Design and Analysis of Rectangular Microstrip Patch Antenna

Final Year Project Report
Submitted in partial fulfillment of the requirements for the degree of
Bachelor of Technology
in
Information Technology

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12 June, 2023

Certificate

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It is certified that the work contained in the project report entitled "Design and Analysis of Rectangular Microstrip Patch Antenna" by the following students has been carried out under my/our supervision and that this work has not been submitted elsewhere for a degree.

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Date:

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Prof. Aditya Kumar Samanta

This project report entitled "Design and Analysis of Rectangular Microstrip Patch Antenna" submitted by the group is approved for the degree of Bachelor of Technology. The viva-voice examination has been held on_______________.

____

Head of Dept. of Information Technology.

Declaration

JGEC Jalpaiguri

12 June 2023

I would like to express my sincere gratitude and appreciation to all those who have contributedto the successful completion of this project report on the "Design and Analysis of Rectangular Microstrip Patch Antenna". The development of this report would not have been possible without the support and collaboration of various individuals and organizations.
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12 June 2023

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Abstract

This abstract aims to provide a concise introduction to microstrip patch antennas, highlighting their key features and applications. It serves as a starting point for further exploration and research in the field of microstrip patch antenna design and implementation. A microstrip antenna, also known as a patch antenna, is a type of planar antenna that is constructed on a thin dielectric substrate and typically consists of a metallic patch or strip placed on one side of the substrate. It is a type of radio antenna that can be mounted on a lower surface. Microstrip antennas find applications in various fields, including wireless communication systems, satellite communication, radar systems, mobile devices, and aerospace applications. In this paper the design and development of microstrip patch antenna using the FR4 substrate with thickness 1.5mm and with 4.3 dielectric constant has been discussed. The design and optimization of microstrip patch antennas involve considerations such as the choice of substrate material, patch dimensions, feeding techniques, and impedance matching. The patch's width is 37.40mm and length is 28.79mm at a resonance frequency of 2.4GHz.

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Introduction

An antenna is a transducer for transmission and reception of electromagnetic waves from a transceiver employed in any wireless communication system. This the most essential component of any wireless communication system. There are many performance parameters such as antenna gain, effective length, bandwidth. There are several types of antennas that include wired, monopole, dipole, microstrip patch.

Microstrip patch antenna primarily consist of conducting path having either non-planar or planar geometry. The conducting path known as patch and ground plane exist on either side of dielectric substrate, as depicted in figure.

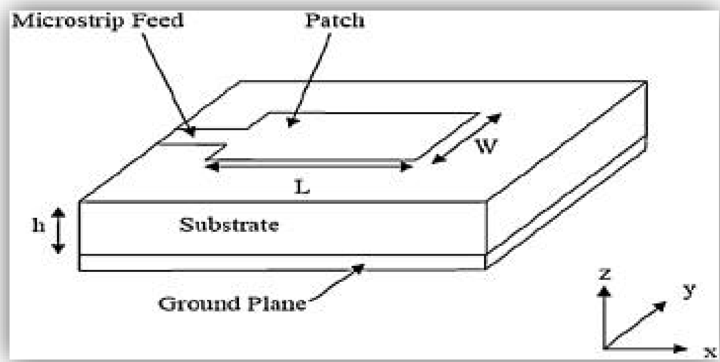

Fig:1

Basic Structure of Microstrip Patch Antenna Microstrip antennas, in general, can be categorized as Microstrip travelling antenna, printed dipole antenna and microstrip patch antenna. The first two types can have circular, rectangular, triangular, or elliptical shape only whereas there is no constraint on any specific geometrical shape for design of microstrip patch antenna. Moreover, they are very light in weight, have planar structure, has economic efficiency and are suitable for both planar and non-planar surfaces for installation purpose. They find applications in aircraft, satellites and missile systems. Its narrower operating bandwidth and lower gain, there are restrictions in its use in conventional wireless systems. The various applications are:-

Wireless Standards	Frequency
1G Analog Cellular Standard	824 - 849 MHz; 869 - 895 MHz
2G GSM Standards	890-915 MHz and 935-960 MHz
PCS	1.85 - 1.99 GHz; 2.18 - 2.2 GHz
Cellular Video	28 GHz
Wireless LAN	2.40 - 2.48 GHz; 5.4 GHz band
Wide Area Wireless Networks	60 GHz

