iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** I **Month of publication:** January 2022

DOI: https://doi.org/10.22214/ijraset.2022.39799

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue I Jan 2022- Available at www.ijraset.com

Investigation on Performance of Microstrip Patch Antenna for a Practical Wireless Local Area Network (WLAN) Application

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Abstract: The performance of a microstrip patch antenna for a practical wireless local area network application is investigated in this research. This design is built around the transmission line concept. The antenna design substrate is FR4 (lossy) with a dielectric constant (Er) of 4.3 dielectric material, and the ground and patch materials are copper (annealed). The substrate is 71.62mm in width and 55.47mm in length. The height of the dielectric material is 1.6mm, which is the normal size for FR4 material. The conducting patch element has a width of 35.81mm and a length of 27.73mm for a resonance frequency of 2.573 GHz. A simulation with CST studio suite was used to optimise the antenna design.

Keywords: Microstrio patch antenna, CST suite, WLAN application, Transmission line, Antenna design

I. INTRODUCTION

Low-cost, low-profile antennas are in high demand in modern communications [6]. The frequency spectrum is a valuable asset in telecommunications, and each band is dedicated to a unique function [4]. In wireless applications microstrip patch antennas are widely used because of its advantages such as easy feeding, light weight, portability, easy integration with external circuitry as well as radiation characteristic that is attractive [1]. These benefits make micro strip patch antennas ideal for applications such as WLAN, WiMAX, satellite communication, and many more [2]. Wireless local area networks with broadband, high capacity, and high speed are becoming increasingly common nowadays, whether indoors or outdoors [3]. A microstrip patch antenna offers several advantages, but it also has certain drawbacks, such as narrow bandwidth and poor strength. Wideband could be produced by making changes to the patch size or introducing slots. Different feeding approaches, on the other hand, could be used to attain large gains. Microstip patch antennas are available in a variety of shapes, including rectangular, elliptical, annular ring, and triangular [5]. A thick dielectric substrate with a low dielectric constant is preferred for optimum antenna performance since it gives more efficiency, bandwidth, and radiation [6]. The dielectric constant, frequency, and height of the substrate must all be determined before the antenna can be designed [9].

II. DESIGN METHODOLOGY

There are several ways for analyzing microstrip patch antennas, including the transmission line model, cavity model, and moment approach [7].

III. STEPS OF DESIGN

The transmission line concept is used as the basis for this design. The equations for transmission lines are as follows:
The following equations can be used to obtain the design parameters.

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (1) \qquad [8]$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + \frac{12h}{W}}} \qquad (2) \qquad [10]$$

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

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \qquad (4)$$

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$$L = L_{eff} - 2\Delta L \quad (5)$$

$$L_g = 2L \quad (6)$$

$$W_g = 2W \quad (7)$$

$W = Width\ of\ the\ patch$
c = speed of light
$\varepsilon_r = Di\ electric\ constant\ of\ substrate$
Wg = Substrate Width
Lg = Substrate Length
$f_r = Resonant\ frequency$
ε_{reff} = Effective Dielectric Constant

In order to carry out the simulation with the CST studio suite, I created a new project template with settings tailored to microwave and RF/Optical. The planar was selected, time domain chosen, and the units were chosen as well. I then clicked finish after selecting the frequency range and monitoring the farfield at 2.573GHz. After that, the design parameters for the WLAN application were chosen. I created bricks from the modelling task bar and then press ESC on the keyboard. I created a ground plane, a substrate, a patch, and some empty space. The empty space is cut and a new one is created. The feed line is also created. I press patch then enter to verify that the patch and feed lines are combined into one item. To run the simulation, I selected wave guide port from simulation, then initiate some settings, and the antenna is ready to run. By selecting simulation, then set up solve, and run the simulation.

IV. RESONANCE FREQUENCY

The operating or resonance frequency of the antenna is calculated using equation 8.

$$f_r = 2.45\,GHz + (last\ 3\ digits\ of\ Student\ matric\ number/2)\ \text{MHz} \quad (8)$$

$$f_r = 2.45\,GHz + (last\ 3\ digits\ of\ 1850246/2)\ \text{MHz}$$

$$f_r = 2.573\,GHz$$

V. THICKNESS OF GROUND, SUBSTRATE AND PATCH

The ground and patch materials are copper (annealed), and the antenna design substrate is FR4 (lossy) with a dielectric constant (Er) of 4.3 dielectric material.The substrate has a width of 71.62mm and a length of 55.47mm. The dielectric material's height is set at 1.6mm, which is the standard size for FR4 material. For a resonance frequency of 2.573 GHz, the conducting patch element has a width of 35.81mm and a length of 27.73mm.

