# Design Analysis of 5G Microstrip Antenna

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***Abstract***

*5G communication network has three distinct characteristics, although not limited to; enhanced network coverage, low latency and massive device connectivity. 5G mobile system has broad spectrum to support high data rates. Such device must deploy corresponding radiating structures to meet the changing technological advancement. In this paper therefore, a microstrip patch antenna operating at 3.6GHz frequency is designed and simulated for 5G application. The choice of frequency of operation is influenced by the broad prospects for 5G. The substrate is the flame resistant four (FR4) with a dielectric constant of 4.6 and a loss tangent of 0.023. The results include; plots of the voltage standing wave ratio, radiation pattern, return loss and radiation efficiency. The result further showed that, the parameters influencing the radiation characteristics of the patch antenna are the relative permittivity of the dielectric material, the position of the slot on the patch, the ground plane, substrate type as well as the dimensions of the feed and patch. The microstrip antenna thus can be effectively deployed for 5G application.*

***Keywords****: Dielectric Substrate, Microstrip Patch, 5G Network, Radiation Pattern, Relative Permitivity.*

## I. INTRODUCTION

Fifth-generation (5G) mobile network is a mobile internet connection that has shown next-level coverage, usage and reliability [1]. Mobile phone network has evolved through four generations, with each generation having specific characteristics that distinguishes it from the other. The frequency, data rate, latency, maximum number of users, modulation technique and network geographical area coverage are some of the underlining parameters that distinguishes one generation from the next. 5G mobile technology greatly increases the communication capacity beyond the 4G and therefore, there is need for improved antenna design with high gain, low cost, high bandwidth, and high radiation efficiency to enhance effective communication process in 5G [2]. 5G has been in existence since 2020 and countries like

South Korea,

China and the United States are among the 61 countries that has deployed this communication network [3].

Wireless communications through radio waves requires the use of antennas at both the transmitting and receiving terminals. Today, antennas are found in many device used in applications such as wireless local area networks (WLANS), mobile telephony and satellite communication, among others (Urul 2020). One requirement of antennas deployed for handheld devices is compactness, as well as the ability to maintain functionality over different applications [4]. Consequently, there is a continued need for both design and realization of compact planar antennas that can support 5G technology and presented in portable gadgets. The dielectric loading of a microstrip antenna affects both its radiation pattern and impedance bandwidth. As the dielectric constant of the substrate increases, the antenna bandwidth decreases which increases the Q factor of the antenna and therefore decreases the impedance bandwidth. This relationship did not immediately follow when using the transmission line model of the antenna, but is apparent when using the cavity model. The radiation from a rectangular microstrip antenna may be understood as a pair of equivalent slots. These slots act as an array and have the highest directivity when the antenna has an air dielectric but decreases with a dielectric substrate that has increased relative permittivity. The shape of a microstrip patch antenna has significant impact in overcoming bandwidth limitations of the antenna [5], [6]. However, [7] considered patch array for bandwidth improvement using increased patch thickness and two slot insertion in each radiating element. Microstrip patch also finds application in multiband communication; Wi-Fi, Wi-Max and 5G considerations with high directional radiation pattern, very small VSWR and high gain [8]

## II. STATEMENT OF THE PROBLEM

5G technology has been an issue of interest due to the enormous traffic of users connected to the network relative to the scarcity of available bandwidth and prevailing challenges of 4G technology. These has led to the need for larger capacity and faster data which are currently 100 times faster, and are expected to be 1000 times faster by 2030.. Wireless channel capacity can be increased in 5G mobile communication without necessarily having additional spectral power in a scattering environment. This paper therefore addresses a design solution of a high gain antenna, simulated as a microstrip 5G antenna using CST software. There are several new mobile phones available that are designed to support 5G, and multiple carriers across the world support the 5G wireless network. As the 5G rollout timeline progresses, more smart phones and carrier subscriptions will become available and 5G compatible devices become more mainstream.
It is therefore imperative to acquire devices that supports 5G to adequately connect and benefit from the network. 5G as expected will be many times faster than 4G and so low latency will be experienced with massive device connectivity and system capacity.

