# A Novel Design of Compact 28 GHz Printed Wideband Antenna for 5G Applications

**Prachi, Vishal Gupta, Sandip Vijay**

***Abstract:** – In this antenna study, a compact thin profile wide band patch antenna is introduced for fifth generation. The overall dimensions of this compact antenna is 5 mm x 5.26 mm only, operating in the 28 GHz frequency in Ka-band. Built on the Rogers Rt/Duroid 5880 substrate having thickness of 0.254 mm, the antenna provides 2.1 GHz (27.3-29.2 GHz) of bandwidth at below -10dB reflection coefficient. The novel proposed design is fed by the coaxial feed having inner radii of 0.254 mm. The motive of this study is to improve the bandwidth by utilizing the DGS (Defective Ground Structure) technique and further to procure the high impedance matching, slotting technique is applied on the partial ground plane in which an X shaped slot is engraved resulting a reflection coefficient of -20.03 dB. The proposed antenna provides desirable values of Gain and Directivity of about 5.2 dB and 6.16 dBi respectively. Discrete parameters of designed antenna such as voltage standing wave ratio, radiation patterns, surface current distribution are also evaluated to study antenna characteristics which implies for 5G applications.*

***Keywords:** Microstrip Patch Antenna (MPA),DGS,Ka-band, Coaxial Feed.*

## I. INTRODUCTION

As the population is increasing the demands are also boosting at an enormous rate. Everyone has their own compulsion for the technology whether it is in terms of speed, power consumption, various access options etc. Therefore, it forced the mobile operators to provide the consumers according to their desire. For the same, the researchers as well as scientists have done numerous experiments and introduces a new mobile technology called fifth generation(5G).

At present, the fourth generation fails to cope up with the requirement of the users. At some areas it is still not providing the speed as the user demands. There are many other cons of the fourth generation which eventually leads to the end of this mobile technology. To satisfy the hunger of the consumers the fifth generation mobile technology is introduced which soon will launch in next year. 5G yields higher speed, high definition video calling, better bandwidth, latency less than 1ms which is not provided by the present technology. For implementing 5G, scientists have chosen the millimeter-wave region in the spectrum[1,2].

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ITU has assigned the range of frequencies in the millimeter spectrum for 5G which varies from 24GHz – 80GHz. Implementing the technology in a millimeter-wave has one major concern that is the travelling waves will get absorbed by the atmosphere. This issue must be rectified and researcher concluded that for this huge gain is needed which can be acquire by the arrays[3,4]. Designing the array is the conventional method to achieve higher gain[5]. Besides the high speed, reduced latency, better bandwidth, another eye catching feature of the fifth generation is the applicability of the Internet of Things(IoT)[6]. The devices will be capable of connecting with the server so that user can control them from anywhere. Microstrip Patch Antennas are prominent in terms of size, installation, weight, cost, efficiency, fabrication[7-9] and have various usage such as in satellite and mobile communication, radar applications and GPS as well. Since the antenna is to be installed in the mobile devices so it has to be small, hence the design parameters must be chosen efficiently[10,11]. In this study, an antenna is designed in such a way which gives a larger bandwidth with enough gain. For 5G bandwidth must be large so that number of applications can be accessed[12,13]. There are plenty of techniques by which antenna bandwidth can be made wider such as parasitic patch, stacked patches, aperture stacked patches, aperture coupling, decreasing relative permittivity etc.[14]. However, in this paper, DGS (Defective Ground Structure) technique [15-17] is preferred and applied on the ground plane to obtain the larger bandwidth and to miniaturize the antenna size. The antenna structure fed by the coaxial feed instead of microstrip feed resonating at 28GHz band allotted by the ITU as the standards for fifth generation[18] is investigated thoroughly in next coming sections.

