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Designing of 24.6 GHz U-Shaped Microstrip Patch Antenna with High gain and Eminent Radiation Efficiency for 5G applications

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***Abstract*—A peculiar design of U-shaped Microstrip patch antenna for the forthcoming 5G technology concentrated frequencies of 24.6 GHz is presented in this paper. The proposed antenna design constitutes of a well-established material Roger RT Duroid 5880 substrate which has uniform electrical properties over wide frequency range. The simulation of the design is done using High Frequency Structure Simulator (HFSS 15) Software. The developed antenna has a high gain of 8.18 dB and radiation efficiency of 99% and is economically efficient, affordable and at the same time easier to design and construct. U shaped antenna is used for military, wireless and civil applications etc.**

***Keywords*—U-shaped antenna, RT Duroid 5880, HFSS (15), high gain, radiation efficiency.**

I. INTRODUCTION

In this 5G era, with the boundless connectivity for all, there has been a lot of development in the area of technology for effective wireless communication and intelligent automation which is enriching people's lives and transforming the industrial process worldwide. Many antennas are developed for these purposes but now the developers of communication system are exploring and utilizing the microstrip patch antennas more and efficiently. Microstrip patch antennas are taking over other conventional antennas as they have better prospects, are lighter in weight, have low volume, low cost and profile. In addition to this, microstrip patch antennas are smaller in dimensions and are very easier to construct and fabricate. In this work, a U-shaped microstrip Patch Antenna is proposed for 5G applications at 24.6 GHz of frequency. This microstrip patch antenna is made up of a very thin metallic strip, which is placed on the ground plane. A dielectric substrate made of Roger RT Duroid 5880 material is also placed between the thin metal strip and the ground plane. The radiating element in this antenna is U- shaped, which is constructed in the substrate with the help of photo-etching process. Along with it, feed lines are also positioned on the substrate, using the microstrip line feeding technique. This proposed antenna has relatively low fabrication cost and is very affordable. The dimensions of the substrate and the ground plane are chosen wisely and then the area of the radiating patch is determined. Further, in this paper you will see the results of some of the top tier factors which determine the performance of the antennas. These factors are gain, radiation pattern, VSWR, directivity, bandwidth, reflection coefficient etc., which are determined by simulating the structural design of the proposed 5G U-Shaped microstrip Antenna in High Frequency Structure Simulator Software.

II. ANTENNA DESIGN

A. Analysis of Dielectric Material

Dielectric material is a non-conducting material which stores electrical charges. These materials are used for enhancing electrical and mechanical stability of the microstrip patch antennas. Generally, there are five different substrates Bakelite, FR4 Glass epoxy, RO4003, Taconic [3] TLC and RT Duroid, which are used for the fabrication of microstrip patch antennas. For this, proposed U-

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shaped microstrip Patch antenna, Rogers RT Duroid is used as it the most efficient out of all five substrates with 80% efficiency and a bandwidth of 15%. The reason for increase in bandwidth is due to the increase in size of the RT Duroid based antenna geometry compared to the other substrate based geometry as bandwidth is directly proportional to antenna dimensions or antenna size. Apart from this RT Duroid is easy to cut and machined to shape. It has resistance to solvents and reagents used in etching or plating edges and holes and are ideal for high moisture environments. Selection of Right substrate is very important as it is used to reduce the size of the antenna (higher permittivity, lower size) and can help to produce displacement current which produces time varying Magnetic Field. RT Duroid has lowest dielectric constant among the five substrates which also increases the bandwidth because bandwidth is inversely proportional to dielectric constant or permittivity. Hence, Rogers RT Duroid is selected for this antenna [1].

