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Design of 5G Microstrip patch array antenna for gain enhancement

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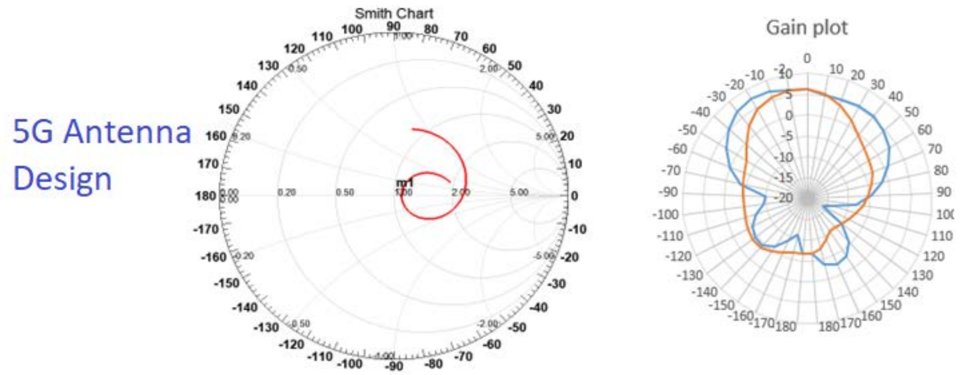
ABSTRACT



A Novel 5G antenna is designed in this research, which resonates at 28GHz. In modern wireless communication, there is a need to develop a 5G antenna with enhanced gain value, and the antenna size should be small and low-profile. The design of the patch of the 5G antenna consists of a rectangular ring of 8mmx5mm. The rectangular ring is of 1mm size from all sides. Various antenna parameters are measured, such as S-parameter [1,1], gain, radiation pattern, and bandwidth. The return loss of the antenna obtained is -24.79dB. The average gain obtained in the proposed 5G antenna is 7.9 dBi, and the radiation pattern of the antenna is Unidirectional, bandwidth range is 27.36-29.29GHz, with centre frequency 28.108GHz, and four-element array antennas are with merits of average gain of 13.385dBi, bandwidth ranges from 27.29-29.14GHz, centre frequency 28.024GHz. A 5G array antenna of the size 1x4 is designed, which greatly increases the antenna's gain. A Defective ground structure (DGS) is implemented on the ground plane to improve the antenna performance. The DGS is implemented on the ground plane by introducing three Concentric circles, and the antenna's bandwidth is improved using the Concentric circles. The array antenna enhances some antenna characteristics. An edge feeding strategy is used to feed the antenna, and the ANSYS HFSS programme simulates the proposed antenna.

Keywords: Return loss, Bandwidth, Impedance, Low-profile, Gain, MPA, Antenna array, DGS

INTRODUCTION

The 5G technology is rapidly growing worldwide. The antenna is easy to manufacture and has low profile characteristics. The various advantages of the patch antennas can be used for 5G applications. Many mobile networks worldwide have implemented 5G network.

The fifth-age (5G) portable correspondence framework has requested fast remote information administration to expand the increasing rate for different applications. The 5G organization works up to three recurrence band-low, medium, and high. Low(600-700MHZ), Mid (2.5-3.7GHZ), High(25-39GHZ). 5G speed will go from 50Mbits/s to over a gigabits/s. The quickest 5G is known as mm-Wave. Due to radio wave proliferation and available transmission speed, bands between 3 and 5 GHz have been developed for 5G services in several countries. There are various 5G remote organization which has helped the interest for 5G base station. Due to its low profile and lightweight, microstrip receiving equipment is a respectable competitor for the radio wire layout of 5G base stations. It also has the benefit of being simple to build and inexpensive.

S.F. Jilani et a.[1] used a 5G Millimeter wave antenna for the multiple-input multiple-output application. The DGS used in this antenna is split-ring slots. The array of four-element MIMO antenna is also designed. The antenna is operating at 36GHz. J.W. Lian et.al.[2] designed a 4x4 Butler matrix. The basic components are stacked in the vertical direction so that the dimension of the antenna can be reduced. The total area of the antenna is 3.8λx0.5λ. The antenna can be used for a 5G application. E. Sandi et.al.[3] has proposed MPA having multiple U slots to improve the bandwidth and the gain. The antenna is operating at 28GHz. The application of the antenna is a 5G millimetre-wave application. B. Bahreimi et.al.[4] reported a Circularly polarized high gain antenna with a