## II. ANTENNA GEOMETRY DESIGNING

The compact element is prepared for 5G by using Rogers RT/Duroid 5880 as a dielectric material for substrate having height of 0.254 mm operating at 28 GHz that is millimeter-wave frequency in Ka-band. The whole dimension of the proposed compact microstrip patch antenna is 5 x 5.26 x 0.254 $mm^3$. Coaxial feeding is used to fed this novel antenna so that desired results can be acquired. In order to satisfy the objective of this study, dual techniques such as Slotting and DGS are applied such that proposed optimized antenna cater wide band at 28GHz maintaining its compact size. Moreover, on the partial ground plane, engraving of X shaped Slot is done to accomplish better impedance matching as the orthogonal modes are amalgamate to create wide band which is the requirement of 5Ged patch antenna with dimensions 5x5.26 $mm^2$ is proposed and designed using Rogers RT/ Duroid 5880 with a height of 0.254 having $\varepsilon_r$ = 2.2 and loss tangent =0.0009.

The antenna resonates at 28 GHz of Millimeter wave high frequency electromagnetic spectrum. For the coaxial feed, the values of Inner (r1) and outer radius (r2) are optimized in such a way to have the characteristic impedance matching equal to 50 Ω. The physical parameters of this element are shown in table 1.

The antenna parameters are calculated by using the (1-5) equations and are optimized.

*a) Length of the Patch:*

$$L = L_{eff} - 2\Delta L \quad (1)$$

*b) Extended Length:*

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.33)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (2)$$

*c) Width of the patch can be found using:*

$$W = \frac{c}{2fr\sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (3)$$

d) *Effective Dielectric Constant:*

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (4)$$

*e) Effective Length of the patch:*

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (5)$$

Table 1 shows the above calculated parameter for proposed compact wide band patch antenna.

The representation of compact antenna is shown in figures 1 a), b) and c) showing top, bottom and side view of the antenna built in the electromagnetic simulation software (CST) using calculated parameters.

**Table 1. Parameters of Main Element**

| ***Parameters*** | ***Description*** | ***Values(mm)*** |
|---|---|---|
| | ***SUBSTRATE*** | |
| $L_s$ | *Length* | *5* |
| $W_s$ | *Width* | *5.26* |
| $t_s$ | *Thickness* | *0.254* |
| | ***PATCH*** | |
| $L_p$ | *Length* | *3.1* |
| $W_p$ | *Width* | *3.8* |
| | ***COAXIAL FEED LINE*** | |
| *R1* | *Inner Radius* | *0.254* |
| *R2* | *Outer Radius* | *0.8128* |
| | ***SLOT*** | |
| *sy* | *Length* | *1.5* |
| *su* | *Width* | *0.35* |