Table 1. Properties of Roger RT Duroid 5880

Parameter	Value
Dielectric Constant	2.2
Loss Tangent	0.009
Substrate Thickness	0.508 mm
Copper Cladding Thickness	0.035 mm

B. *Feeding Technique*

Many Feeding techniques for microstrip patch antennas are accessible, which are broadly classified into two main categories i.e., contacting and non-contacting. The feeding technique used in this antenna is microstrip Line feeding technique in which the patch is wider than the conducting strip and both are directly connected to each other. In this feeding technique, the feed of the antenna is etched on the same surface to provide a planer structure to the microstrip patch antenna. Also, an inset cut is properly positioned and then, is made in the patch, for impedance matching of the feed line, so as to avoid additional impedance matching element. Thus, keeping the model simple, easy to construct and fabricate, we used the microstrip line feeding technique in this work [5].

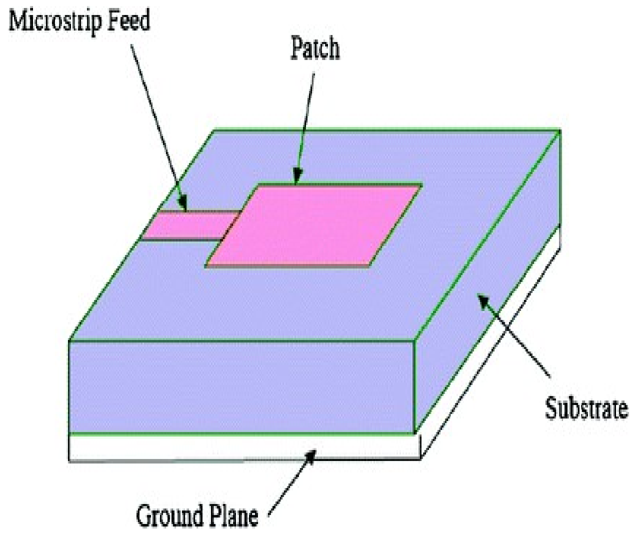

Fig. 1. Microstrip line feeding in antenna

C. *Analysis of Structure*

The radiator of microstrip patch antenna is available in many different shapes. In which, some of the most popular ones are square, rectangular, and circular shapes, but we can make the radiator of microstrip patch antenna in any continuous shape. Thus, the radiating element which is selected for this work is U- shaped. In order to lower the fringing field effect, the patch is constructed at the core of the antenna, in such a way, that it attains the extension length requirements. For calculating the area of the U-shaped patch, we first determine the area of the rectangular patch, using the design equations at desired the frequency. Because the area of the rectangular patch will be coequal to the area of the U-shaped Patch, that we desire [2].

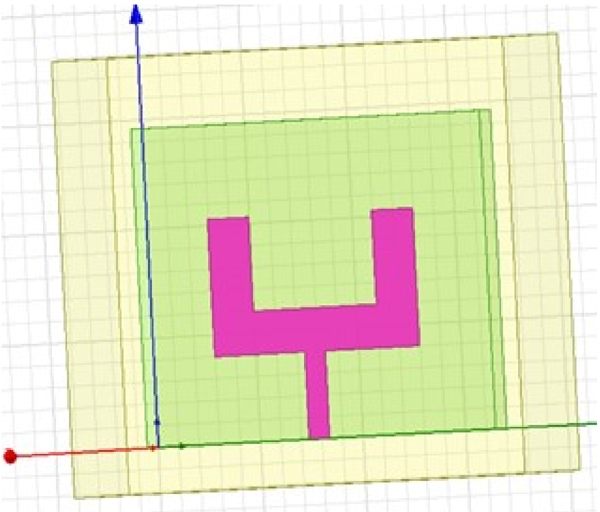

Fig. 2. U-Shaped radiator in microstrip patch antenna

D. Dimensions

The antenna is designed using the material Roger RT Duroid 5880 for the substrate whose dimensions are 8.5 mm x 7.3 mm x 1.0 mm. The length and width of the ground plane are equivalent to that of the substrate i.e., 8.5 mm x 7.3 mm. The area of the radiator, that we calculated using the design equation is 9.30 mm2 [4].

