IMPROVED DESIGN OF COMPACT MICROSTRIP PATCH ANTENNA FOR FUTURE 5G APPLICATIONS

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Abstract
A microstrip patch that can be used for future 5G applications is presented in this paper. The proposed antenna has a compact size of 20 mm x 20 mm x 1.6 mm and operates at 10.031 GHz which is suitable for future 5G applications and hand held devices. The antenna was designed and simulated using Computer Simulation Technology (CST) microwave suit studio on FR4. A rectangular slot was designed on the surface of the patch element while Defected Ground Structure (DGS) was designed at the ground plane of the antenna. These two structures result to a significance increased in the bandwidth of the antenna. The simulation results produced an improved bandwidth of 575 MHz with an improved gain of 4.09 dB. The Voltage Standing Wave Ratio (VSWR) was also 1.0151.

Keywords – Microstrip Patch Antenna, 5G, Defective Ground Structure, Rectangular slot, Hand held devices

I. INTRODUCTION

The concept of microstrip patch antenna was proposed in 1970s [1] and that was due to the constant decrease in the size of electronic equipments. Hence, in the era of modern world where communication has become indispensable, antennas are rightly to be said as electronic eyes and ears of the world due to their undeniable place in the communication technology. While, the revolution in antenna engineering leads the fast growing communication systems, Microstrip Patch Antennas have been one of the most innovative developments in the era of miniaturization. Microstrip Patch Antennas are increasingly finding their applications in a broad range of microwave systems from radars, telemetry, navigation, biomedical systems, mobile and satellite communications, missile systems, global positioning system (GPS) for remote sensing and etc. [2] because of their light weight, low volume, low cost, low profile, ease of fabrication, conformability to mounting hosts and ability to be printed directly onto a circuit board.

The conventional structure of a Microstrip Patch Antenna comprises of a metallic radiating patch element, embedded into a grounded dielectric substrate as seen in Fig.1 [3]. The shape of the conducting patch can be of any geometrical shape as seen in Fig.2 [3] however; rectangular is the most common one. The rectangular Microstrip patch antennas is used as simple and for the extensive and most demanding applications as it easily provide with feed line flexibility, multiple frequency operation, linear and circular polarizations, frequency agility, good bandwidth etc [4, 5].

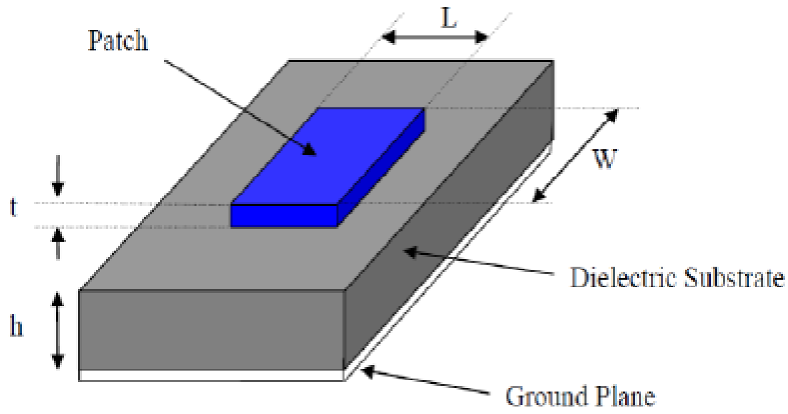

Fig.1 Structure of Microstrip Patch Antenna [4]

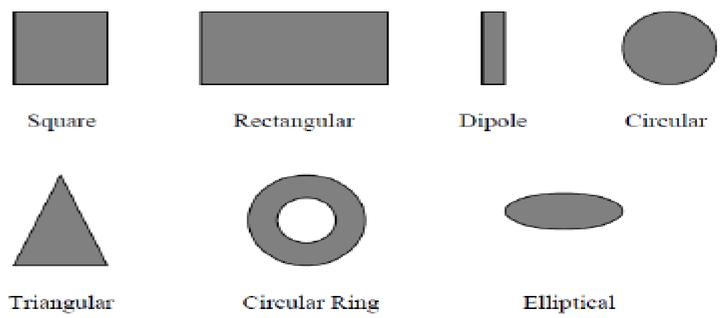

Fig.2 some possible shapes of patch element in Microstrip Patch Antenna [4]

