Millimeter -Wave Inverted U-Slot Antenna for 5G Applications

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Abstract : This paper acknowledges the design for the 5G application using slotting technique. The proposed design is implemented using Rogers RO4350B as a substrate which has a dimension of 15.8 x 13.1 mm^2 with the thickness of 1.57 mm. The design consists of inverted U-slot on microstrip patch antenna. The designed antenna has been simulated with commercially available software known as Computer Simulation Technology. The antenna provides the gain of 4.92dB with a return loss of -18.50dB. Distinct parameters for instance s-parameter, VSWR, gain and side lobe level are considered in analyzing the proposed design which operates at 28 GHz resonating frequency.

IndexTerms **- Inverted U-slot, Coaxial Feeding, MPA (Microstrip patch antenna), CST.**

I. INTRODUCTION

From 1G cellular network to wireless controlling of machines a lot has improved in 5 decades. The advancement in technology which means a need for high transfer rates of data from source to receiver. Increase in demand of high speed data rates by the consumers needs to bring a new generation network. Latency is the time that data is received by the receiver from the moment the data is sent by the source. Low latency means instant transfer of data. Evolution is must for high connectivity and low latency [1-3]. **The new generation telecom technology called Fifth Generation denoted by 5G.**

In 2009, the 4G network was first launched commercially by the TeliaSonera telecom operator. The network promises the crystal clear voice, reduced latency and seven times faster in downloading/uploading speed compared to the third generation. The LTE network (Long Term Evolution) has good bandwidth which is an advantage for mobile devices but the network has its own limit in terms of connectivity. With the launch of 5G in 2020, there will be real-time controlling of machines takes place. The higher frequencies in the spectrum that is 28, 38 and 73GHz will be occupied by the telecom operators in near future for next generation, hence the fifth generation will use the upper range of spectrum that is millimeter wave with speed in gigabits per second and latency less than 1ms [4-7]. The fifth generation will not only allow us to load 4K videos without buffering but also the concept of the Internet of Things(IoT) will be possible [8,9]. After the launchof 5G, implementation of IoT will take place, whole society will be set up by fast speed by which intelligent systems will build with the help of sensors. For improving the class of living there must be uninterrupted connectivity in order to send the controls signals/commands to the machines which are very far away from the owners. Hence the 5G network is expected to provide the smooth connectivity and more secure connection.

A Sweden based telecommunication and networking company had achieved the downlink speed of 3.6Gbps using advanced beamforming technology. However, at the Qualcomm, it presented the real-world speed. The company has given the download speed result up to 186Mbps on 5G. The quality of high-resolution videos will also be improved.

Size, weight, cost and easy installation have always been constraints in antenna designing. Hence microstrip antennas are preferred because of their low cost, high performance, and when selected with appropriate patch and mode then it will be very functional in respect of resonant frequency, radiation pattern etc. The design consists of an inverted U slot instead of simple U slot and parasitic patches[10-13]. The thickness of the substrate is 1.57mm and the dielectric constant $\varepsilon r = 3.66$. For feeding, coaxial line feed is used here because it is easy to fabricate and impedance matching. After simulation, it is seen that the resonating frequency decreases on increasing the slot length and it is directly proportional to the slot width as well as feed length. Furthermore, the size of the antenna is compact and it provides good gain as well as radiation pattern.

II. ANTENNA DESIGN AND PARAMETERS

The very first step in antenna designing is the substrate selection. Various substrates can be used in designing a microstrip patch antenna whose permittivity lies between $2.2 \leq \varepsilon r \leq 12$. For good antenna performance, thick substrates are preferred since they provide better efficiency and high bandwidth. In this proposed design, Rogers RO4350 material having $\varepsilon r = 3.66$ is selected for the substrate. Coaxial feed method is used to feed the patch antenna. The inner radius is of 0.009mm whereas outer radii is of 0.03mm at an offset = 1.27mm.
Several parameters are considered in this design such as resonating frequency (f = 28GHz), dielectric constant εr of substrate that will help us to obtain the dimensions of patch as

$$W = \frac{c}{2fr\sqrt{\frac{\varepsilon_r+1}{2}}}$$

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

$$L = L_{eff} - 2\Delta L$$

TABLE 1

MPA DIMENSIONS

PARAMETERS	DIMENSIONS(mm)
Substrate Width (W_S)	15.8
Substrate Length (L_s)	13.1
Width of Patch(W_p)	3.35
Length of Patch(L_p)	2.45