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dielectric resonator for the 5G network. Parasitic elements are used to increase the gain of the antenna. Significant spacing between the elements is chosen. The feeding is done through the X-shaped slot. L. Chen et.al.[5] proposed an array antenna for 5G mobile terminals. The bandwidth of the antenna is increased by using DGS. Ten elements array is designed. The antenna is designed for a 5G wireless network. The feeding of the MPA is done using the Meandering feeding probe.[6] A MIMO antenna for 5G mm-wave application is proposed by Y. Zhang et.al.[7] with Rectangular Dielectric resonators. Two dielectric resonators are used, which are mounted on s substrate. The antenna covers the band from 27.25GHz to 28.59GHz. Y. Li et.al.[8] proposed an eight-element MIMO array antenna. The antenna is operating at the 3.5GHz band.[9] The polarization diversity can be achieved by properly arranging the spacing between the eight elements. An MPA with a stable radiation pattern with a low profile is proposed by W. An. Et al.[10] for 5G applications. The average gain obtained is 5dBi, and to improve the impedance, matching folded walls are used. A unidirectional radiation pattern is achieved. A miniaturized 5G antenna is proposed by J.Seo et.al.[11] The antenna is working in two bands, 28GHz and 39GHz. The antenna incorporates end-fire and broadside arrays. L. Wang et.al.[12] proposed a broadBand antenna for a 5G application. The antenna operates at a low frequency of 6GHz. Dual polarization is achieved in the antenna. In this antenna, two dipoles are used, which are bent, and they are placed orthogonally. A doughnut shape slot is made on the patch of the antenna.[13] The antenna resonates at two frequencies, i.e., 28GHz and 45.54GHz and is compact. DGS changes the capacitance and the inductance. It brings about numerous resounding frequencies to deliver a multiband radio wire[17] or can upgrade the band indenting ability of a receiving wire or a channel.[14,16] A 5G millimetre wave antenna is proposed in this paper. The antenna has stable radiation patterns. It consists of a 4x4 antenna array to increase the antenna's gain.[15] Notice that many detailed DGS radio wires are intended for low-recurrence or single-band MMW activity.[16] A broadBand end-fire antenna is designed. The stepped slots are used in the array antenna. The size of the array is 4x4. The impedance bandwidth of 29.3% is achieved. The antenna is an end-fire antenna useful for 5G applications.[18] The antenna has a stable radiation pattern and operates relatively in a wide band. The bandwidth is enhanced, and the gain is stable. The gain obtained is 5dBi. The radiation pattern is also stable. This antenna is proposed for 5G applications.[19] The research gap in the current work showed that the antenna gain and bandwidth could be further enhanced.[20]

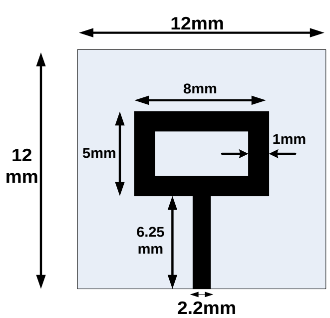

Figure 1. 5G Antenna patch side (Top View)

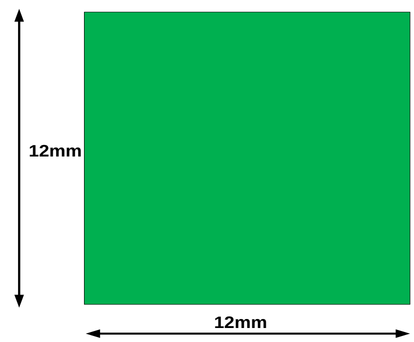

Figure 2. 5G Antenna Ground side (Bottom View)

STRUCTURE OF THE ANTENNA AND RESULT ANALYSIS

ANTENNA STRUCTURE

The Proposed 5G MPA's top view is shown in Figure.1. The ground plane of the 5G antenna is shown in Figure.2. Rogers RT Duroid 5880 substrate is used with a dielectric constant (εr) of 2.2, and the height (h) of the substrate is 0.8 mm. The size of the substrate is 12mm×12mm. The patch is a rectangular ring of size 5mmx8mm. The width of a ring of the patch is 1mm from all sides. The feedline has a length of 6.25mm and a width of 2.2mm.