Several designs of Microstrip patch Antenna for 5G applications have been developed. A design of rectangular microstrip patch antenna was proposed. In this paper, the antenna was designed using Advance Design System Momentum (ADS Momentum) on FR4 substrate which has a dielectric constant of 4.4. The simulation results produce a bandwidth of less than 50 MHz, a gain of 3.48 dB at a resonance frequency of 4.1GHz. In addition, a VSWR of 1.6 to 1.7 through 3 GHz to 5 GHz was also obtained [6]. The bandwidth of this antenna is too small; similarly, the VSWR has not been taken into consideration.

In another development, a small microstrip patch antenna for 5G applications was proposed. In this paper, the antenna was designed using Higher Frequency Structure Simulator (HFSS) Software and the simulation results produced a gain of 4.47 dB, a bandwidth of around 400 MHz and a return loss of around -18.27 at a resonance frequency of 10.15 GHz [7].

In this paper, a microstrip patch antenna for 5G applications was presented. Some design techniques such as rectangular slot [8, 9, 10, 11 and 12] and Defected Ground Structure (DGS) [13, 14] were employed and the simulation results have higher bandwidth compared to the referenced design. In addition the VSWR of the modified design was closer to the ideal value 1.0.

II. ANTENNA DESIGN

The geometry of the antenna was designed using equations (1) to (9) [15]

(a) Dimensions of the Patch Element

The width of the Rectangular Patch Element can be calculated using equation (1)

$$W = \frac{v_o}{2f_c}\sqrt{\frac{2}{1+\varepsilon_r}} \quad (1)$$

Where:
W, is the width of the patch element.
V_o, is the velocity of light, a constant whose value is$3\ X\ 10^8\ m/s$.
f_c, is the center frequency whose value is 10.15 GHZ
$\mathcal{E}r$, is the dielectric constant of FR4 substrate whose value is 4.3
Moreover, the effective dielectric constant $\mathcal{E}_{eff}$, was also calculated from equation (2).

$$\varepsilon_{eff} = \frac{1+\varepsilon_r}{2} + \frac{\varepsilon_r - 1}{2}[1 + \frac{12h}{W}]^{-1/2} \quad (2)$$

Where:
$h,$ is the height (thickness) of the substrate material and its value is 1.6 mm, all other components of the formula are already defined.

In addition, the change in lengthΔL, of the patch element due to fringing effect which was caused by the power radiating from the surface of patch element, was calculated from equation (3).

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - o.258)(\frac{W}{h} + 0.8)} \quad (3)$$

Similarly, the effective change in length of the patch element ΔL_{eff}, was calculated from equation (4)

$$\Delta L_{eff} = L + 2\Delta L \quad (4)$$

The actual length of the patch element L, was calculated from equation 3.5

$$L = \frac{v_o}{2f_c\sqrt{\varepsilon_{eff}}} - 2\Delta L \quad (5)$$

(b) Dimensions of Substrate Material

According to Rule of Thumb [16], the distance from the patch element to the substrate, should be at least three times the thickness of substrate material. The thickness of FR4 is 1.6 mm.

