planned antenna shows small1 dimensions, huge frequency coverage, and consistent radiation properties throughout the SUB frequency spectrum.

The replicated output defines that the intended antenna has a Broad bandwidth across 3.2GHz – 3.8 GHz, which covers the whole SUB frequency range. The antenna has a maximal gain of 6.05dBi, max. directivity of 7.0dB and 95% radiation efficiency at 3.5GHz frequency. The antenna also has a better radiation pattern as compared form others, with a nearly omnidirectional radiation pattern. Thus, the intended antenna can be used for future solicitation of Sub 6Ghz 5G like enhanced mobile broadband internet of things, and industrial automation respectively.

VI. ACKNOWLEDGEMENT

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