ANTENNA RESULT ANALYSIS

This section observes and presents antenna parameters, such as return loss[S11], gain, bandwidth, and impedance.

Figure.3. shows the S [1,1] plot of the 5G antenna. The value of the S[1,1] obtained is -24.79dB. This value is below -10dB, meaning the signal's reflection from the antenna to the source is less. The bandwidth of the antenna is obtained from the return loss plot. The bandwidth of the 5G antenna is 1.39GHz. The antenna pattern is unidirectional, as shown in Figure. 4. The antenna's gain is 7.9dBi.

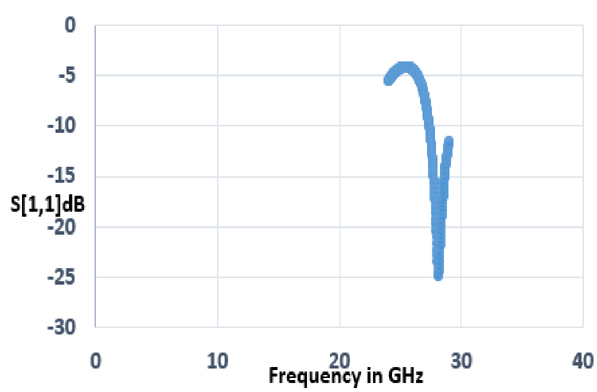

Figure 3. Return loss plot 5G antenna

Antenna impedance is calculated from the smith chart shown in Figure. 5. The impedance value obtained from the smith chart is 1.11 x 50=55.5ohms, which is used for impedance measurement of the antenna.

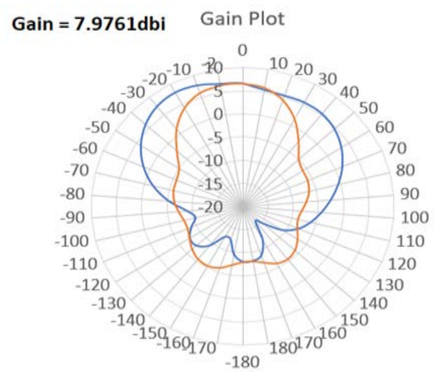

Figure 4. Gain plot of the 5G antenna

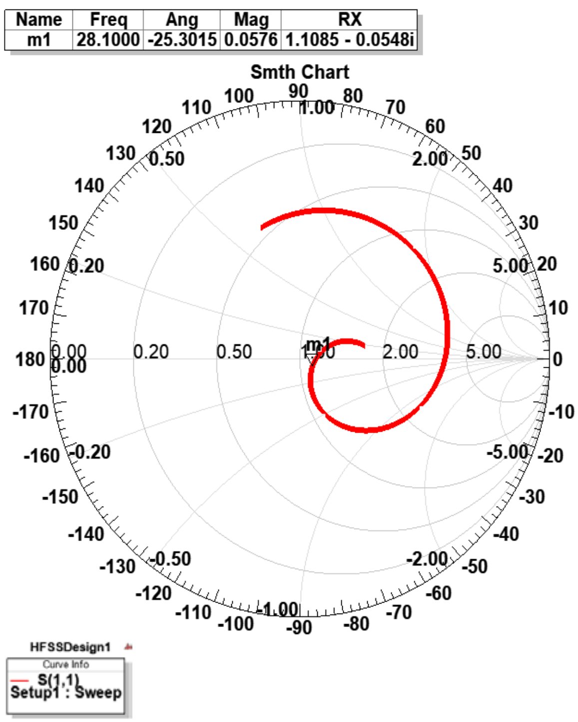

Figure 5. Smith chart of 5G antenna

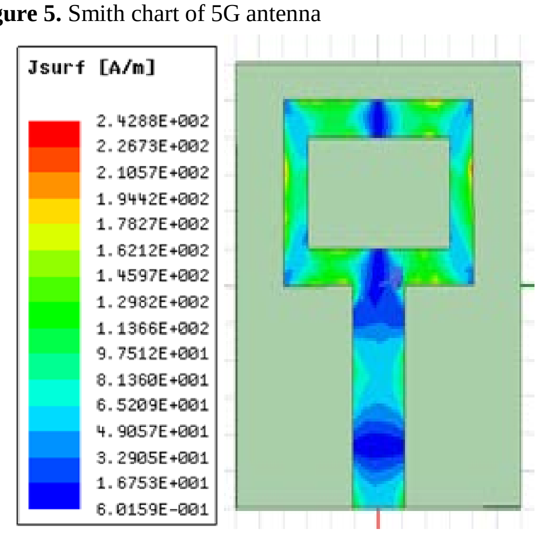

Figure 6. The surface current density of the antenna

The surface current density of the antenna is shown in Figure.6. The current is maximum on the rectangular ring, which means that the ring is responsible for resonating the antenna at 28.10 GHz.