## III . METHODOLOGY

This paper presents a high gain microstrip antenna resonating at 3.6GHz for efficient information transmission and reception for 5G application. The rectangular patch antenna is simulated using a CST studio while the parameters of the antenna are considered and computed. The most commonly employed microstrip antenna is the rectangular patch which looks like a truncated microstrip transmission line. It is approximately one-half wavelength long. When air is used as the dielectric substrate, the length of the rectangular patch is approximately one-half of free-space wavelength. As the antenna is loaded with a dielectric substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. The resonant length of the antenna is slightly shorter because of the extended electric "fringing fields" which increase the electrical length of the antenna slightly. An early model of the microstrip antenna is a section of microstrip transmission line with equivalent loads on either end to represent the radiation loss[9] .

### *A. Antenna Formulations*

The overall goal of any antenna design is to achieve specific performance characteristics at a desired operating frequency. The preliminary approach in formulating the design requirement of the microstrip patch includes but not limited to choosing the operating frequency, substrate type, and substrate thickness. The next phase include ; dimensioning the antenna structure which include; substrate height, width, length of the patch and ground plane dimensions. These parameters are governed by the following fundamental equations.

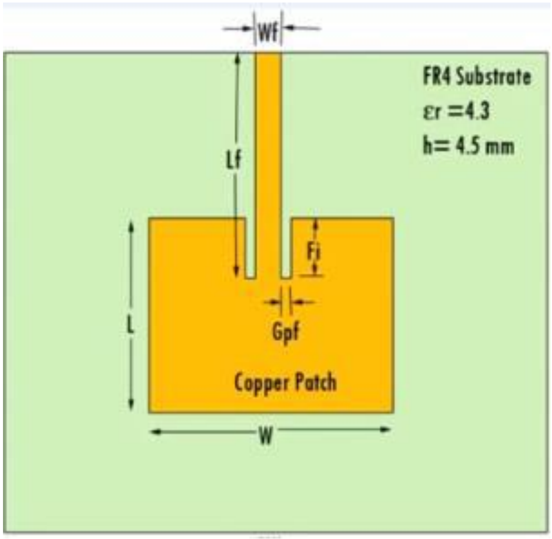


Figure 1: The inset feed of the Microstrip patch antenna

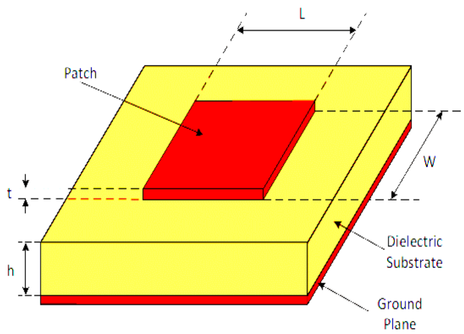


Figure 2: The structure of a microstrip rectangular patch antenna

*B. Height of the Substrate*

The height h of the microstrip antenna is related to substrate thickness or height (SH). For a rectangular patch, the substrate height h ranges between $0.003\lambda 0 \leq h \leq 0.05\lambda 0$. The dielectric constant of the substrate $\varepsilon_r$ is ordinarily in the range of 2.2 to 12. For efficient radiation, the practical rectangular patch width W is given by:

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where;

$F_r$ = the resonant frequency of the antenna

C = is the speed of light in space.

$\varepsilon_{reff}$ = The effective dielectric constant of rectangular patch antenna is expressed as

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{W}}}\right] for\ \frac{w}{h} > 1 \qquad (2)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \qquad (3)$$

Where;

$L_{eff}$ = the effective length

Fringing makes the patch to appear bigger (electrically) compared to the physical dimension of the patch. To account for the fringing of the electric field above the microstrip, an effective dielectric constant is defined. However, the physical length of the patch is extended by a length ΔL.

*C. Patch Length*

For a given patch antenna, the particular length of the patch is a critical parameter. Because of its inherent narrow bandwidth, it controls the resonant frequency. The patch length is sometimes selected within the range of $0.3333\ \lambda 0 < PL < 0.5\ \lambda 0$. Therefore, the actual patch length (PL) is given;

$$\boldsymbol{L = L_{eff} - 2\Delta L} \qquad (4)$$

Where;

L = Length of the Patch

ΔL is extension length and given by

$$\boldsymbol{\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}} \qquad (5)$$

*D. Patch Width*

The patch width (PW) has less effect on the resonant frequency and radiation pattern. But it significantly affects the bandwidth and radiation efficiency of antenna. The PW is calculated thus;

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (6)$$

*E. Antenna Gain*

This is the direction in which there is more radiation. It is a measure of the antenna to direct its input power into a particular direction, measured at the peak radiation intensity and is given as

$$G(\theta, \emptyset) = \frac{V(\theta,\emptyset)}{P_{in}/_{4\pi}} \qquad (7)$$

Where;
Pin = Input power
G ($\theta$,Φ) = Radiation Density
4π = constant
Gain is attained by administering the radiation far from different parts of the radiating surface