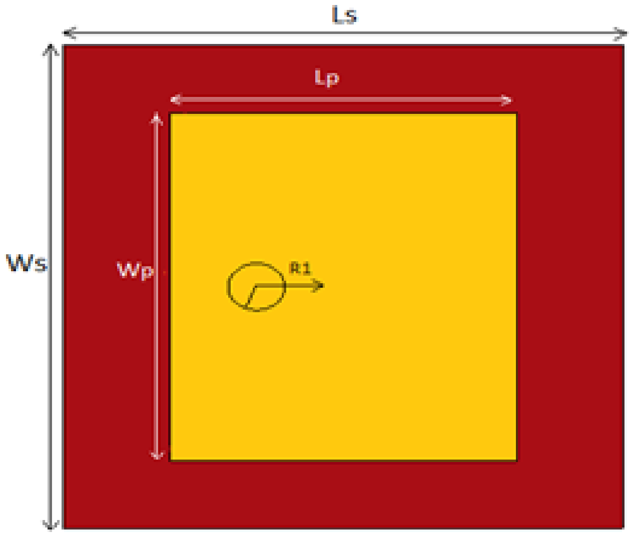


**Fig.1 a) Proposed Compact Antenna (Top View)**

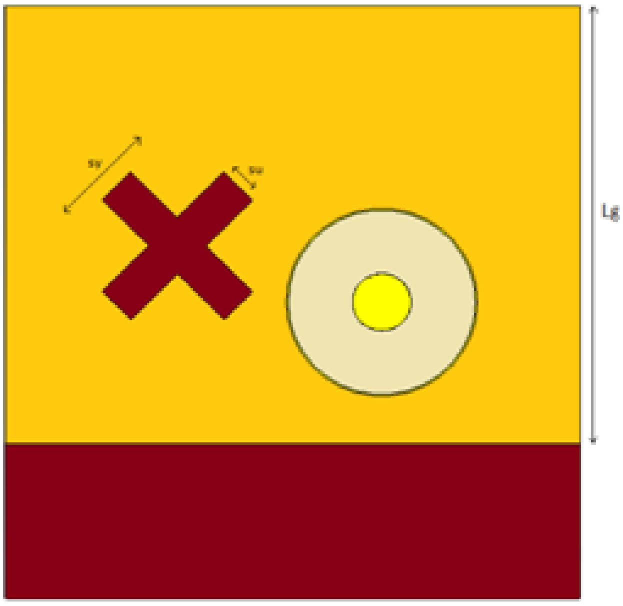


**Fig.1 b) Proposed Compact Antenna (Bottom View)**

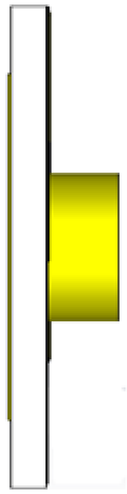

**Fig.1 c) Proposed Compact Antenna (Side View)**

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## III. ANTENNA RESULTS AND DISCUSSION

### A. S-Parameter

The reflection coefficient or S1,1 parameter gives the input output power relationship of ports in an antenna. When S11 = 0, it means antenna is not radiating at all and for antenna to be resonating the s-parameter must be -10dB or less. In this proposed antenna, to achieve high the impedance matching, on partial ground plane X-shape slot is etched and further its width has been increased to attain -20.03 dB reflection coefficient at 28GHz.

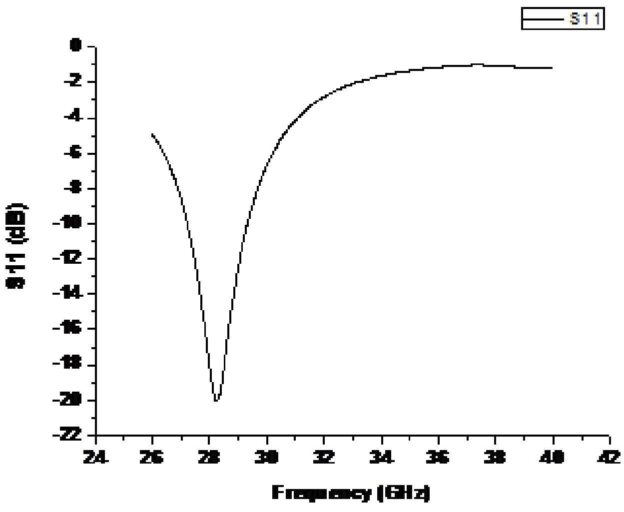


**Fig.2 Return Loss is -20.03 dB at 28 GHz**

### B. *VSWR*

In a RF system, impedance matching at load to the transmission line is given by VSWR. The designed antenna provides the VSWR as 1.22 at 28GHz. The graph of voltage standing wave is shown in fig.3.