Table: 1

The simplicity and versatility of microstrip patch antennas make them highly attractive for various applications. The antennas can be designed to operate at different frequencies, ranging from a few megahertz (MHz) to several gigahertz (GHz), depending on the dimensions of the patch and the substrate material properties. By adjusting the patch dimensions and shapes, the resonant frequency of the antenna can be used to meet specific frequency requirements.
One of the key advantages of microstrip patch antennas is their planar structure, which allows for easy integration with printed circuit boards (PCBs) and other electronic components. This integration capability facilitates the development of compact and lightweight systems, making them suitable for portable devices and space-constrained applications. Substrate is important in the design of antenna and selection of appropriate substrate is vital because it has an affect over the electrical performance. Also it gives the required mechanical support to antenna. Table 2 presents commonly used layer material in microstrip patch antenna.

Type of Layer	Type of Material Used
Microstrip Line	Copper
Patch	Copper
Substrate	Dielectric substrate material
Ground plane	Copper

Table: 2

The goal of the study is to address the growing need for wireless communication in a variety of applications. By this proposal paper works going on,

- Increase an antenna’s bandwidth
- Antenna gain improvement

Literature Study

After examining and analyzing the existing published research and scholarly articles related to our project on antenna design, we gather some information about various antennas. They are:

1. Dipole Antenna: A dipole antenna consists of two conductive elements, typically in the form of straight rods or wire.
2. Monopole Antenna: A monopole antenna is similar to a dipole antenna but consists of a single conductive element above a conductive ground plane. It is commonly used in applications where a ground plane is available, such as in radio and television broadcasting.
3. Loop Antenna: A loop antenna is a closed-loop of wire or conductor that forms a loop shape. It can be either a simple loop or a coil. Loop antennas are often used for receiving AM radio signals.
4. Yagi-Uda Antenna: The Yagi-Uda antenna, also known as a Yagi antenna, is a directional antenna that consists of a driven element, one or more directors, and a reflector. It is widely used for long-range communication and television reception.
5. Horn Antenna: It has a wide bandwidth and is often used for microwave and radar applications.
6. Patch Antenna: A patch antenna, also known as a microstrip antenna, is a flat metallic patch on a dielectric substrate. It is commonly used in mobile devices, wireless communication systems, and RFID applications.
7. Helical Antenna: A helical antenna is a three-dimensional structure that consists of a wire wound in the shape of a helix. It is often used for satellite communication, GPS systems, and amateur radio.

TYPES OF DIPOLE ANTENNA ACCORDING TO SHAPE

- Straight Dipole Antenna
- Folded Dipole Antenna
- Bowtie Dipole Antenna
- Discone Antenna:

TYPES OF LOOP ANTENNA ACCORDING TO SHAPE

- Circular Loop Antenna.
- Rectangular Loop Antenna
- Elliptical Loop Antenna.
- Octagonal Loop Antenna:

TYPES OF MONOPOLE ANTENNA ACCORDING TO SHAPE

- Whip Antenna.
- Sleeve or Tubular Monopole:
- Planar Monopole Antenna.
- Cone or Conical Monopole.
- Blade or Patch Antenna.

TYPES OF YAGI-UDA ANTENNA ACCORDING TO SHAPE

- Straight Yagi-Uda Antenna.
- Tapered Yagi-Uda Antenna.
- Stepped Yagi-Uda Antenna.

TYPES OF HORN ANTENNA ACCORDING TO SHAPE

- Rectangular Horn Antenna
- Pyramidal Horn Antenna
- Conical Horn Antenna
- Sectoral Horn Antenna

TYPES OF PATCH ANTENNA ACCORDING TO SHAPE

- Rectangular Patch Antenna
- Square Patch Antenna
- Circular Patch Antenna
- Triangular Patch Antenna