Table 2. Dimensions of Proposed U-shaped Patch Antenna

Parameters	Dimensions
Substrate Length	8.5 mm
Substrate Width	7.3 mm
Substrate Height	0.508 mm
Length of Ground Plane	8.5 mm
Width of ground Plane	7.3 mm
Area of Radiating Element	9.30 mm^2

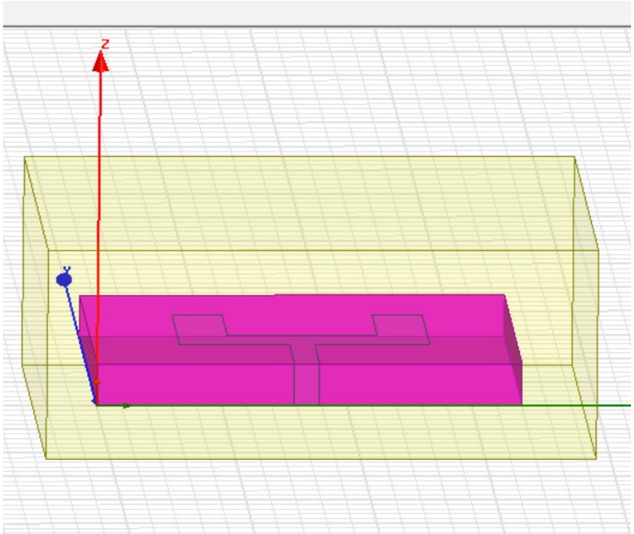

Fig. 3. Substrate of the proposed 5G U-Shaped microstrip patch antenna

E. Software

For simulation, we used Ansys HFSS 15 software, which is a 3D electromagnetic field simulator and is used worldwide by the engineers for designing and simulating high frequency products like antennas, RF and other electronic products [6].

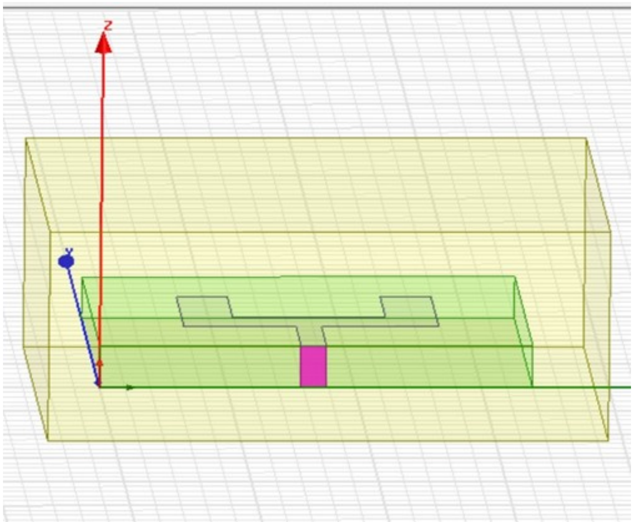

Fig. 4. Structure of the proposed antenna in Ansys HFFS 15 software (Pink area marked here depicts the port of the proposed antenna)

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III. SIMULATION RESULTS

The simulations result of the proposed U-shaped microstrip patch antenna, are mentioned below:

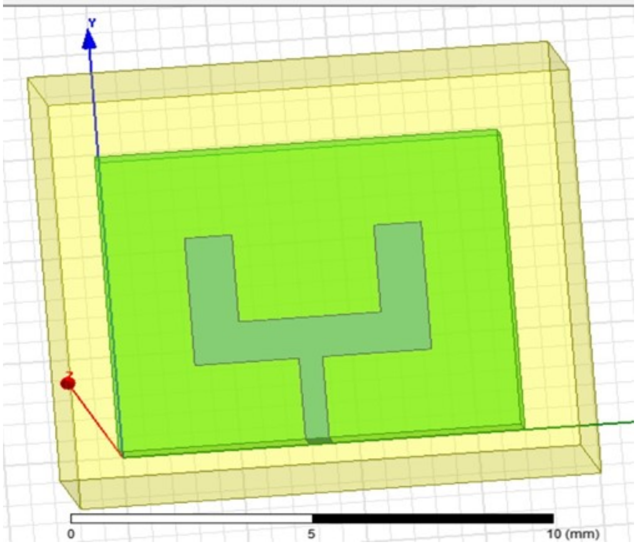

Fig. 5. Geometry of the Proposed 5G U-Shaped Patch Antenna

A. Return Loss

Return loss is measured in decibels and is defined as the loss of power in the signal, which is returned back, due to the dislocation of the transferal lines. In antennas, smaller return loss means that lesser energy is going into the antenna and more return loss means, more power into the antenna. Return loss of an antenna can be calculated by the formula,