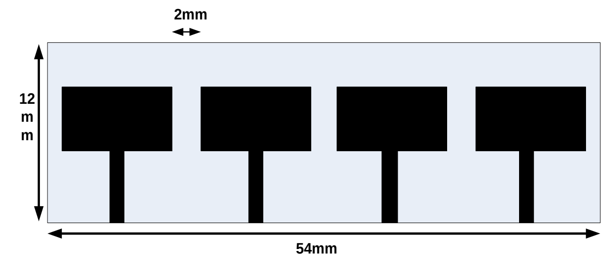

Figure 7. 1x4 Element Array Antenna Design (Top View)

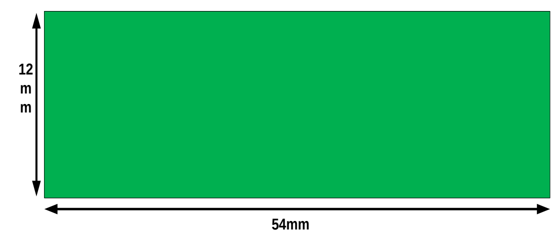

Figure 8. Array Antenna Design (Bottom View)

Figure. 7 shows The Patch side of the 1x4 array antenna, and Figure. 8 shows the ground side of the array antenna, with the array size being 12x54mm2.