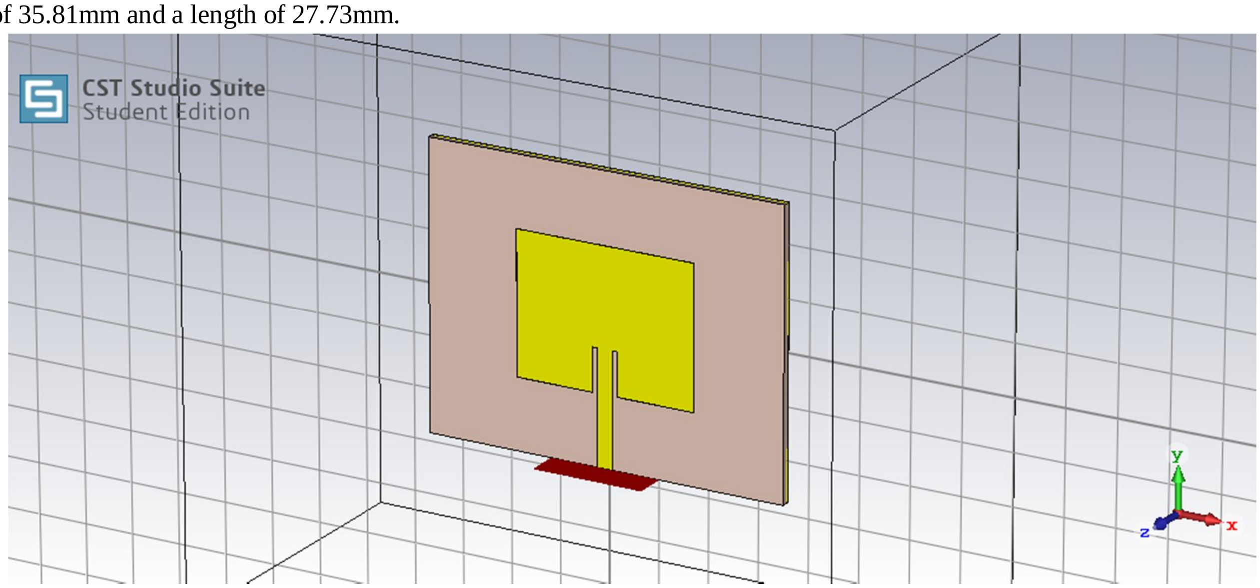

Fig. 1: Design geometry (a)

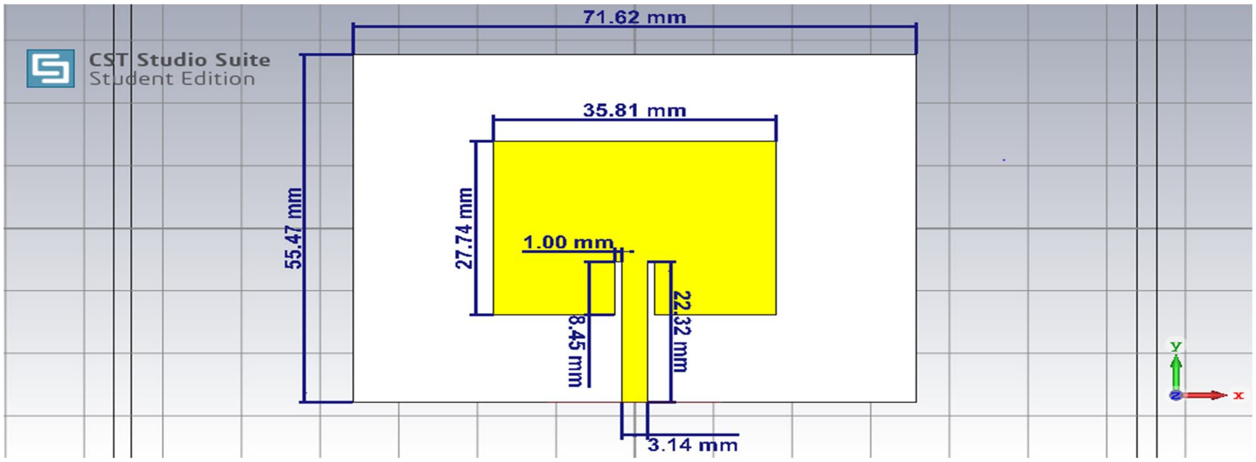

Fig.2: Design geometry (b)

VI. CALCULATION OF WIDTH AND LENGTH

The calculation of width and length was done by substituting the design parameters in Table 1 using the equations 1 – 7. The width and length are important calculation in microstrip patch antenna because the input impedance is controlled by the antenna's width. The higher the width, the higher the bandwidth and the lower the width, the lower the bandwidth. Increasing the width reduces the impedance; however, lowering the input impedance may necessitate a very broad patch antenna, which takes up more space and regulates the pattern of radiation.