	A	B	C	D	E
1	**NAME**	**GAIN(dBi = 10log(ηD))**	**DIRECTIVITY**	**FREQUENCY**	**Radiation Pattern**
2	**DIPOLE antenna**	1.64 (2.15 dBi)	1.64 or 2.15 dBi.	2.2 GHz.	omnidirectional antenna
3	Straight Dipole Antenna	1.5 (1.76 dBi)	1 (or 0 dB).	216 MHz	omnidirectional antenna
4	Folded Dipole Antenna	2.735 and 2.989 dB	2.15 dBi;	300MHz	Omni-directional antenna
5	Bowtie Dipole Antenna	1.5 (1.76 dBi)	1 db	120 MHz	Omni-directional antenna
6	Discone Antenna	1.75 to 2.3 dBi.	1 (or 0 dB).	862 MHz	Omni-directional antenna
7	**LOOP ANTENNA**	8.2 dBi.	1.5 (1.76 dB)	3GHz	Omni-directional antenna
8	Circular Loop Antenna	3.694dB	1 dbi	90MHz.	Omni-directional antenna
9	Rectangular Loop Antenna	7.5 dBi	1 dbi	53 MHZ	Omni-directional antenna
10	Elliptical Loop Antenna	4.4dbi	1.5 dbi	30 MHz	Omni-directional antenna
11	Helical Loop Antenna	2.5 dB	1 dbi	3GHz	Omni-directional antenna
12	**MONOPOLE ANTENNA**	2.15 dBi	4.2dB	2 GHz	Omni-directional antenna
13	Whip Antenna	4 dBi	2.15 dBi;	1.9 GHz	Omni-directional antenna
14	Planar Monopole Antenna	4.9 dBi	1.25 dbi	900 MHz	Omni-directional antenna
15	**YAGI-UDA ANTENNA**	20 dBi	10 dBi	3GHz	directional antenna
16	**HORN ANTENNA**	25 dBi	20 dB	20 GHz	Omni-directional antenna
17	**PATCH ANTENNA**	9 dBi	5-7 dB	2.4 GHz	Omni-directional antenna
18	Rectangular Patch Antenna	5.6692 dB	5-7 dB	5.2 GHz	Omni-directional antenna
19	Square Patch Antenna	9.179 dB	5-7 dB	2.4 GHz	Omni-directional antenna
20	Circular Patch Antenna	3 dB	5-7 dB	2.42 GHz	Omni-directional antenna
21	Triangular Patch Antenna	2.9 dB	5-7 dB	2.4 GHz	Omni-directional antenna
22	Hexagonal Patch Antenna	5.32 dB	5-7 dB	10.6 GHz	Omni-directional antenna

Table: 3

Design Process

Step I:

- Create Project Template.
- Select Microwave & RF/ Optical and select antenna.
- After that we need to select Planar Workflow as we are going to work with Microstrip Patch Antenna and then select time domains (for wideband or multiband antennas).
- Then select the units (dimension, frequency, temperature,voltage etc.)
- Then select the fields for measuring antenna frequency of 2.0GHz as minimum and 2.8GHz as maximum and the resonance frequency is set to 2.4GHz.