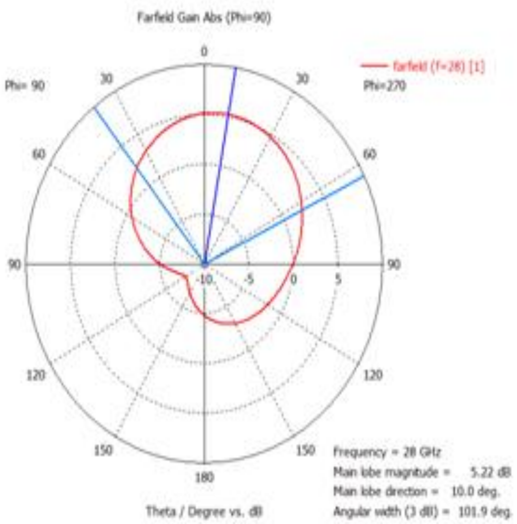


**Fig.3 VSWR is 1.22 at 28 GHz**

### C. Bandwidth

The main motive behind designing this compact antenna is to produce a large bandwidth which is a must for fifth generation. The next challenge is to keep it small hence the dimensions aren't tampered therefore, partial ground plane is used so that the antenna yields larger bandwidth of about 2.11GHz.

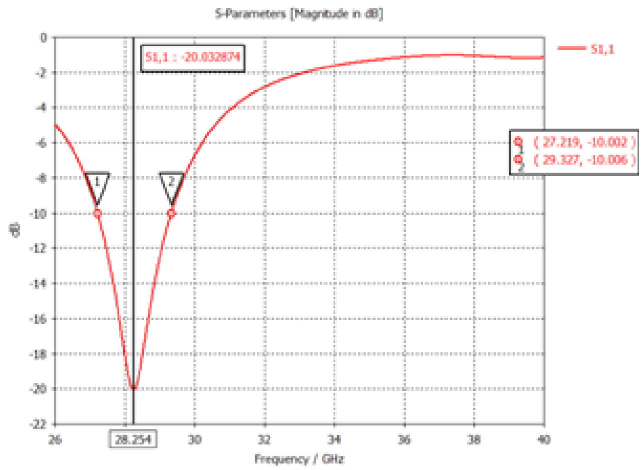


**Fig.4 Bandwidth is 2.11GHz**

### D. Radiation Pattern

After simulation, the radiation pattern obtained for the proposed wideband antenna shown in fig.5 represents the radiation pattern at 28GHz showing a 3 dB beam width of 101.9 degree.

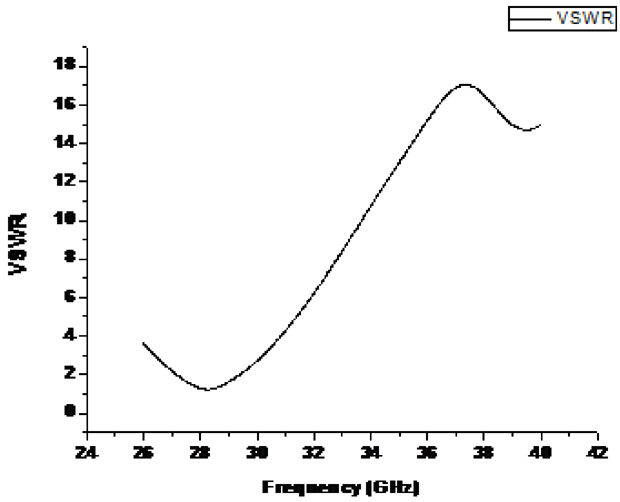


**Fig.5 Radiation Pattern at 28GHz**

### E. Gain

The gain of the antenna tells us the amount of power provided by the antenna in the specified direction. The simulated results shows the gain of 5.23 dB which is acceptable for 5G. Fig.6depicts the 3D-plot of the compact wide band antenna.