VII. DESIGN PARAMETERS

The design parameters for the simulation in CST Studio Suite (Student Edition) is shown below

Table 1: Design Parameters

PARAMETERS	VALUE
Matric No:	1850246
3 Last Digits:	246
Resonant Frequency	2.57GHz
Dielectric Constant	4.3
Speed of Light, c	300000000 m/s
Height of the Dielectric Substrate(hs)	1.6mm
Patch Width (W)	35.81mm
Effective Dielectric Constant	3.98
Extension Length	0.74mm
Effective Length	29.22mm
Patch Length (L)	27.73mm
Substrate Width (Wg)	71.62mm
Substrate Length (Lg)	55.472mm
Conductor Height (ht)	0.035 mm
Gap between the patch and inset-fed (Gpf)	1
Microstrip feed line width (Wf)	3.14mm
Inset Length (Fi)	8.45mm

VIII. TESTS/RESULTS AND EVALUATION

A. Radiation Pattern

The power radiated by an antenna is defined by its radiation pattern. At 2.573GHz, the radiation pattern is depicted in Figure 3. At 2.573GHz, the main lobe magnitude is -6.96Db, the main lobe direction is 1.0 degree, and the angular width(3db)=93.6. The side lobe level is -13.4Db, as shown in Figure 2.3 (a).

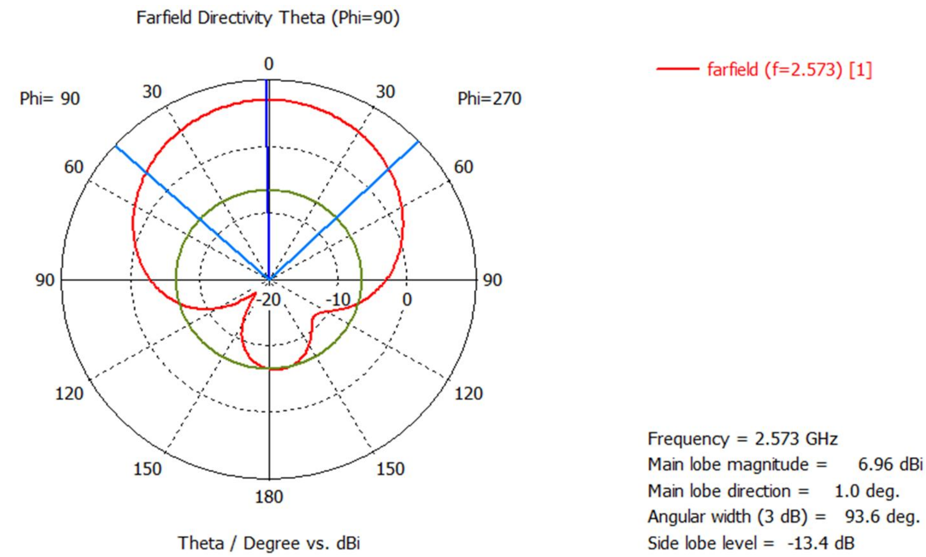

Fig.3 (a): Radiation pattern

Fig.3 (b): Radiation pattern shows that the main lobe magnitude is -2.54dB, the main lobe direction is 60.0 degrees, and the angular width (3dB) is 166.9 degrees.