TABLE 2

INVERTED U-SLOT

PARAMETERS	DIMENSIONS(mm)
Slot Length (Sy1)	1.82
Slot Width (Sx1)	1.42
Slot Thickness (S1)	0.26
Offset(d)	1.27

The parameters are calculated to achieve desired resonating frequency of 28GHz. In Fig.1 the construction of proposed patch antenna is discussed.

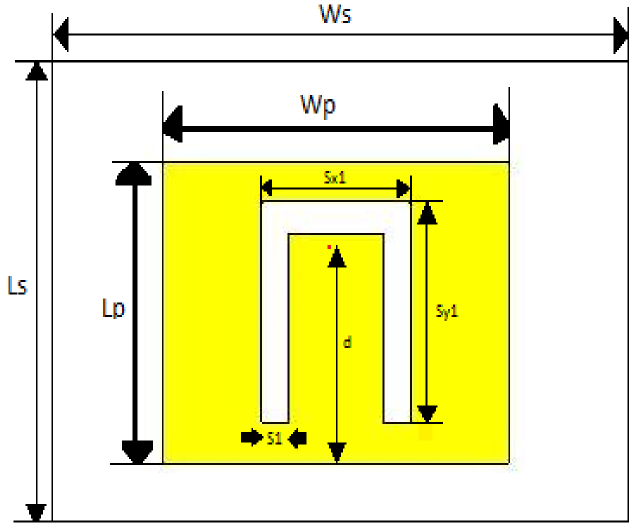

Fig.1

$$\varepsilon_{REFF} = \frac{\varepsilon_R + 1}{2} + \frac{\varepsilon_R - 1}{2}\left[1 + 12\frac{H}{W}\right]^{-\frac{1}{2}}$$

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

Where W and L are the width and length of patch whereas ε_{reff} is the effective dielectric constant and ΔL is the incremental length of the patch respectively.

Table 1 shows the dimensions for both substrate and patch whereas the Table 2 shows the dimension for the inverted U-slot etched from the patch.

III. ANTENNA DESIGN ANALYSIS

Commercially available software is used for simulation purpose of antenna. For determining the key factors in antenna design such as return loss, radiation pattern, gain, VSWR Computer Simulation Technology (CST) Microwave Studio 2018 is preferred.

For proposed design, the analysis is discussed below:

a) Return Loss

The return loss shows us how good the matching takes place between the transmitter and receiver. In this proposed design the return loss is found to be -18.50dB at 28GHz resonating frequency. The results are shown in figure 2(a).

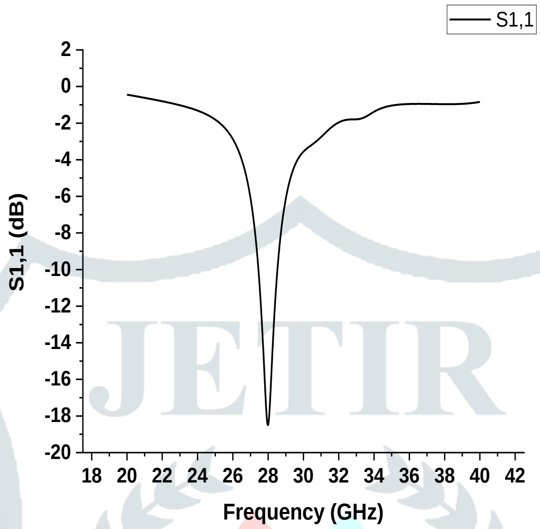

Fig. 2(a) S-parameter

b) VSWR

The graph of the standing wave ratio for this antenna design is shown in in figure 2(b). From the graph, the value of the VSWR for 28GHz is 1.26, which is an acceptable value and tells us about the impedance coupling of the antenna.