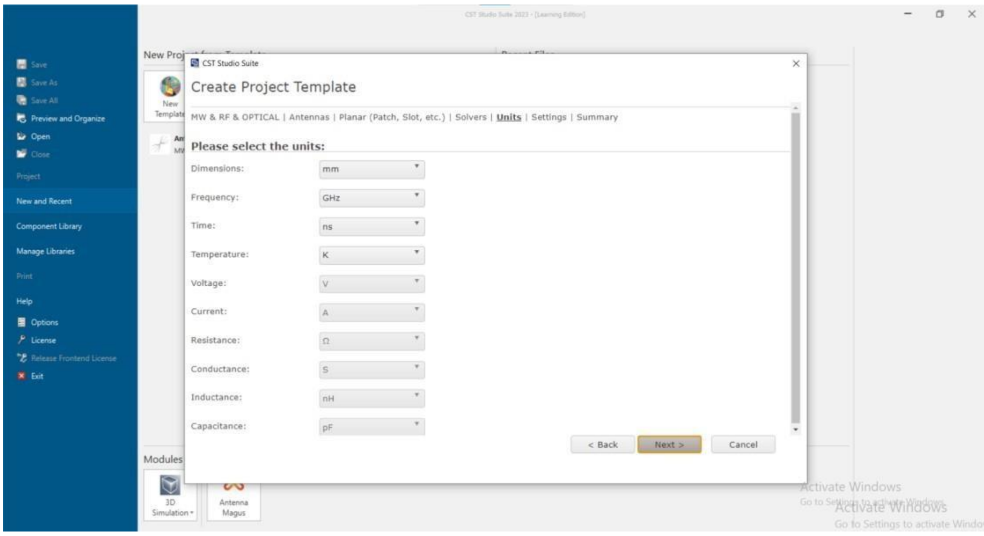

Fig:2

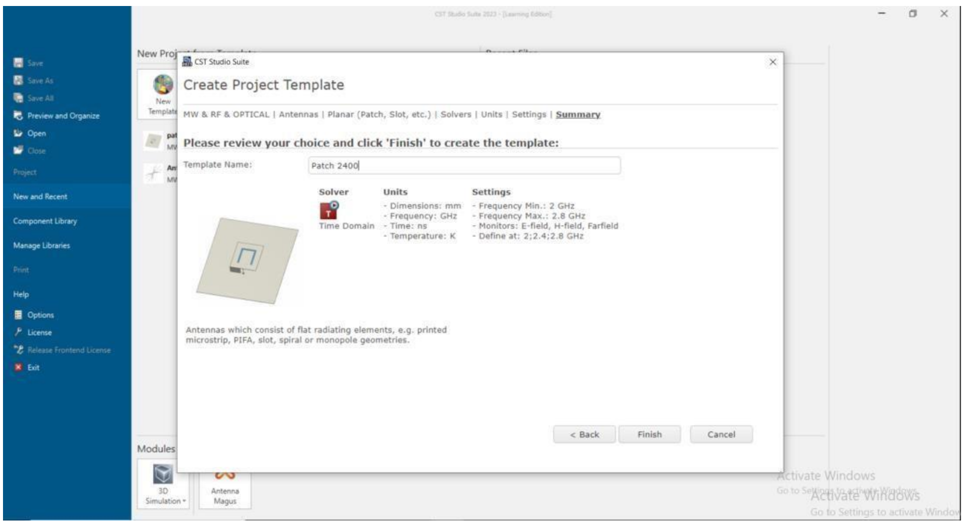

Fig:3

Step II:

- Next we need to give the antenna name and after that 3D shaped antenna will appear.
- In order to do conversions or calculations we can refer to www.pasternack.com and put the values for dielectric constant, dielectric height, operational frequency.

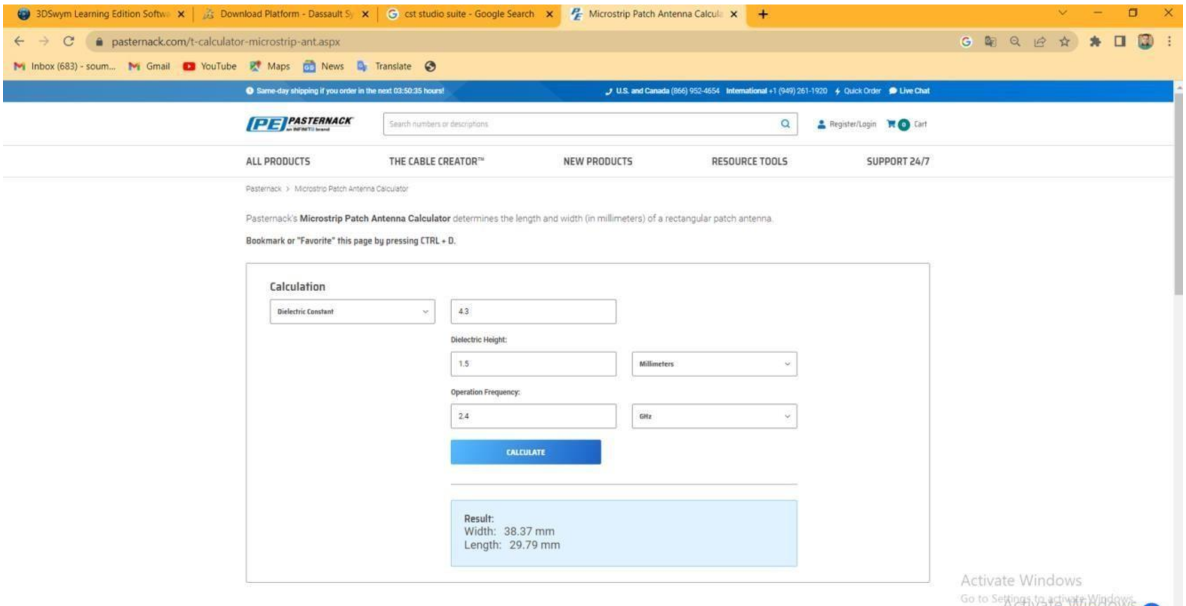

Fig:4

Step III:

- Now let's move on to the modelling tab and select brick which will help create ground plane , the antenna we want to design will be on X-Y plane.
- Select ground material (annealed copper/ pure copper), here the annealed copper is taken because it is a good conducting material and then press on load button and then preview.
- Again select brick and create substrate and then select FR-4 (Lossy) and then we will be able to see the dielectric constant that we put the values, then load and preview.
- The substrate depth is same as the dielectric height and the base is finally created.
- Again in order to create Antenna, select brick with certain measurements and annealed copper as material and the second layer of copper is created.