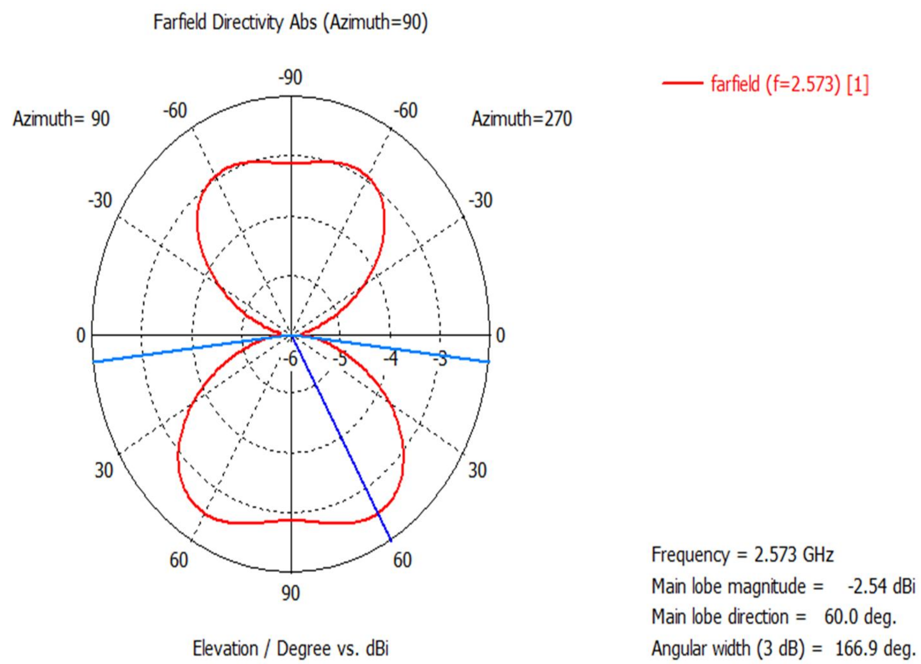

Fig. 3 (b): Radiation pattern

B. Input Impedance

Fig. 4 depicts the smith chart of the designed antenna which shows that impedance is 48.64 ohms at 2.573GHz ,impedance matching is therefore achieved .

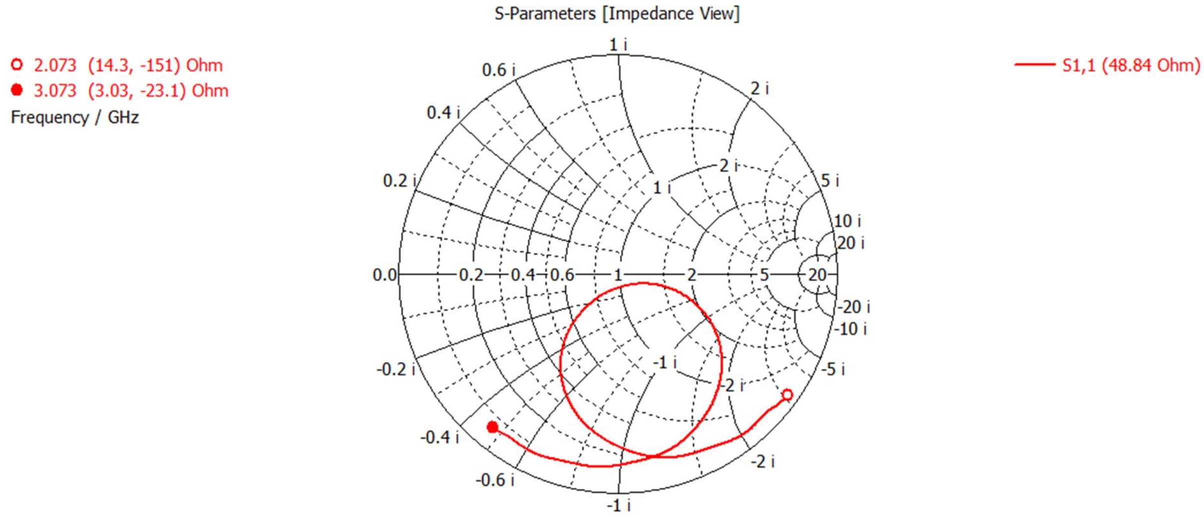

Fig. 4 : Smith Chart

C. Return Loss

The simulated was done based on CST studio suite (student version). The antenna resonates at the expected frequency of 2.573 GHz, with a -7.21 return loss, according to the simulation results.