The Length of the substrate material $Sl,$ should be at least six times the thickness of the substrate plus length of patch element as presented in equation (6).

$$Sl = 6Sh + Pl \quad (6)$$

Where:
$h,$ is the thickness of the substrate whose value is 1.6 mm.
Similarly, the width of the substrate material $Sw,$ should be at least six times the thickness of the substrate plus length of the patch element as presented in equation (7).

$$Sw = 6Sh + Pw \quad (7)$$

(b) Dimensions of Ground Plane of the Patch Antenna

The ground plane is a layer usually lied at the bottom of the microstrip patch antenna. It is normally made up of made up of conducting materials such as, aluminium, copper, etc.
A copper material is used as a ground plane in this thesis whose thickness is 0.035 mm as loaded from CST microwave suit studio library.
The length $Gl,$ and width $Gw,$ of the ground plane should be the same as the dimension of substrate as indicated in equations (8) and (9).

$$Gl = Sl \qquad (8)$$

$$Gw = Sw \qquad (9)$$

TABLE 1. LIST OF DESIGNS PARAMETERS

PARAMETERS/UNITS	NUMERICAL VALUES
Operating frequency (GHz)	10.15
Length of patch element (mm)	11.3
With of patch element (mm)	10.2
Thickness of patch element (mm)	0.035
Length of substrate material (mm)	20
Width of substrate material Sw (mm)	20
Thickness of substrate material Sh (mm)	1.6
Length of ground plane Gl (mm)	20
Width of ground plane Gw (mm)	20
Thickness of ground plane Gt (mm)	0.035
Length of feedline Fl (mm)	7.5
Width of feedline Fw (mm)	1.9
Length of defected ground structure (mm)	
Width of defected ground structure (mm)	
Length of rectangular slot (mm)	9
Width of rectangular slot (mm)	0.8

(c) Structure of the Antenna

The compete structure of the proposed antenna is presented by Fig.3 and Fig.4 below

Front view of the proposed antenna

Fig. 3 presents the front view of the proposed antenna displaying all the dimensions for the substrate, the patch element, rectangular slot and the feedline.

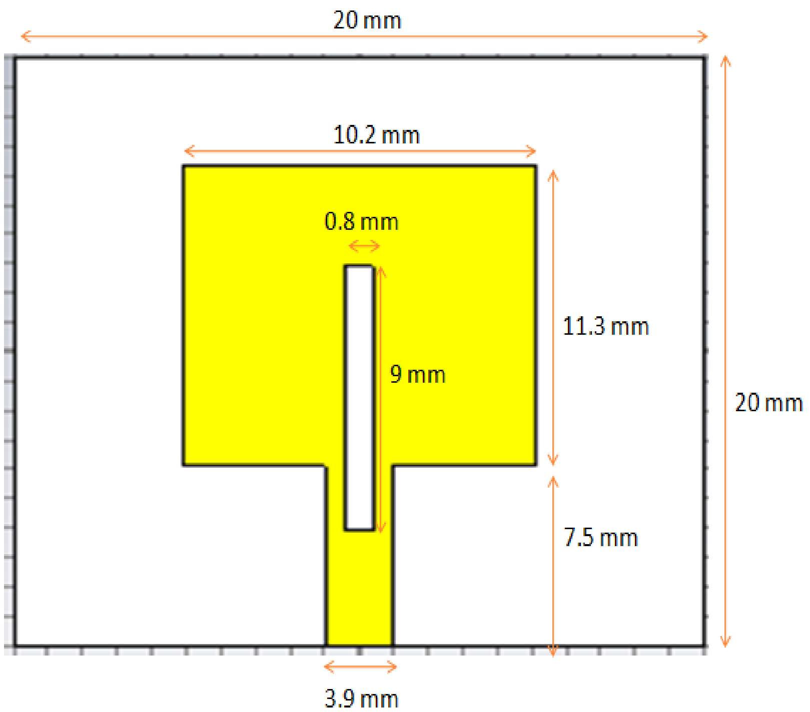

Fig.3 Front view of the proposed antenna

Rear view of the proposed antenna

Fig.4 is the rear view of the proposed antenna displaying the Defected ground structure and its dimensions as well as the remaining portion of the ground plane.