$$R = 10 \log 10 \frac{Pi}{Pr}$$

When the return loss is 0dB, it means, there is 100% reflection and no power into the antenna, as all the power is lost and when written loss is 20 DB, it implies, that there is only 1% of reflection and 99 % of power into the antenna. In this work, the proposed antenna has the reflection coefficient of -16.70dB at 24.6 GHz of operating frequency, which is a good value and can be practical implemented [7].

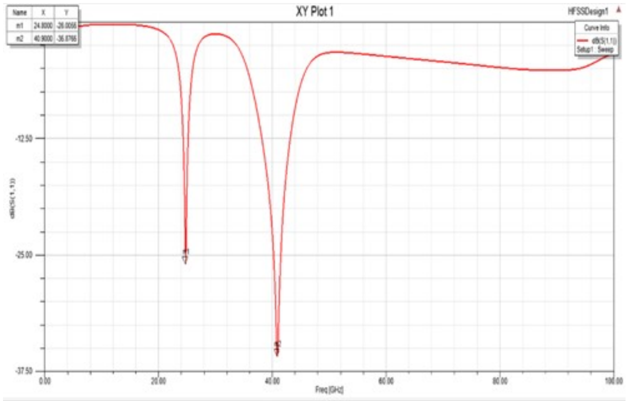

Fig. 6. Return loss

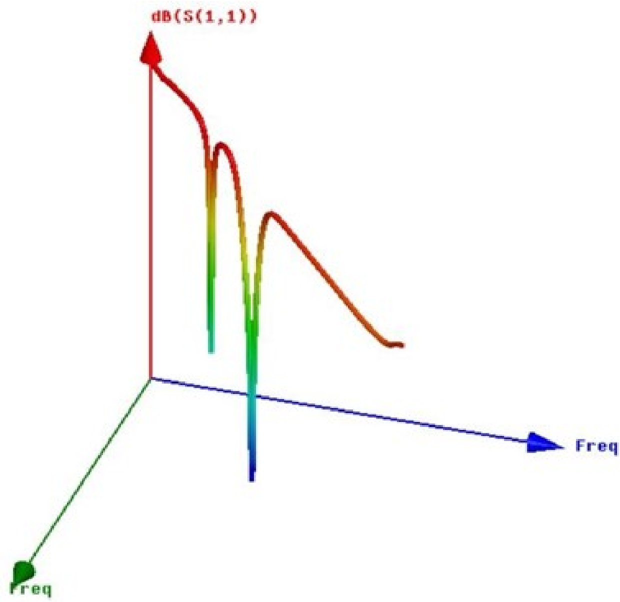

Fig. 7. 3-D Plot of return loss of the proposed antenna

B. VSWR

VSWR stands for Voltage Standing Wave Ratio and is an important criterion to look upon while working with antennas. Standing waves implies the power that is not accepted by the load and thus, VSWR is the measure of the level of standing waves on the feeder or transmission line. To know, how efficiently radio frequency power is transmitted through the feeder into the load, we calculate the VSWR.

Mathematically, VSWR=|V(max)|/|V(min)|

For 100% energy transmission, an exact impedance matching between the source, the transmission line, and the load is required which means that the AC voltage of the signal will remain same throughout the transmission process and will run, end to end, without any interference. However, in practicality, mismatched impedance causes some power loss. The proposed 5G antenna has 1.38 VSWR value at 24.6 GHz [8].