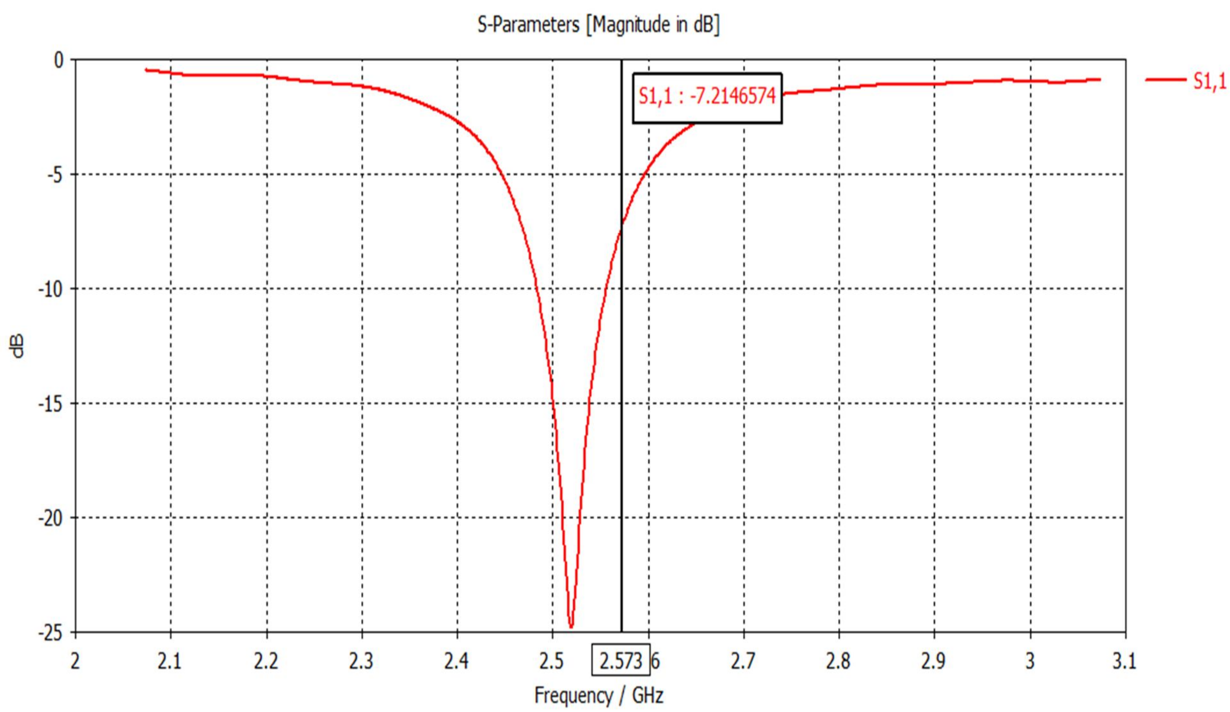

Fig. 5: Return Loss

D. Voltage Standing Wave Ratio

Figure 6 depicts VSWR and justify better matching of the designed antenna with -7.21 VSWR at frequency 2.573GHz

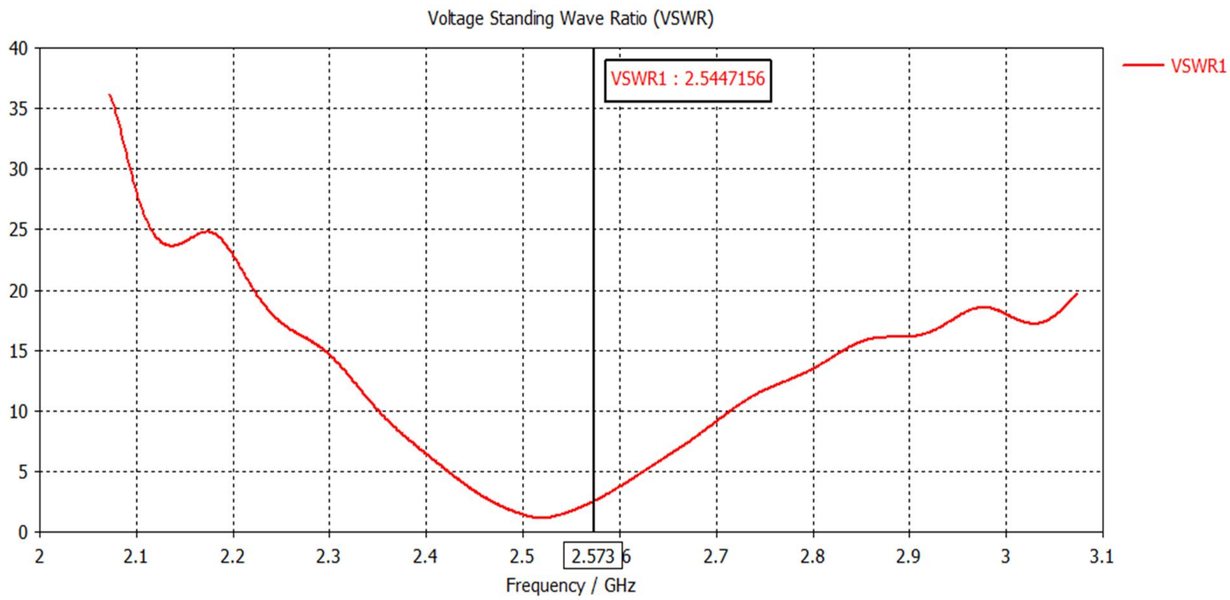

Fig. 6: VSWR

E. Radiation Efficiency and Total Efficiency

The simulation results in figure 2.7 show a good radiation efficiency and total efficiency of -4.93dB .