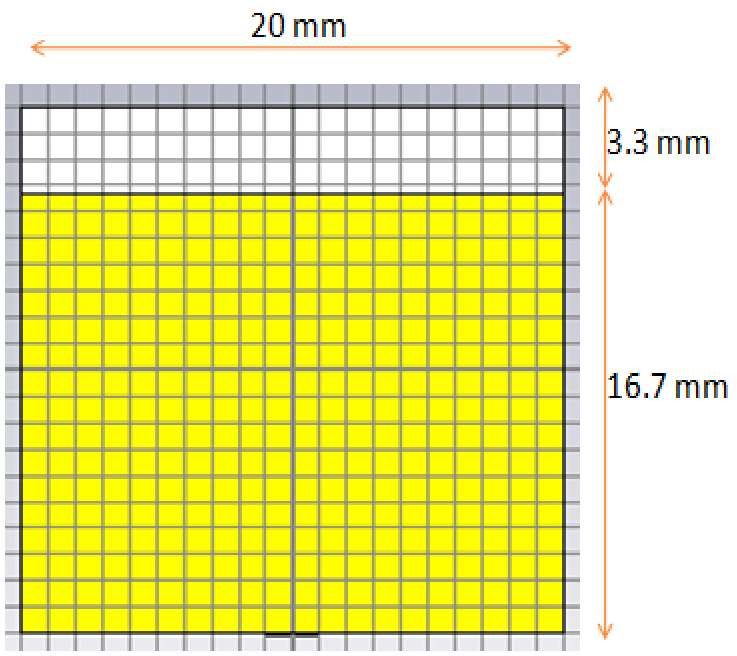

Fig.4 Rear view of the proposed antenna

IV. SIMULATION RESULTS AND DISCUSSIONS

The Return Loss plot of the propose Antenna

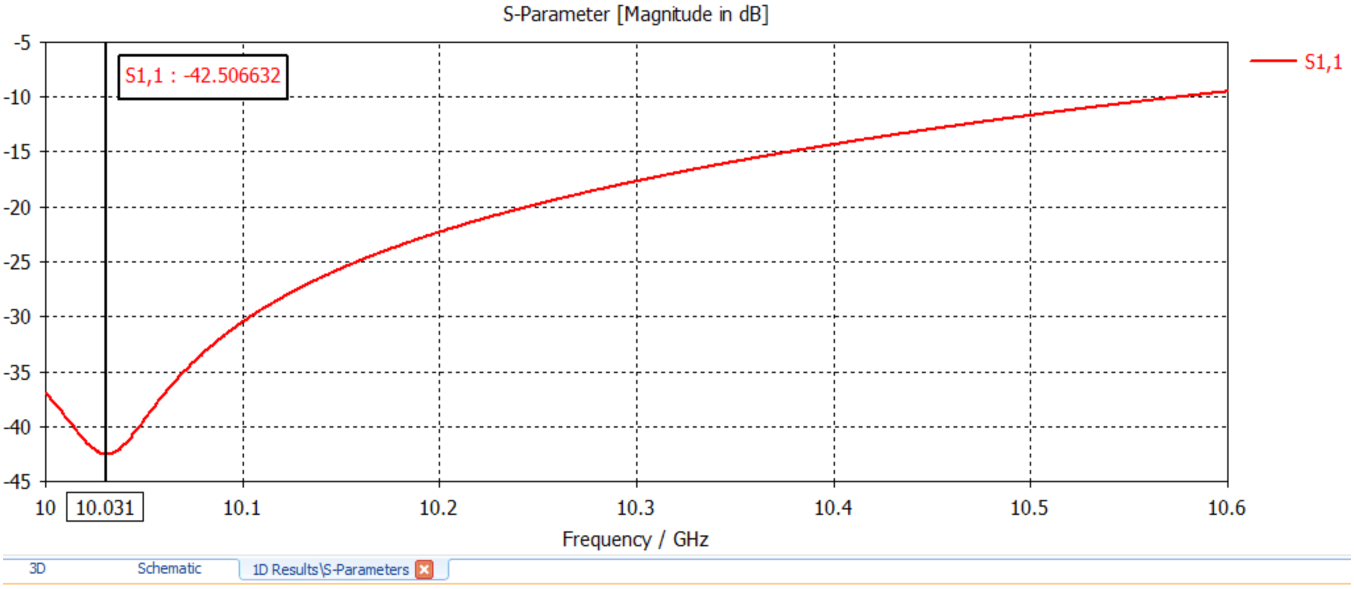

Fig.5 Return loss plot of the propose antenna

Fig5. Is the return loss plot of the propose antenna and from this graph it can be observed that, the return loss (S11) of the antenna is - 42.50 dB at a resonance frequency of 10.031 GHz however, that of reference design is -18.27 dB. The base value of the return loss was considered to be –10 dB which is