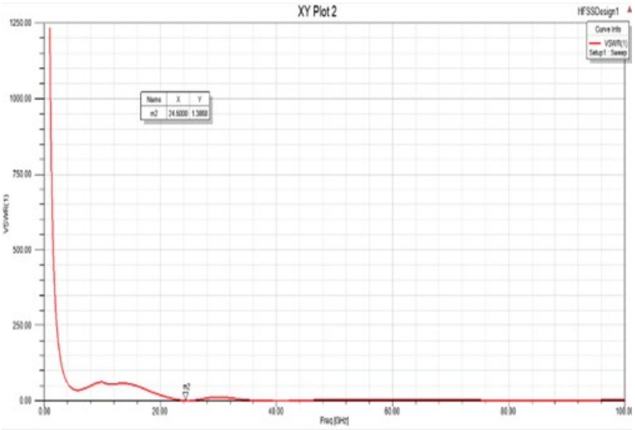

Fig. 8. VSWR plot of the proposed antenna

C. Gain, Radiation Efficiency and Polar Plots

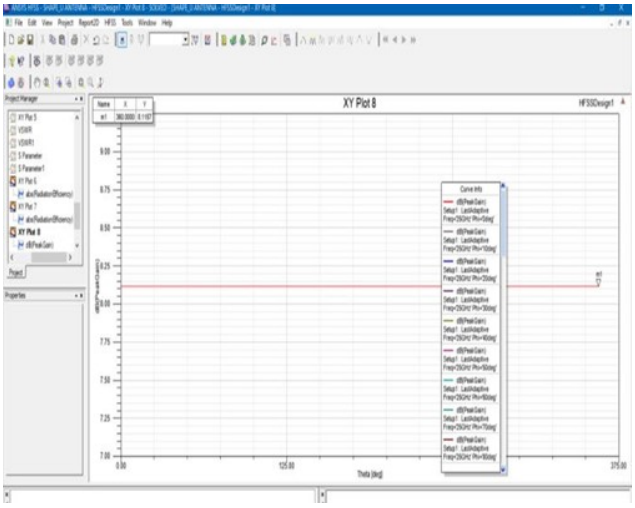

Fig. 9. Gain plot of the proposed antenna

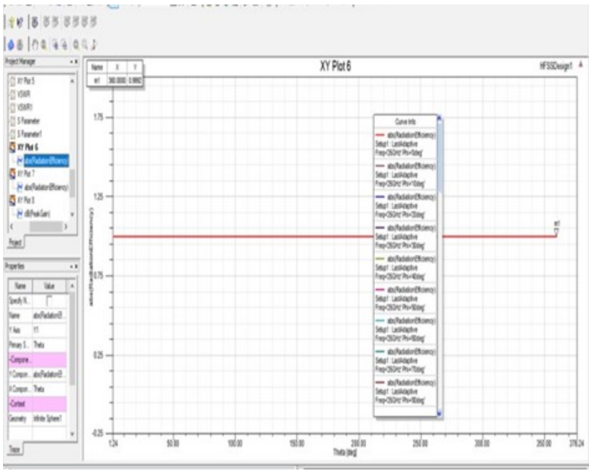

Fig. 10. Radiation Efficiency of the proposed antenna

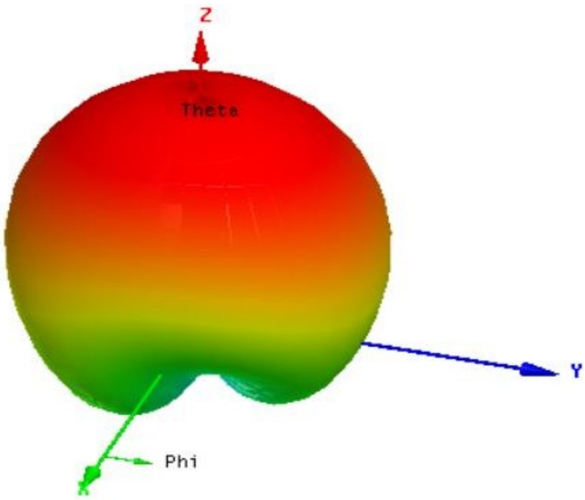

Fig. 11. Polar plot of the proposed antenna

D. Radiation Pattern

The directional dependence of the strength of Radio waves emitted from the antenna is its radiation pattern. The complexity of the radiation pattern depends upon the design and the construction of the antenna. The radiation pattern of the proposed 5G antenna operating at 24.5 GHz frequency is shown below:

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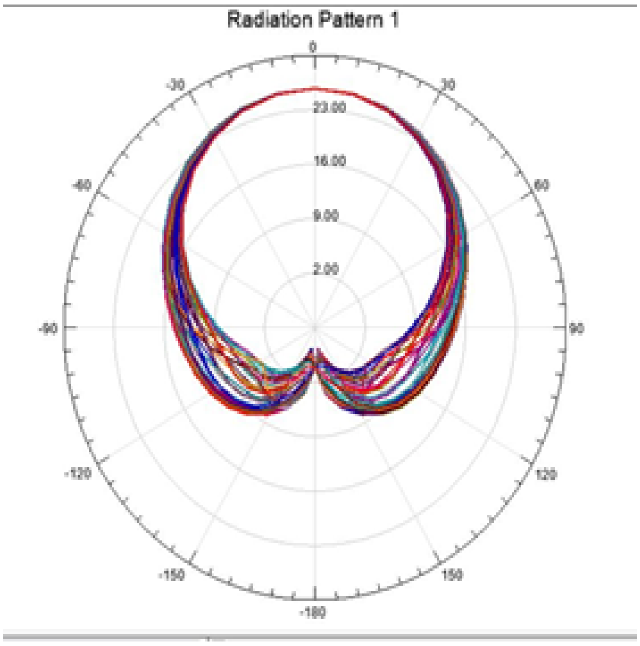

Fig. 12. Radiation pattern

E. Smith Chart

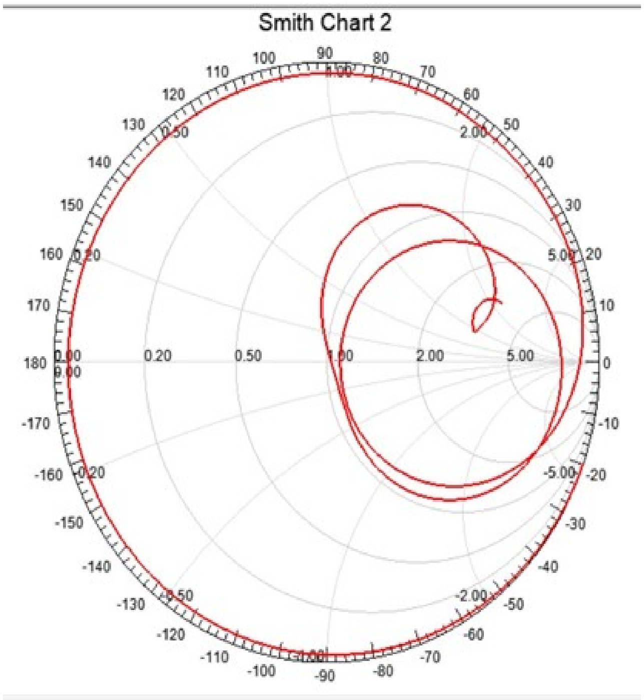

Fig. 13. Smith chart of the proposed 5G antenna

Table 3. Typical Radiation Parameter Values of the proposed 5G Antennas

Parameter	Value
Resonant Frequency	24.6 GHz
Reflection coefficient	-16.72 dB
Gain	8.18 dB
Directivity	8.16 dB
Radiation Efficiency	99%
Bandwidth	1.1

IV. CONCLUSION

In this research paper, a U-shaped microstrip patch antenna with resonant frequency 25 GHz, bandwidth 1.1 GHz, High gain 8.18 Db and eminent 99% of radiation efficiency is proposed. The design is successfully simulated in Ansys HFSS software and its notable results are also presented in this paper. Although, the proposed antenna is very economically efficient, easy to construct and efficient in terms of high gain and radiation efficiency but parameters can always be improved. Also, this design can be taken to a next level for much awaited 6G Communication technology for future work.

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