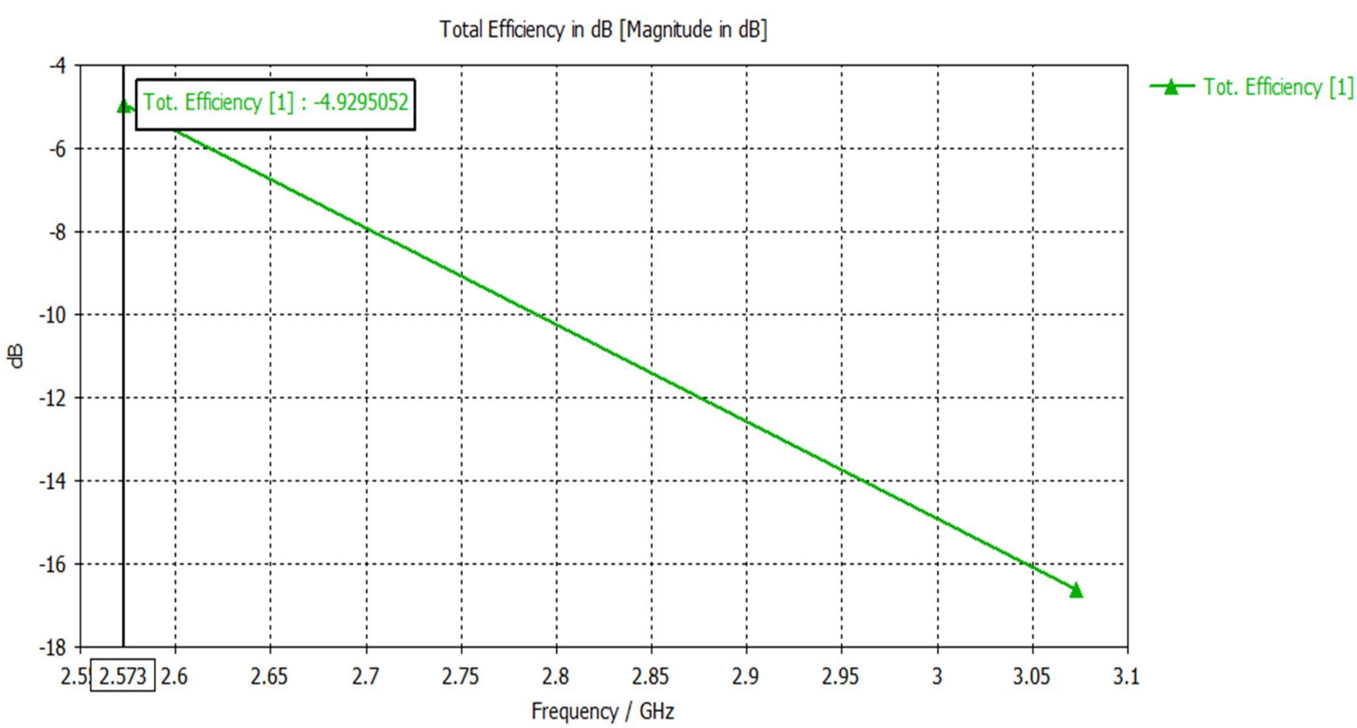

Fig. 7: Radiation efficiency and total efficiency

F. Surface Currents

The distribution of current throughout entire surface of patch element is presented in figure 2.8(a) and figure 2.8(b)