excellent for mobile communication; hence, the value obtained indicates that, the antenna is highly excellent.

Bandwidth of the Proposed Antenna

SIMULATION RESULTS

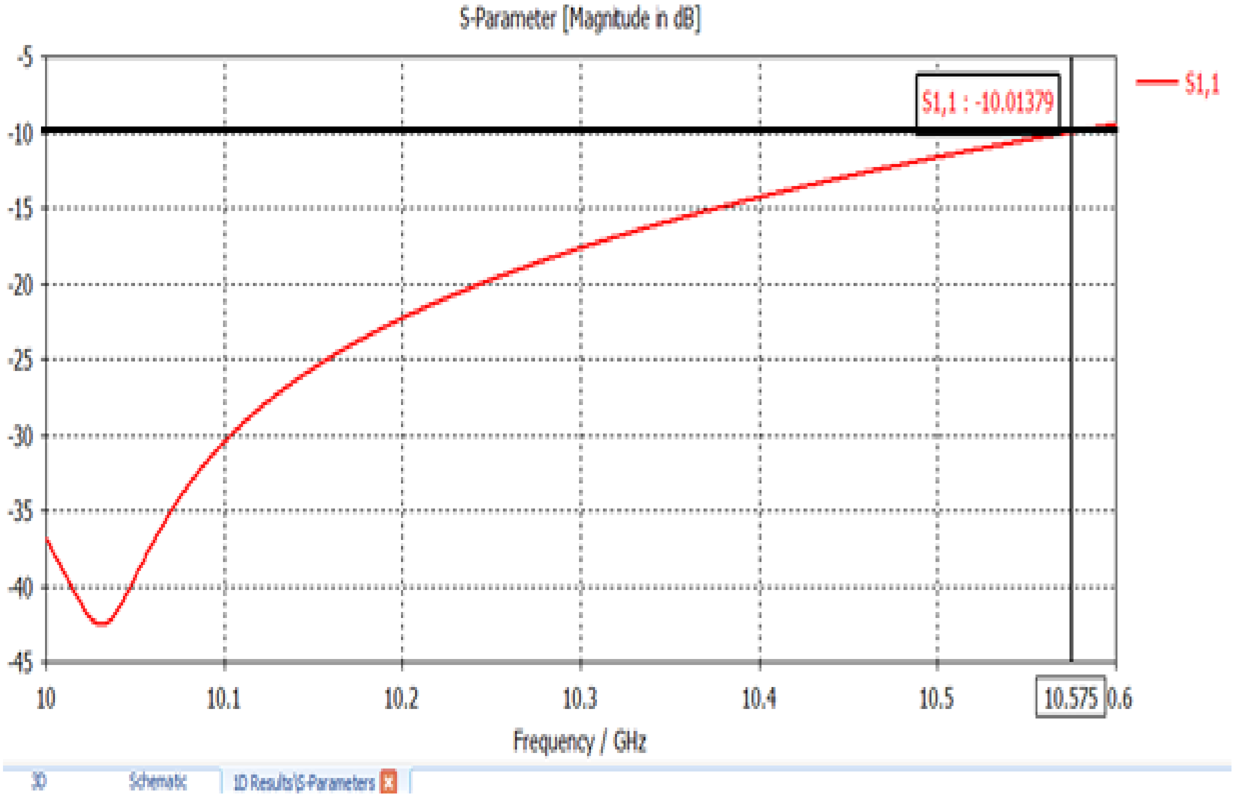

Fig.6 Bandwidth of the proposed antenna

From Fig.6 above it can be observed that, at -10 dB the lower and upper frequencies covered by the graph are 10.000 GHz and 10.575 GHz, hence the bandwidth of the proposed antenna is 575 MHz and however that of the reference design is 400 MHz. The modified design thus has higher bandwidth compared to the reference one.