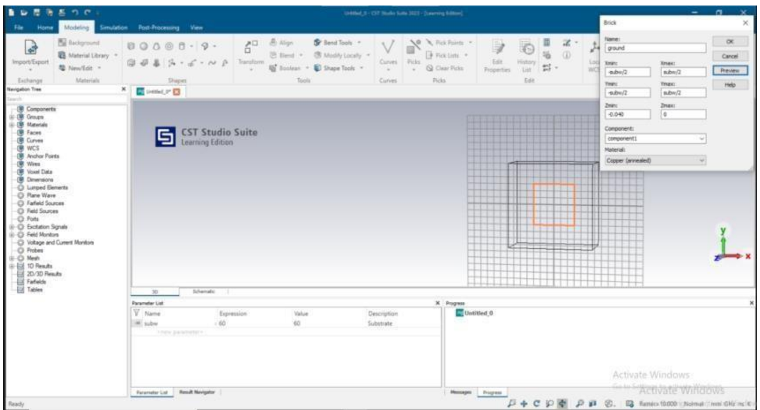

Fig:5

Step IV:

- Then press esc and select brick and name transmission line with certain measurements and select annealed copper material and press preview and then define the parameters
- Then select brick and press esc to create inset(increses the antenna performance) with certain measurements and select annealed copper material and after defining the parameters an inset is created just above the antenna line and in order to do inset on both sides we need to copy.
- In order to copy inset, select component, press inset option and then press transform button present above , select the mirror option and then press copy and unite to make both insets work together.
- Select Antenna from Component option and press minus from keyboard to subtract from Component Antenna.
- Add input port to the head of the transmission line and in order to select the face select f12 on keyboard and after double click a dotted-line appears and then select macros, then solver, then press ports and press to calculate port extension coefficient and then give Microstrip dimensions and select component and input port will appear.