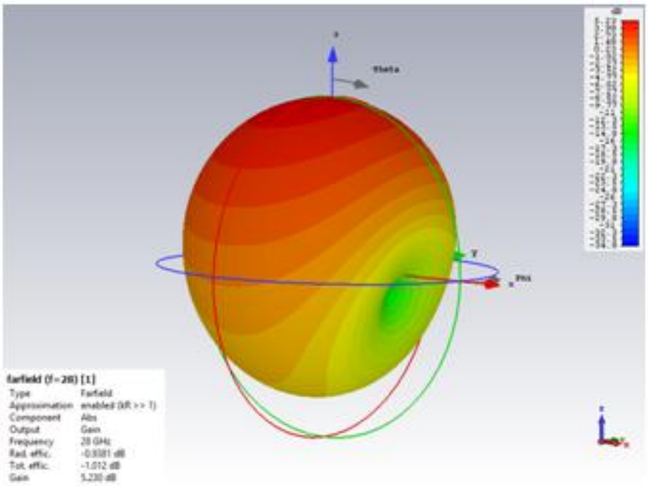

**Fig.6 3D Gain is 5.23 dB at 28 GHz**

### F. Surface Current Distribution

To further explore the antenna performance for 5G, the surface current distribution for the proposed compact antenna is analyzed showing the current is distributed mainly on the patch as represented in fig.7.

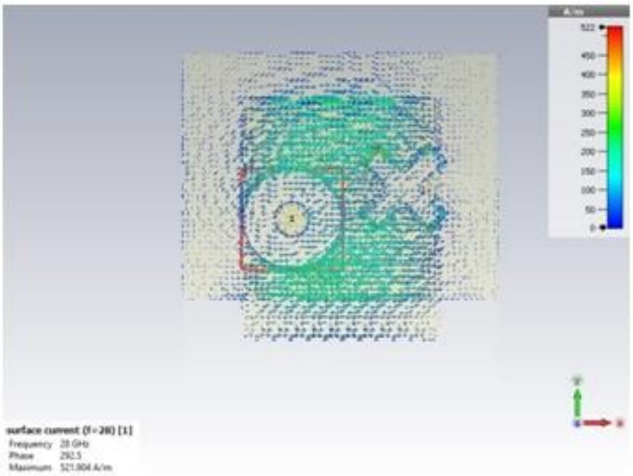

**Fig.7 Surface Current Distribution at 28 GHz**

A comparative study with previous related works have been mentioned in the table 2. It has been observed that proposed novel antenna provides better outcomes in terms of bandwidth and size being a single element in comparison to other literatures.

**Table 2. Comparison With Previous Literatures**

| Reference Work | Resonating Frequency (GHz) | Dimensions ($mm^3$) | Bandwidth (GHz) |
|---|---|---|---|
| **[19]** | 28 | 5x5.26x0.254 | 1.7 |
| **[20]** | 28 | 5x11x0.254 | 0.82 |
| **Proposed Design** | **28** | **5x5.26x0.254** | **2.1** |

## IV. CONCLUSION

For 5G, a compact novel wide band coaxial fed patch antenna built on Rogers substrate is investigated with overall dimensions of 5 x 5.26 x 0.254 $mm^3$ resonating at 28GHz. The partial ground plane is incorporated using DGS technique in order to obtain wide bandwidth with reduced size. Further, the slotting has been done on partial ground plane in which an X shaped slot is made to achieve high impedance bandwidth of 2.1 GHz ranging from 27.3 GHz – 29.2 GHz. The proposed compact wide band antenna offers a good candidature for fifth generation mobile technology operating in millimeter-wave frequency. In order to enhance gain of the antenna, various techniques such as parasitic patch, array and similar concepts can be used in the future.

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**Ms. Prachi,** is currently working as an Assistant professor at Model Institute of Engineering and Technology, Jammu. She is having total experience of 4.8 years in reputed Universities. She is currently pursuing her Ph.D. on 5G Antennas from ICFAI University, Dehradun. She earned her Bachelor of engineering in electronics and communication with first division from Jammu University, Jammu & Kashmir and completed her M.Tech with honors in Wireless and Mobile Communication from Uttarakhand Technical University, Uttarakhand, India. She worked as Junior Research Fellow in DST sponsored project at Mody University, Laxmangarh, Rajasthan. She served as Assistant Professor at ICFAI University, Dehradun for 3 yrs. She has published 8 research papers in reputed International and National journals and 5 conference papers. Her research interest includes 5G antennas, Microstrip Patch Antenna Arrays, Electromagnetic field theory, Plasmonics etc.

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