3D Radiation of the Propose Antenna

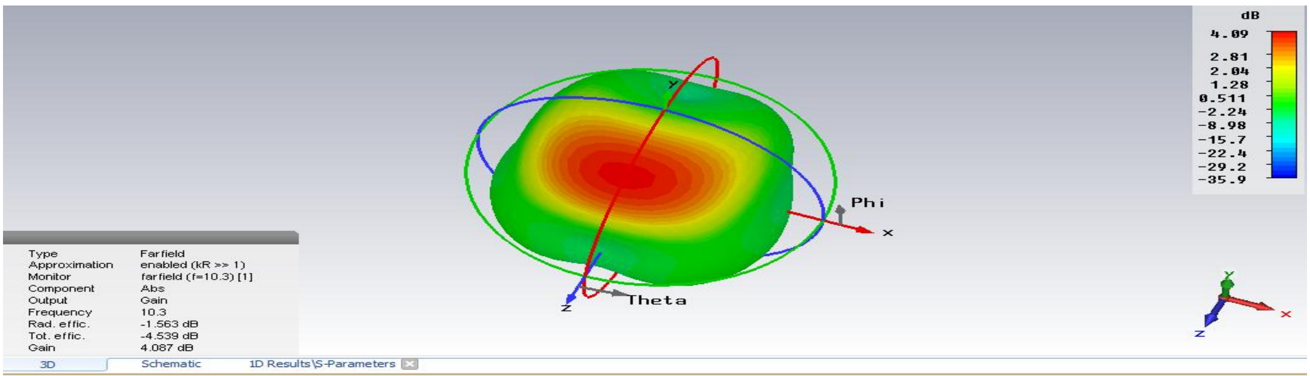

Fig.7 3D radiation of the propose antenna

Fig.7 is the 3D radiation of the modified design; from this radiation it can be observed that, the gain of the antenna is 4.09 dB at a resonance frequency of 10.031 GHz. The directivity of the antenna was also 5.65 dBi; however, that of the reference design is 4.46 dB. From these results, the gain of the referenced design is higher than that of the modified design; however, all the gains are excellent for a compact antenna design of this kind.