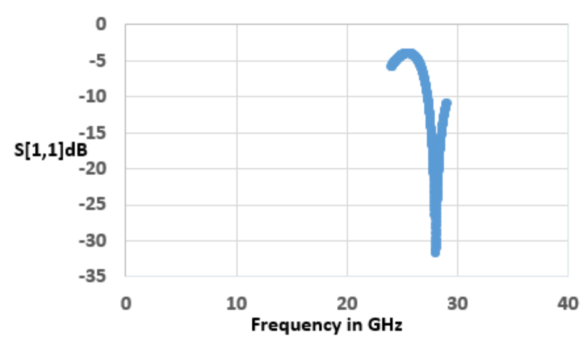

Figure 9. Return loss plot for 5G array antenna

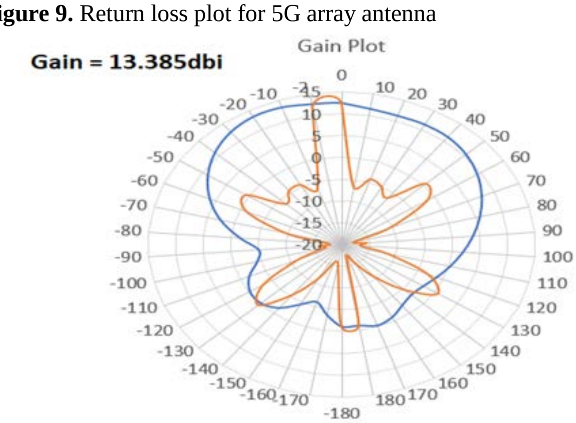

Figure 10. Gain plot of the 5G array antenna

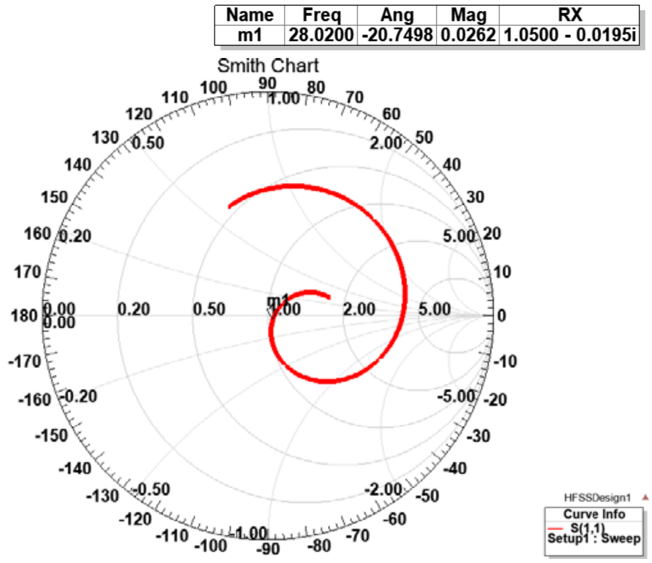

Figure 11. Smith chart of the 5G array antenna

The reflections from the antenna to the source are given by return loss shown in Figure.9. The S[1,1] value is -31.47dB at 28.02GHz resonating frequency. The bandwidth obtained is 1.85GHz. As shown in Figure. 10, the antenna's gain is 13.385dBi with a unidirectional radiation pattern. The antenna impedance obtained from the smith chart shown in Figure.11 is 52.5ohms. It can be seen that better impedance matching is achieved.

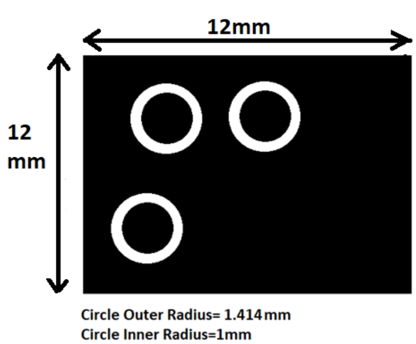

Figure 12. Defected Ground Structure of the 5G antenna

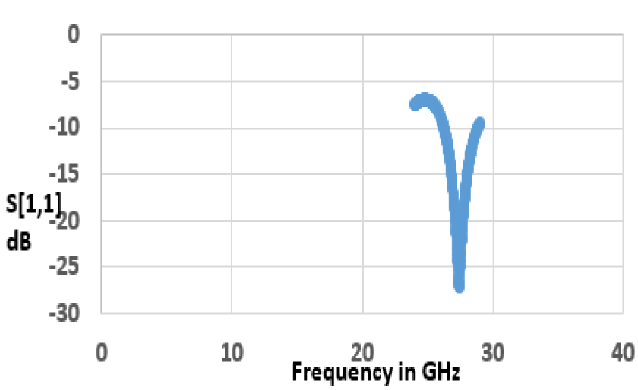

Figure 13. Return loss plot of 5G antenna with DGS

Three Concentric circles are etched on the ground plane, as shown in Figure.12. As shown in Figure. 13, the antenna resonates at a frequency of 27.40 GHz. The S[1,1] obtained with DGS is -27.0547dB. The bandwidth obtained is 2.58GHz. The gain obtained is 7.49dBi. By using three Concentric circles, the antenna's bandwidth is increased considerably.

