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Improvement of Efficiency Parameters of Millimeter Wave RMSA using DGS

Nitesh Kumar Srivastav[a], Pavankumar[b]
[a]*M.tech (Microwave Engineering) student of MUIT, Lucknow, India*
[b] *Asst. Prof.,Dept of EC,Maharishi University of Information Technology, Lucknow, India*
Corresponding Author: Nitesh Kumar Srivastav

Abstract:*In this paper, the design and performance analysis of millimeter wave microstrip patch antenna for 5G mobile communication has been proposed. In this proposed antenna design, the substrate of the material FR4 having dielectric contact 4.4 have been used. The ground, patch and feedline are of copper material. The performance of proposed antenna is analyzed by introducing rectangular DGS of various dimensions. The proposed antenna design has been fed by micro strip feedline. The performance of antenna has been analyzed in terms of return loss (dB), impedance bandwidth (GHz), directivity (dBi), gain (dB), VSWR. The proposed antenna design resonates at 29 GHz frequency with minimum return loss of -20.227 dB, realized gain of -2.553 dB and directivity of 3.025dBi for a DGS at ground plane of 0.61mm X 2.2 mm dimension. The proposed antenna has been designed and simulated using CST Microwave Studio 2017.*

Keywords*: CST Microwave Studio 2017; directivity; dB; dBi; FR 4; gain; GHz; MHz; VSWR; DGS, MIMO; millimeter wave; spectrum, efficiency.*

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I. Introduction

Since from the evolution of mobile communication (1G in 1980 to the current 4G) the mobile industry witnessed an exponential growth in mobile users and in every 10 years, a new wireless generation is available due to the advancement in electronics and wireless communication technologies.Today people are using many devices (smartphones, tablets, laptops etc) that support many services and applications that require simultaneous management of multiple technologies in the same band limited spectrum with customer base ofapprox. 5 billion all over the world, cellular service providers are facing global bandwidth shortage. They are limited to a carrier frequency spectrum ranging between 700 MHz and 2.6 GHz, where each major wireless provider has approximately 200 MHz across all of the different cellular bands of spectrum available to them.Also, the demand for capacity in mobile broadband communication increases dramatically every year and is expected to a thousand fold increase in total traffic by 2020. Therefore, to minimize current traffic congestion and to support the ever growing consumer data rate demand and predicted traffic volumes an efficient radio access technologies combined with more spectrum is essential.[1]-[2].

II. Millimeter Wave For Future Wireless Communication

As per the predictions made by the mobile industry experts, the future cellular networks will need to support billions of devices running applications including voice, video, multimedia etc with required data rates in the range of multiple Gbps. To support such a huge mobile traffic and high data rates cellular networks will need – 1- More useful radio spectrum, 2- Efficient channel access technology.

Using Millimeter wave spectrum and antennas can serve all the above purposes well.

1- Solution for spectrum availability- Mm waves is the radio waves that have the wave length of the order of 10 mm to 1 mm and frequencies in the range of 30 to 300 GHz.

Millimeter wave will open up more spectrums. Over 20 GHz of spectrum is available to be used for cellular or WLAN traffic in the 28, 38 and 72 GHz bands alone and hundreds of GHz more spectrum could be used above 100 GHz. It also provides the opportunity for mobile communications to use channel bandwidths of 1 GHz or more at the above mentioned bands that is far beyond the present 20 MHz channels used by 4G customers. By such a increased bandwidth for mobile radio channels, the data capacity is greatly increased while the latency for digital traffic is greatly decreased thus supporting much better internet based access and applications that require minimal latency.One disadvantage of millimeter waves haslimited range. But this can be overcome by designing antennas with good receiver sensitivity; high transmit power, and high antenna gains.

2- Today's wireless systems use MIMO systems approach. MIMO systems use multiple antennas at both ends and constructively explore multi-path propagation using different transmission paths to the receiver. These paths can be exploited to provide redundancy of transmitted data, thus improving the reliability of transmission (diversity gain) or increasing the number of simultaneously transmitted data streams and increasing the data rate of the system (multiplexing gain). The multiple spatial signatures can also be used for combating interference in the system (interferences reduction).The MIMO channel capacity is limited by the number of antennas, the antenna element spacing.At millimeter wave frequencies, very small antenna elements can be designed. Using mmwave antennas can help in building antenna arrays which contains a large number of antenna elements as compared to the present arrays because the required spacing between two antennas (<= λ/2) is very small in mm wave antennas.Hence millimeter wave antenna arrays combined with spatial multiplexing can dramatically enhance the wireless system capacity and reliability. [1],[2],[7].

Micro strip antennas are one of the most suitable antenna types for millimeter wave applications. The main advantages are low profile, low weight, planar configuration and lower manufacturing cost.Though there are few limitations such as narrow bandwidth and low power capability but the numerous advantages outweigh them.