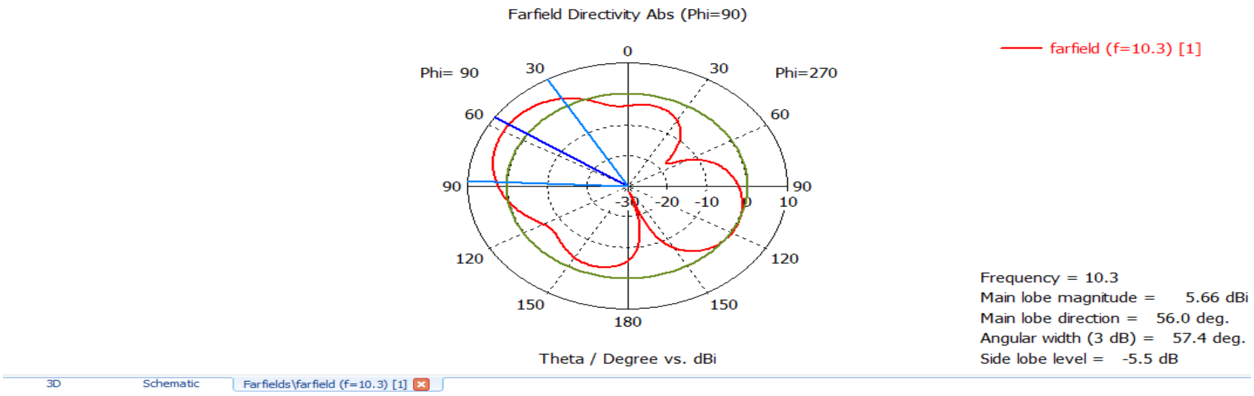

Fig.8 polar radiation of the propose antenna

Fig.8 is the 2D (polar) radiation of the modified antenna design and from this plot it can be observed that, the antenna has an omni directional pattern which is highly desirable for mobile communication.

The Voltage Standing Wave Ratio of the Propose antenna (VSWR)

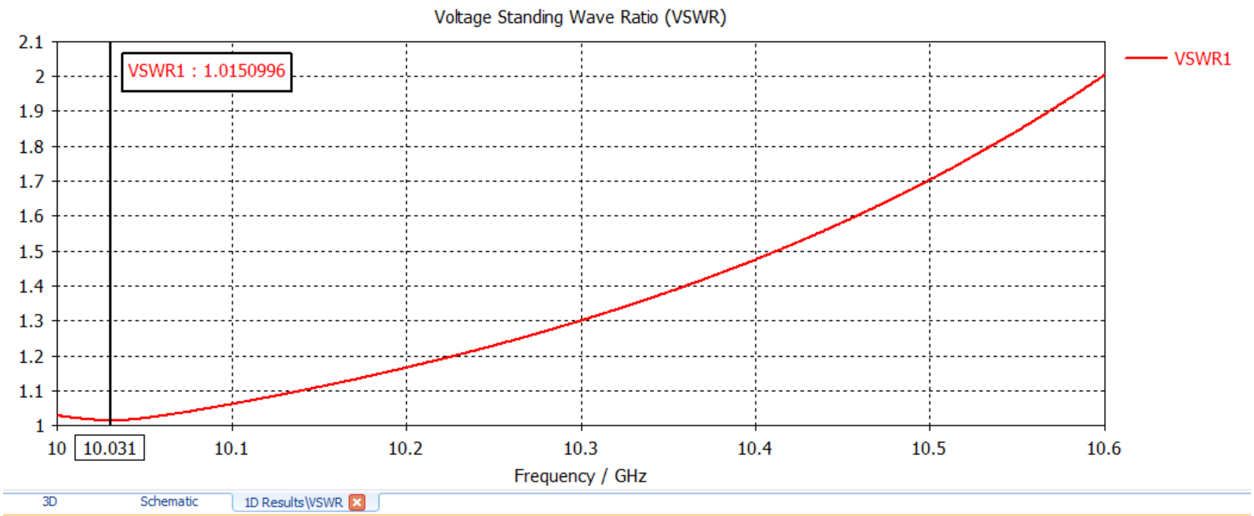

Fig.9 Is the VSWR of the proposed antenna; from this plot it can be observed that, the value of VSWR is 1.0151 which indicates that, the antenna is perfectly matched since the ideal value of VSWR is 1.0000; however, that of the referenced design is 2.13. The proposed antenna thus has good VSWR than that of referenced design.

TABLE II. COMPARISON BETWEEN THE REFERENCED AND MODIFIED DESIGN

PARAMETERS/UNIT	MODIFIED DESIGN	REFERENCED DESIGN
S11 (dBi)	- 42.5	-18.27
Bandwidth (MHz)	575	400
Gain (dB)	4.09	4.46
VSWR	1.0151	2.13

IV. CONCLUSION

This paper presents a compact microstrip patch antenna that can be used for future 5G wireless communications. The simulation results of the antenna, produces a return loss (S11) whose value is -42.50 dBi, similarly its bandwidth 575 MHz, its gain is also 4.09 dB all at a resonance frequency of 10.031 GHz. Hence, these results are excellent for future 5G wireless communication.

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