*F. Directivity*

The directivity describes the directional properties of the antenna, and it is therefore controlled only by the radiation pattern. Directivity is given as

$$\frac{\textbf{Maximum radiation intensity}}{\textbf{Average radiation intensity}} = \frac{U_{max}}{V_o} \qquad (8)$$

*G. Return loss*

It is a parameter that is used to measure the power reflected by the antenna due to the mismatch of the antenna.

$$R_L = \frac{P_T}{W_l} \qquad (9)$$

where;
RL= effective area (m$^2$)
PT= power delivered to the load (W)
Wι =power density of incident wave (W/m$^2$)

Equations 10 and equation (11) are used to determine the dimension of the ground plane.

$$L_g = 6h + L \qquad (10)$$

$$W_g = 6h + W \qquad (11)$$

*I. Modelling and Simulating in CST Studio 2011*

In modelling an antenna using the CST studio, the type of antenna to be considered is selected which in this case is the rectangular microstrip antenna. The operating frequency of 3.6GHz is chosen and monitored at that choice.
The ground plane is the first component to be modelled in CST studio by selecting the appropriate block and providing the relevant parameters (Lg 60 mm and $W_g$ 55mm) as calculated using equation 10 and equation 11 respectively. The ground plane used is the copper plate which has a thickness of 0.1mm.
Then the next component which comes on top of the dielectric substance is the (Fr) substrate which have the dielectric constant of 4.6

The height (h) of the substrate is 1.8 mm, and this informs the distance between the radiating patch and the substrate. Then the block of radiating patch is placed on top of the substrate and the radiating patch consist of height of 0.1mm which is almost equivalent to that of the ground plane. The insertion gap where the microstrip transmission feed line to be inserted is also created. The values of the length and width of the antenna are also inputted $L_p$ 31.3 mm and Wp 42.2 mm respectively.

Lastly there is need to compute the coordinate of the waveguide port at the antenna feed given as Lif 8 mm, Lf 19.4 mm. Having inputted the parameters; the patch antenna is then placed on top of the substrate. The simulation process is carried out and the results are also presented in the graphs that follow.