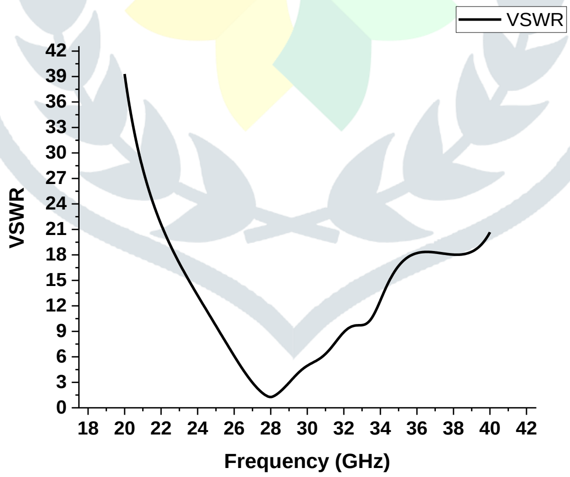

Fig. 2(b) VSWR of the antenna

c) Radiation and Gain

According to simulation result, the proposed antenna gives the total gain of 4.91dB. Both 3D and 2D views are depicted in the figure 2(c) and (d).

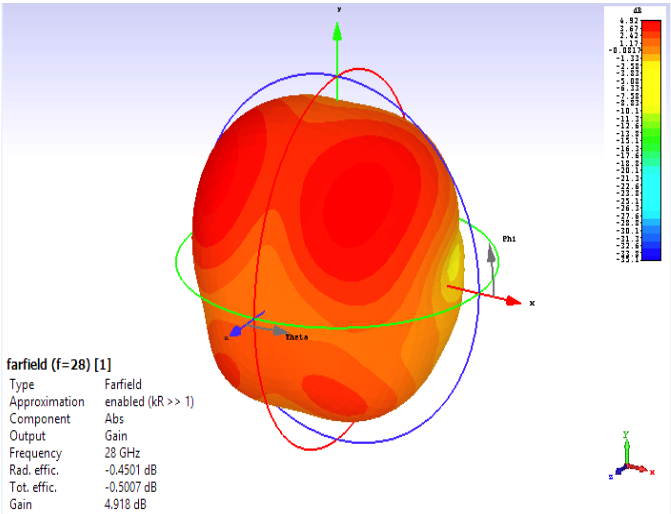

Fig. 2(c) 3D plot of radiation pattern, giving radiation efficiency as = -0.4501dB whereas total efficiency = -0.5007 dB

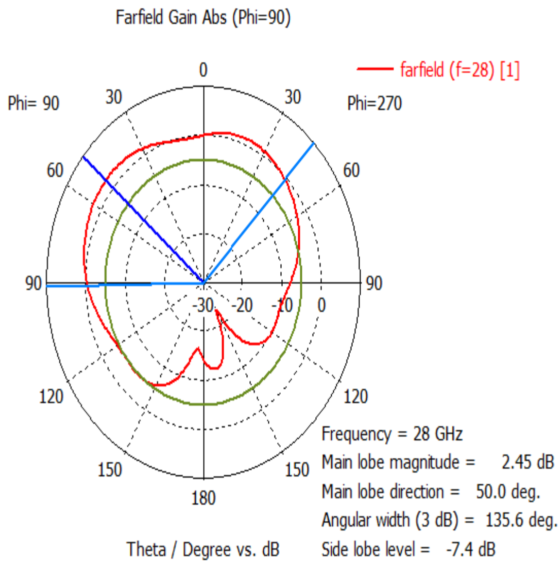

Fig. 2(d) 2D plot for 28Ghz frequency, shows the Main lobe magnitude = 2.45 dB, main lobe direction = 50.0 deg, angular width (3 dB) = 135.6 deg and side lobe level = -7.4 dB

IV. CONCLUSION

This paper reveals a single MPA(microstrip patch antenna) for 5G applications, with the coaxial feeding line on the substrate of Rogers RO4350 having the dimensions 15.8 x 13.1 x 1.57 mm^2. The design consists of a microstrip patch of 3.35 x 2.45 mm^2 from which an inverted U-slot has been etched. The obtained values for parameters such as gain, VSWR, and side lobe level are 4.92dB, 1.2, -7.4dB respectively. All the simulated parameters are in the acceptable range for the resonating frequency of 28 GHz. Furthermore, we can improve the gain by optimisation techniques

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