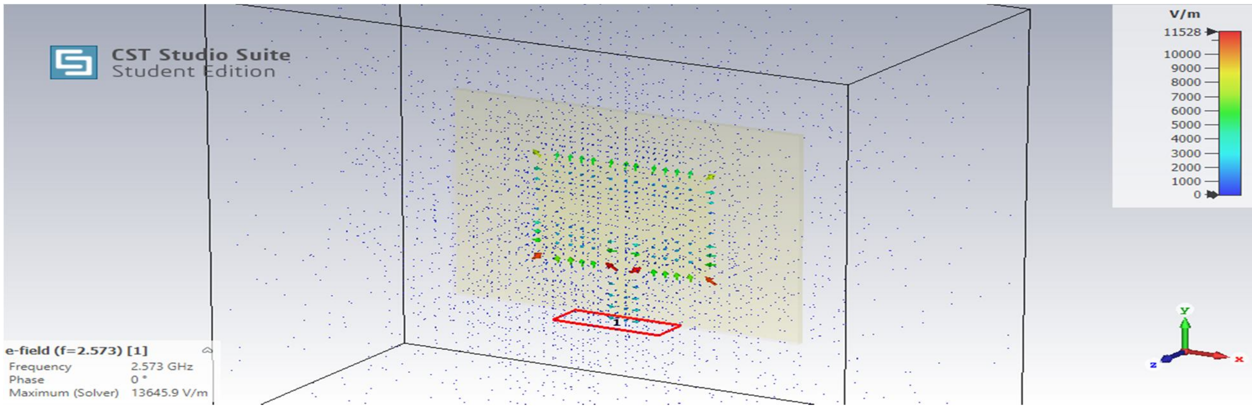

Fig. 8(a): Surface current distribution

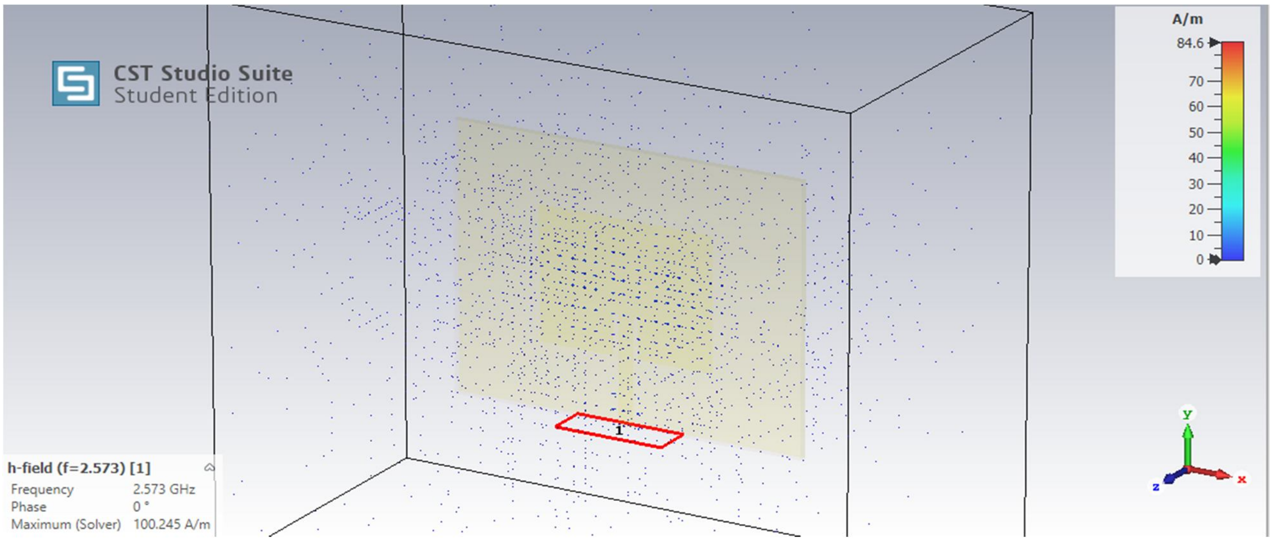

Fig. 8(b): Surface current distribution

G. Antenna Gain

The detail analysis of loss in dielectric, loss in metals, power absorbed at all parts, power accepted power outgoing all ports ,power accepted, power absorbed at all ports, power radiated and power stimulated is shown below.