Figure 3. Pictorial view of the platform of CST software

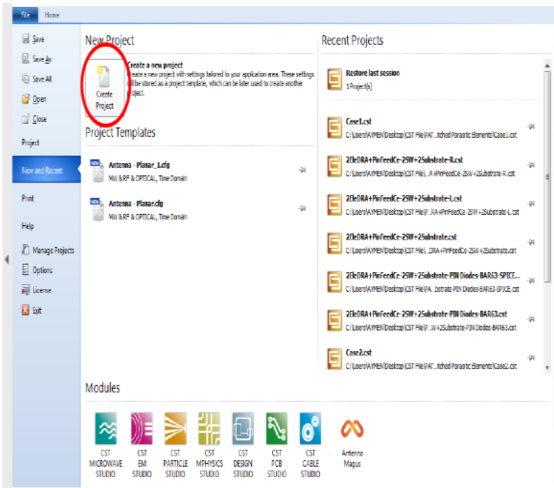


Figure 4 Creating a project On a CST software

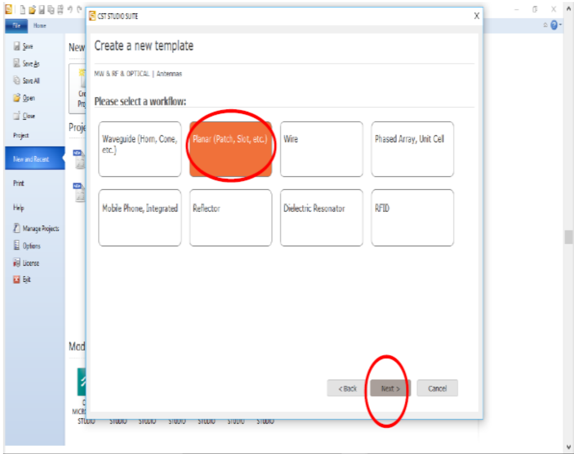


Figure 5 showing the type of templates to be used: select MW & RF & optical

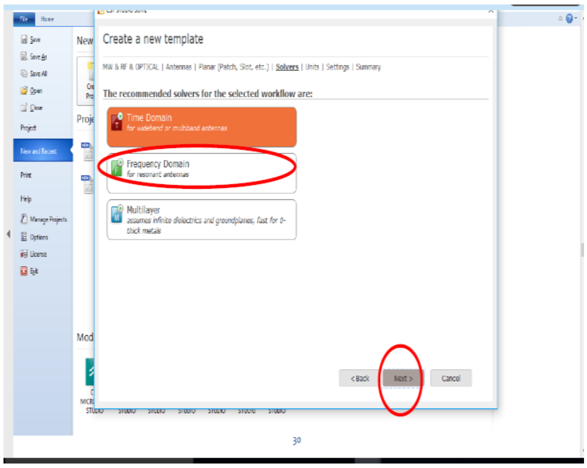


Figure 6. showing the type of antenna to be used. Select Planar (patch, Slot, etc.)

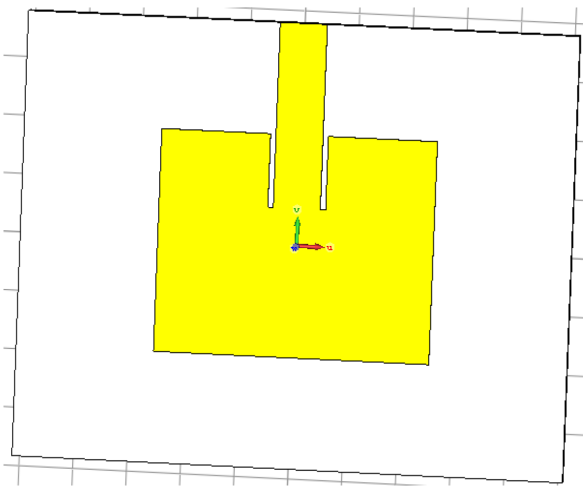

Figure 7. Side view of the patch antenna during simulation

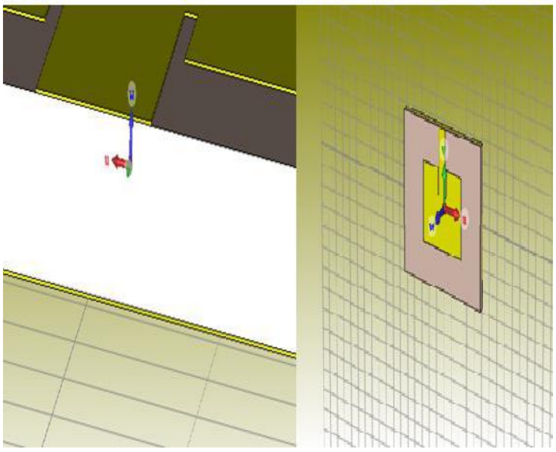

Figure 8. CST studio showing the patch antenna.

**TABLE I. PROPOSED ANTENNA DIMENSIONS**

| Name | Value(mm) | Description |
|---|---|---|
| Lp | 31.3 | Length |
| Wp | 42.4 | Weight |
| Lg | 60.0 | Length |
| Wg | 55.0 | Weight |
| Lif | 8.00 | Length |
| Wfi | 4.60 | Weight |
| Lf | 19. 4 | Length |
| Wf | 4.60 | Weight |
| H | 1.80 | Length |

## IV. RESULTS

The microstrip antenna modelled and simulated using CST software relates the physical as well as the electrical properties of the antenna. The calculation of some parameters such as the voltage standing wave ratio (VSWR), return loss (S11), directivity, radiation pattern and gain of the microstrip patch antenna achieved are described and evaluated. The results of the simulation are compared to theoretical values (parameters) which serves as validation to the work.