The patch antenna usually has spurious frequency and to overcome this Defected Ground Structure (DGS) on the ground plane of the transmission is made. The DGS components are the dominant technology which can provide size reduction and has the capability of harmonics and spurious suppression. DGS is realized by etching off a simple shape in the ground plane, depending on the shape and dimensions of the defected the shielded current distribution in the ground plane is disturbed, resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer, the shape of the defect may be changed from the simple shape to the complicated shape for the better performance. The DGS is easy to be an equivalent L-C resonator circuit. DGS can be in different size like rectangular, triangular, and circular dumb shell.[3]-[4].

III. Methodology of Proposed Antenna

A rectangular patch antenna is designed with rectangular DGS introduced at the ground plane. Micro stripfeed line is used to excite the antenna. The calculated feedline width is 0.39 mm and depth is 0.61 mm. The proposed antenna has the dimension of 6.188 mm x 5.378 mm. The radiating patch has dimensions of 4 mm x 2.45 mm. Width of the patch is selected slightly higher above the calculated value of 3.24 mm. The FR4 substrate is used with thickness h = 0.24 mm and permittivity 4.4. Rectangular DGS of various dimensions are etched off in the ground and performance parameters are analyzed. The results are shown in table 2.[3],[4],[5].

Table 1 Antenna Dimensions:

Antenna Dimensions	**Dimension (mm)**
Patch Width, Wp	4
Patch length, Lp	2.45
Substrate thickness, h	0.24
Ground plane width, Wg	6.188
Ground plane length, Lg	5.378
Feed line width, Wf	0.390
Patch & ground plane thickness	0.1

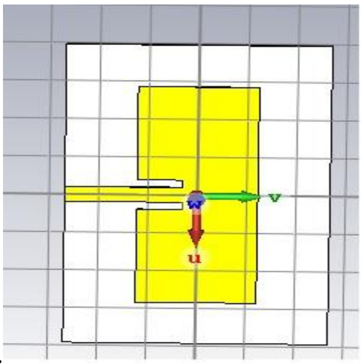

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Figure – 1 Patch antenna (top view)

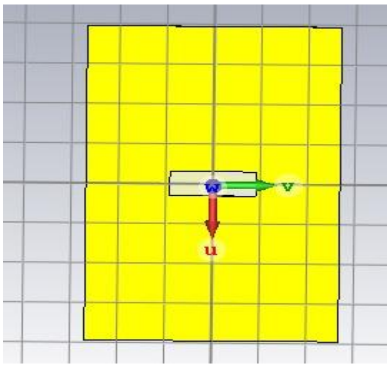
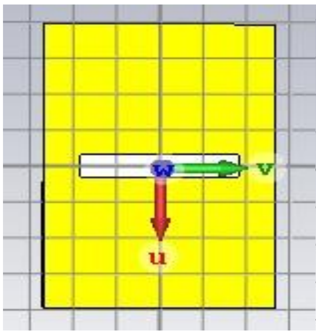


Figure-2 DGS on ground plane



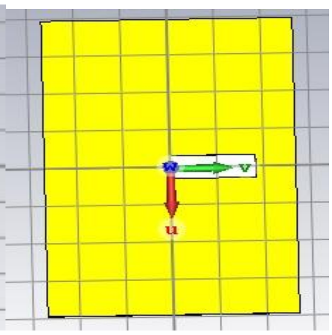


Figure-3 **Figure-4**

IV. Simulated Result and Discussion

The performance of antenna with DGS of various dimensions has been compared and analyzed in terms of eturn loss (dB), directivity (dBi), gain (dB), bandwidth (GHz), VSWR shown in table 3.

Table-2 Antenna Parameters Without DGS	
S – parameter, S11	-20.117 dB
VSWR	1.22
Directivity	2.524 dBi
Realized Gain	-3.449 dB
Total Efficiency	-5.973 dB

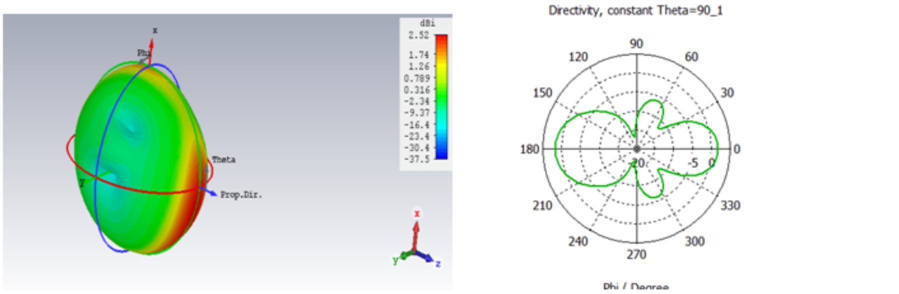


Figure 5 a& b

Table 2 shows the antenna parameters without a DGS in ground plane. Figure 5a & 5b shows the radiation pattern. Table 3 shows the antenna parameters when a DGS is introduced in the ground plane. Here rectangular DGS of different dimensions are etched off. Type A,B and C are the DGS etched off at the center of the ground plane. It is observed that performance parameters improved till certain dimensions of DGS after that reduction in parameters is observed. The location of DGS is also shifted in the ground plane and it is found that rectangular shape DGS in the ground plane just beneath the feed line improves the performance of antenna as shown in the table 3 (type D, E and F).