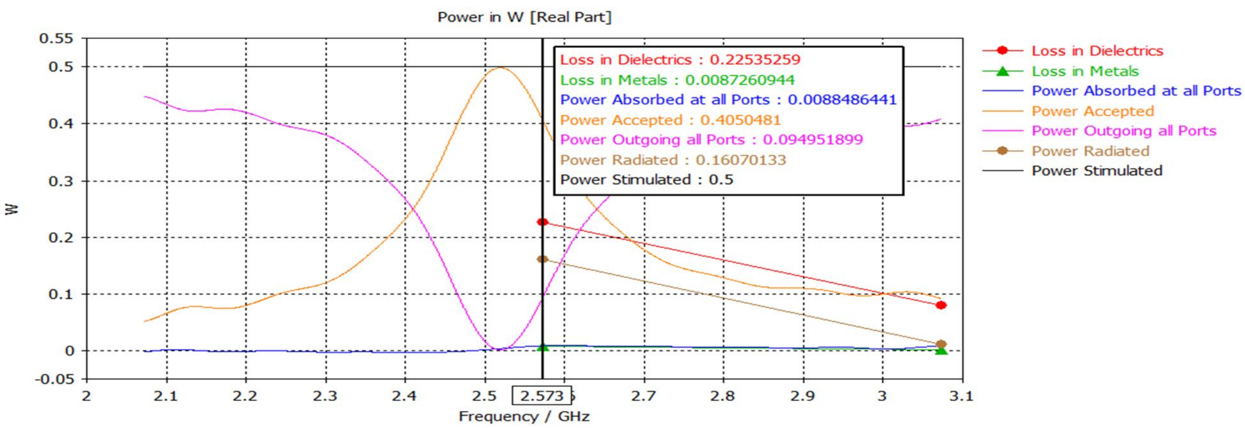

Fig. 9: Power Analysis

IX. CONCLUSION

The designed antenna has been optimized using a simulation approach based on CST studio suite (student version) in this research. As a result, the designed antenna is compatible for practical WLAN application because of its small size, low antenna substrate, designed gain, radiating pattern, return loss, and VSWR achieved.

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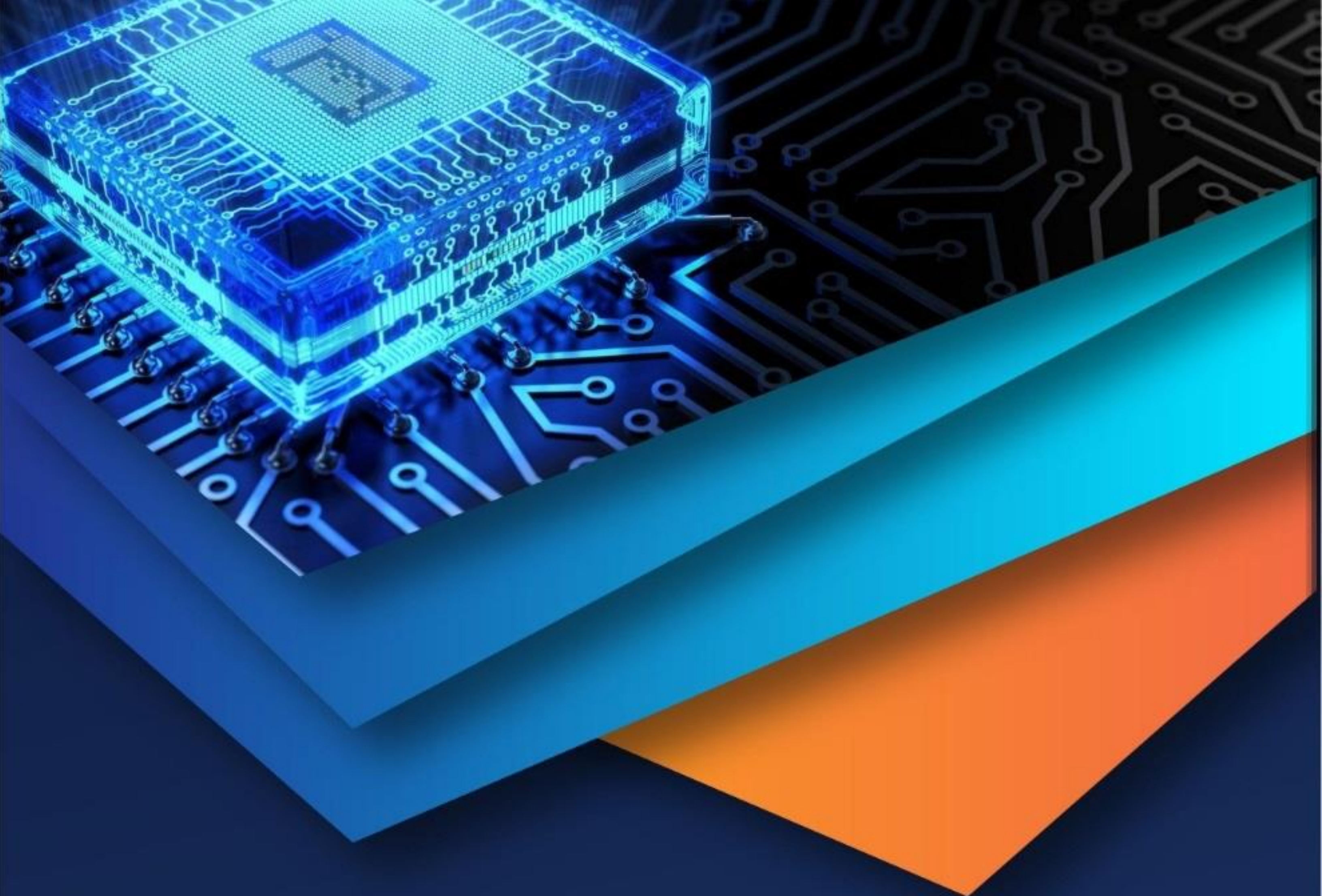

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