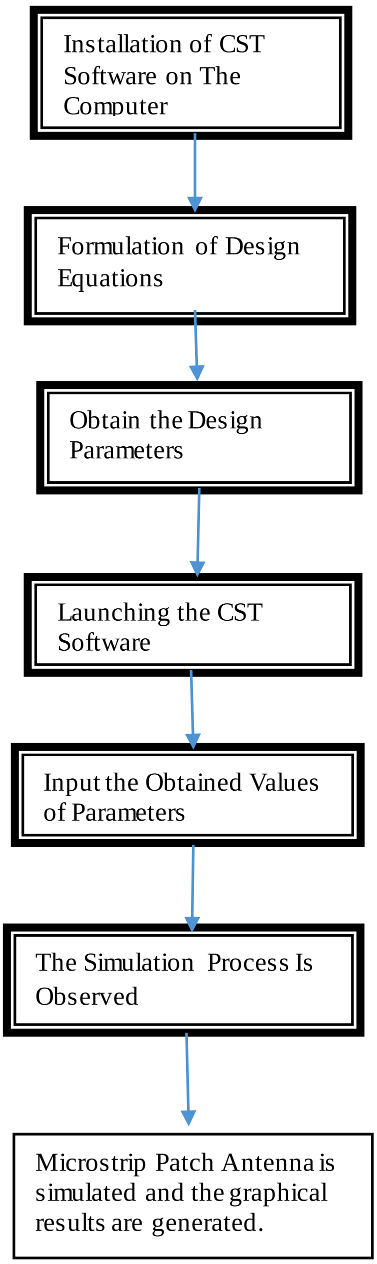


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Figure 9. Block diagram showing the design methodology of a microstrip antenna

A. Return Loss

Return loss measures the power reflected by the antenna due to the mismatch of the antenna. A return loss of 0dB implies that there is little or no antenna mismatch because the power provided to the antenna is completely reflected by the antenna for which power input is equal to the power reflected.
The graph of frequency versus return loss shows that the frequency of the desired antenna is at 3.6GHz and the return loss is 1dB meaning that the antenna will radiate efficiently.

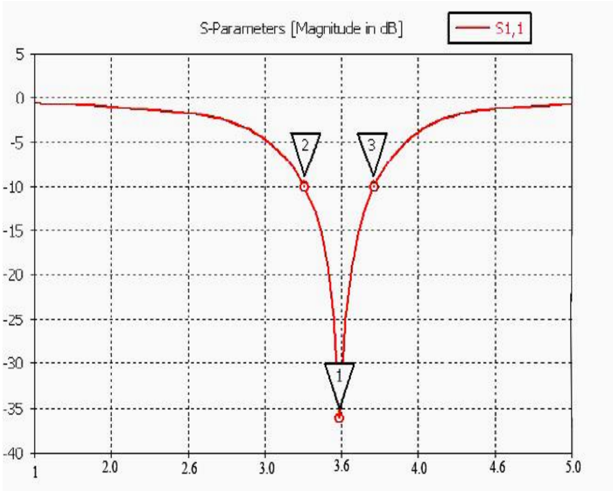


Figure 10. Graph of frequency versus return loss of the simulated microstrip antenna.

*B. VSWR*

VSWR is a measure that numerically describes how well impedance matching between the antenna feed and the transmission line. The minimum VSWR for the antenna simulated is 1. The antenna with less VSWR has the better return loss compared to other antenna with higher VSWR. The return loss and the VSWR of the antenna simulated are shown in figure 10 and figure 11 respectively.

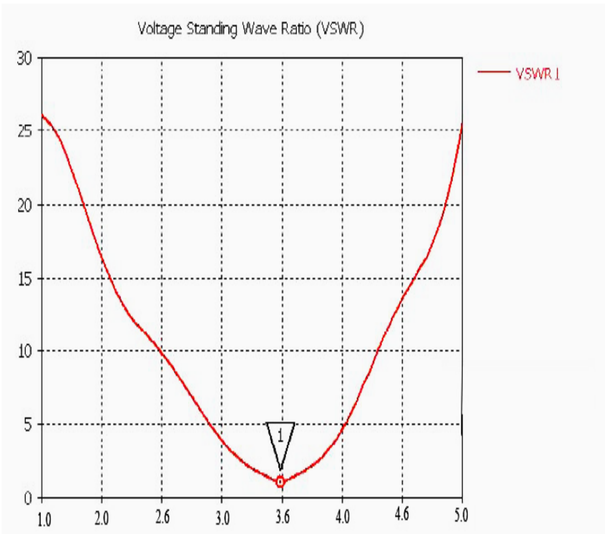


Figure 11. Graph of frequency versus VSWR.

As shown in the graph of figure 11, at a frequency of 3.6GHz the VSWR is almost at 1 which show that the antenna is performing efficiently as also validated from theoretical concept. The smaller the VSWR, the better the antenna is matched to the transmission line and more power is delivered to the antenna. However. VSWR value below 2 is considered suitable for most antenna applications. From the graph, between 2.4 GHz and 5 GHz increase in frequency increases the VSWR. With the patch antenna, the characteristics of the VSWR seems to vary in the same pattern as the return loss. The characteristics of the return loss graph in terms of its presentation is almost similar to that of the VSWR.