Table-3 Antenna Parameters with DGS							
Parameters ↓	DGS dimensions →	0.305 mm x 0.305 mm A	0.61 mm x 1.83 mm (center) B	0.61mm x 3.66mm C (center)	0.61mm x 1.83mm (shifted in x-direction) D	0.61mm x 2mm (shifted) E	0.61 mm x 2.2mm (shifted) F
S11, dB		-20.139	-20.194	-20.185	-20.182	-20.201	-20.227
VSWR		1.2183	1.2174	1.216	1.210	1.2158	1.2158
Directivity, dBi		2.546	3.058	2.381	2.842	2.970	3.025
Realized Gain, dB		-3.410	-2.699	-3.350	-2.874	-2.666	-2.553
Total Efficiency, dB		-5.956	-5.757	-5.731	-5.716	-5.636	-5.578

Figure 6a, 6b, 6c, 6d shows the radiation pattern, return loss, VSWR of the final antenna type F.

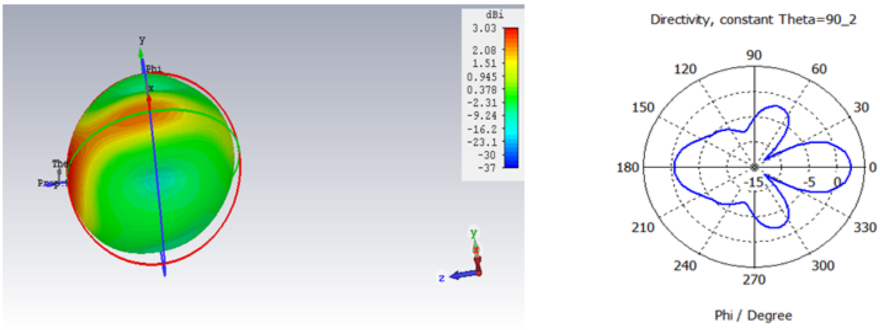


Figure 6a & 6b.

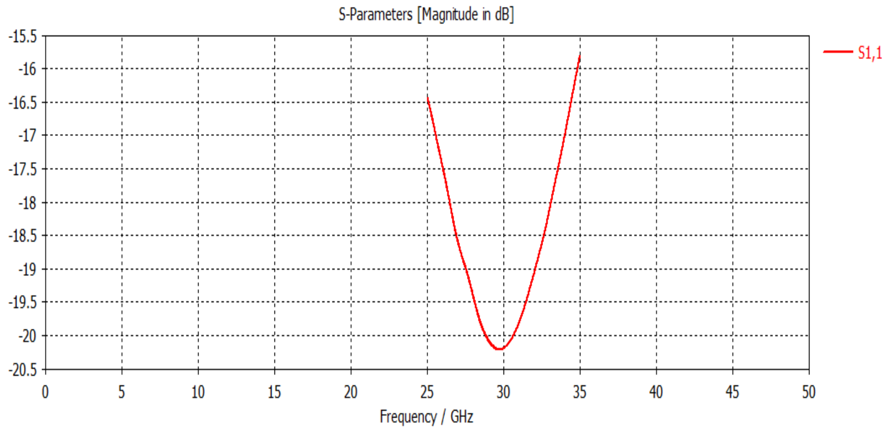


Figure 6c.

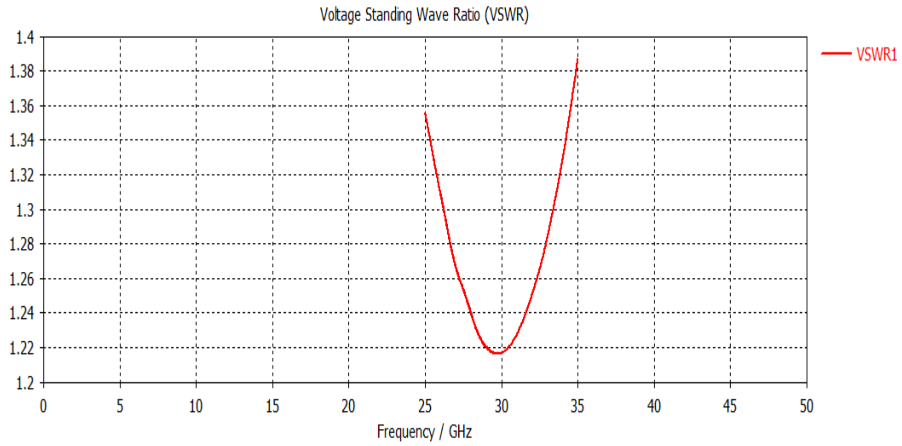


Figure 6d.

V. Conclusion

The proposed antenna design has been designed and simulated using CST MWS 2017. It has been observed that etching off a DGS of suitable size at suitable position in ground plane enhances the directivity, realized gain,efficiency; return loss of a patch antenna. The proposed antenna has directivity of 3.025 dBi, realized gain of -2.553 dB, total efficiency -5.578 dB, return loss of -20.227 dB. The proposed antenna is suitable for 5G mobile communication.

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