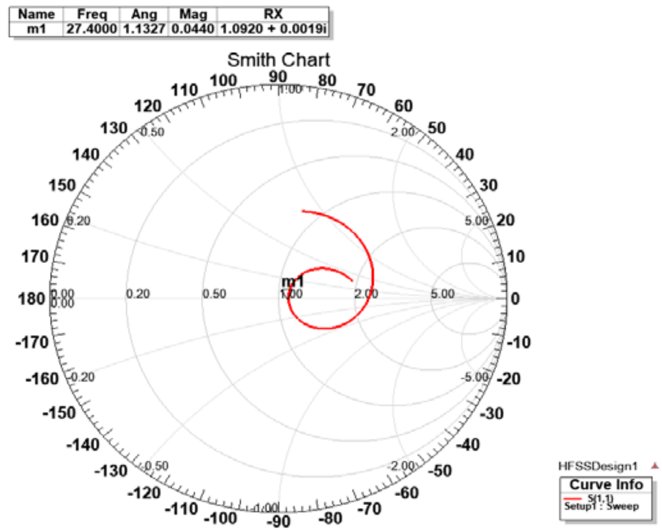

Figure 14. Smith chart of 5G antenna with DGS

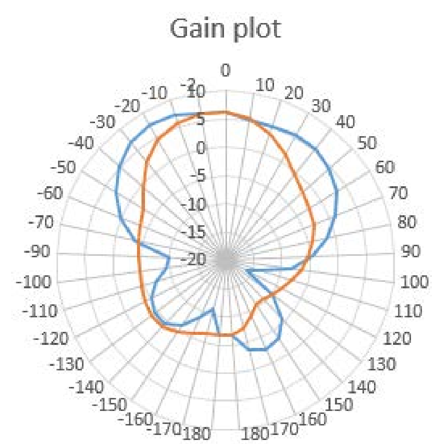

Figure 15. Gain plot of 5G antenna with DGS

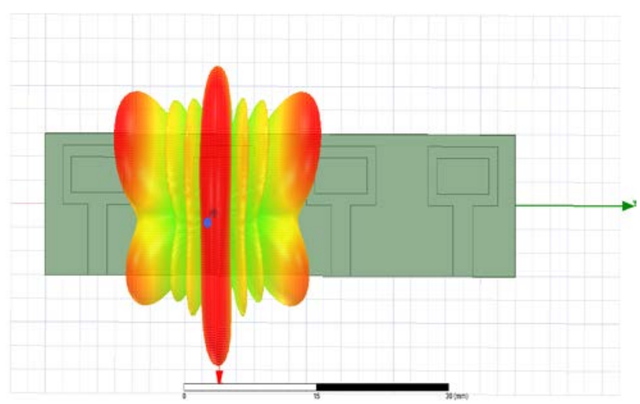

Figure 16. Beam steering of 5G array antenna

Figure.14. and Figure.15 show the Smith chart and the Gain plot of the 5G antenna with DGS. The impedance obtained from the smith chart is 54.5ohms, and the gain obtained from the gain plot is 7.49dBi.

The beam steering for the array antenna is seen in Figure. 16., which changes the phase between the array elements. It can work as a smart antenna by steering the beam in a particular direction. The beam can be steered from 0 to 360 degrees. The work's main contribution is that it is a Novel antenna with a small size and gives an enhanced gain and bandwidth with good return loss values. Parametric analysis is also carried out to get the best possible dimensions of the antenna (Figure 17).

The 5G antenna, four-element array antenna and the 5G antenna with DGS are compared, and the results are shown in Table 1.

Table 1. Result table

PARAMETER	5G ANTENNA	5G Antenna with DGS	Four elements 5G ARRAY ANTENNA
Resonating frequency	28.1080GHz	27.40GHz	28.0240GHz
Bandwidth	1.93GHz	2.58GHz	1.85GHz
Return Loss	-24.7971dB	-27.05 dB	-31.4789dB
Gain	7.97 dBi	7.49dBi	13.38dBi
Impedance	55.50Ω	54.50Ω	52.5Ω

Table I compares the 5G antenna and the 4element 5G array antennas. A considerable amount of bandwidth is obtained in all the antennas. Excellent impedance matching is obtained. A considerable amount of return loss and gain is obtained (Figure 17).

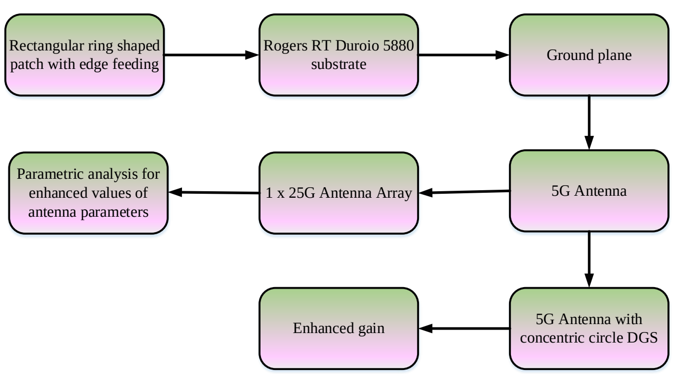

Figure 17. The designing process of 5G antenna.

CONCLUSION

An MPA Rectangular Ring on the patch side with DGS is designed for a 5G application. The size of the antenna designed is also very small. The resonating frequency of a single 5G antenna is 28.1080GHz, and the 4-element array antenna is 28.0240GHz. The gain of the 5G antenna is 7.97dBi, and the gain of the four-element 5G array antenna is 13.385dBi. It can be seen that a considerable amount increases the gain by using a 5G array antenna. The radiation pattern is obtained in a single direction. By creating the 4-element array antenna, the gain is increased. A 5G array antenna now offers a much higher gain. The high bandwidth value is attained. DGS of Concentric Circles is used on the ground plane to increase bandwidth further. With DGS, the bandwidth value obtained is 2.58GHz, and a better value of impedance matching of the antenna is obtained. Significant return loss values below -10dB are obtained for all antennas.

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