*C. Far Field Polar Plot*

From the polar plot, the radiation pattern is on a broad angular range in a specified direction thereby depicting a broad beam width. This implies that, antennas at lower frequency radiates in all direction. Since the directivity is directly proportional to the gain of the antenna, it can be said that for a lower frequency the gain finds application in Wi-Fi broadcasting or even as a receiver.

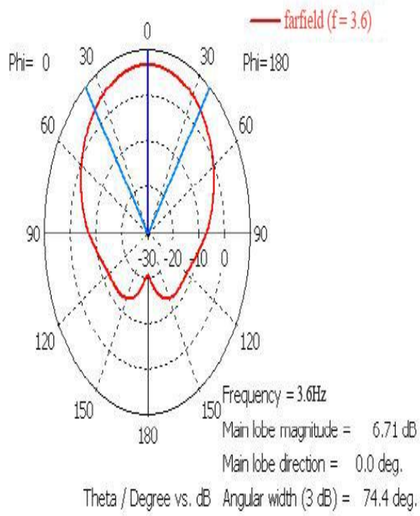


Figure 12. Radiation pattern at 3.6GHz.

In Figure 12, the antenna is radiating in all direction and this shows that at 3.6GHZ the antenna radiates normal to its patch source. The main lobe direction is at 0.0 degree. It is shown that at 180 degrees the magnitude of the antenna seems to have decreased to almost zero where as the main lobe have a magnitude of 6.71dB.

*D. The Three Dimensional View of the Microstrip Patch Antenna*

The three dimensional plot shows the main lobe as well as the side lobe. Although the side lobe is not very obvious when compared to a two dimensional plot.

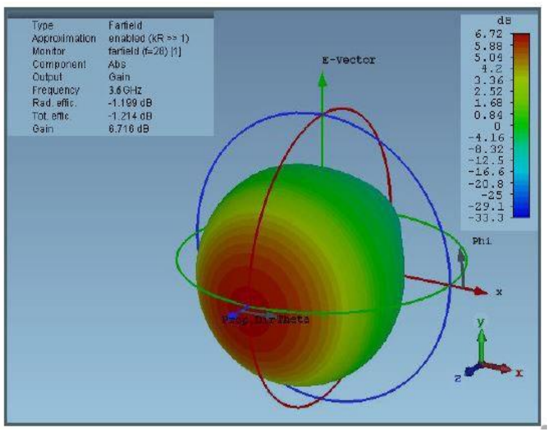


Figure 13. Radiation pattern 3D at 3.6GHz simulation result.

The plot also shows that the directivity concentrates more in the region with the orange colour. It can also be said that; as the radiating angle increases, the directivity of the patch antenna also decreases. It is worth noting that; when the antenna is operating at higher frequency the directivity will be almost fixed.

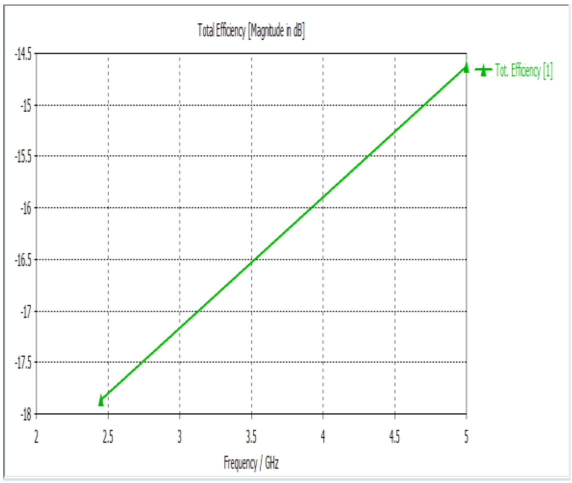


Figure 14 Total radiation efficiency

The graph of figure 14 shows the total radiation efficiency of the antenna. This efficiency may decreases as the frequency increases.

## V. CONCLUSIONS

Microstrip patch antenna is recommended for 5G applications because they are easy to fabricate, light in weight and very compact. With the help of CST studio, the antenna can be designed upon analysis and virtually fabricated to investigate design parameters. All materials which are necessary in modelling the said antenna are found in the CST Studio. Based on the results of the proposed 5G antenna, the patch showed the required design features. Results of the radiation pattern, antenna gain, return loss, efficiency and the VSWR of the microstrip 5G antenna aligned with design requirement.

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