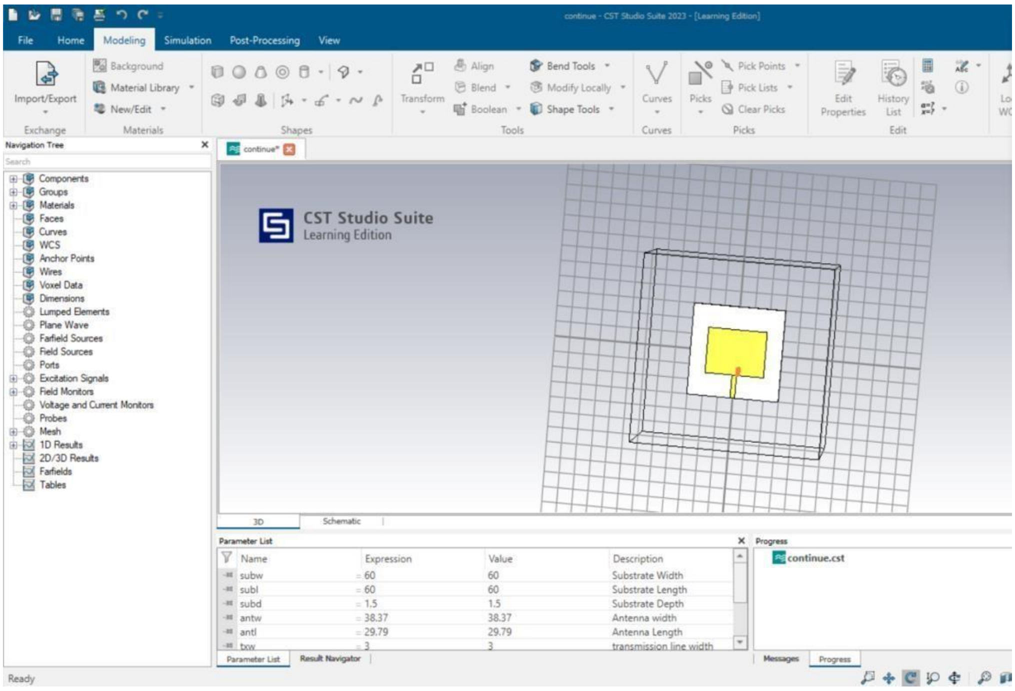

Fig:6

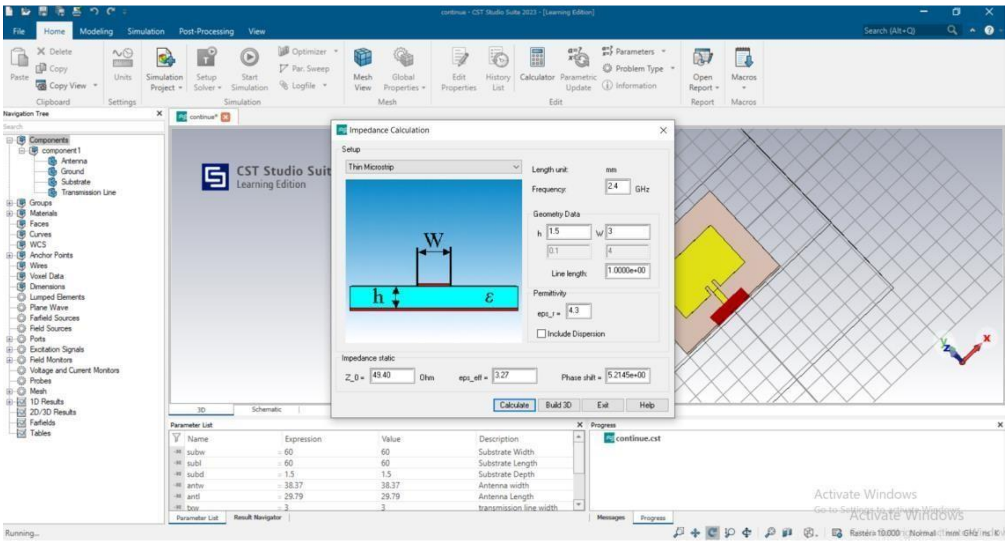

Fig:7

Results and Discussion

To stimulate the findings, Computer simulation technology CST software with student edition is utilized. This version is chosen since it is available at the university. The simulation results displayed are for the suggested design which are created using a FR4 substrate. The acquired values are in the optimal dimension. The simulated results are shown:

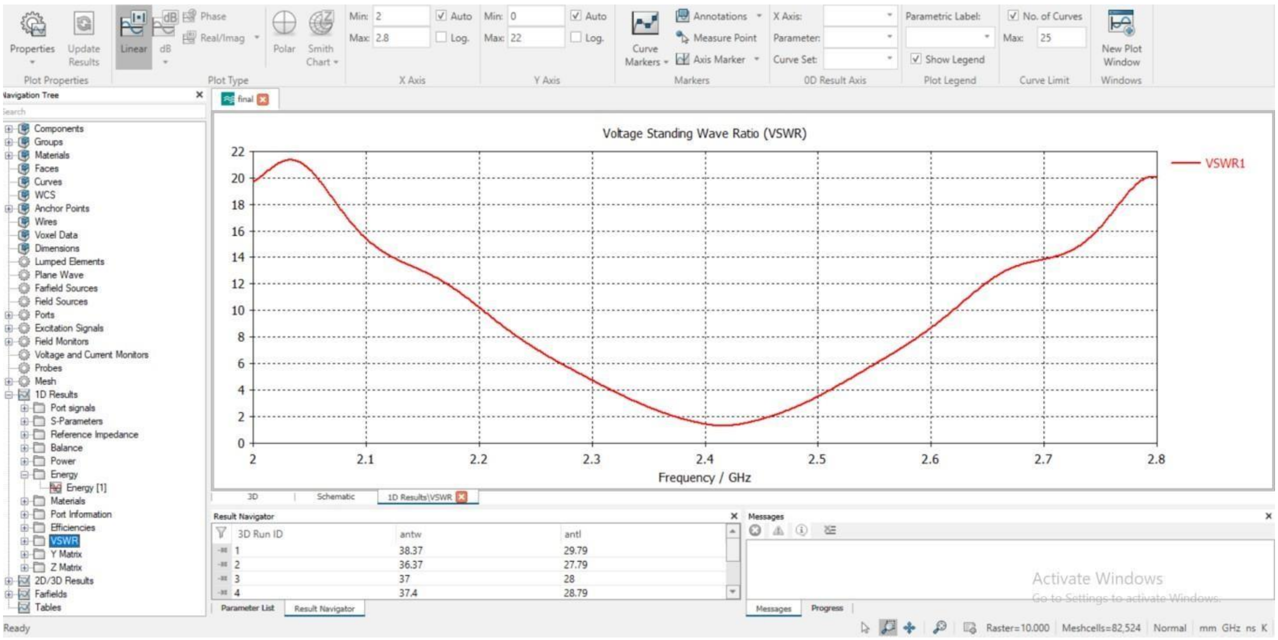

Fig:8

In this figure the voltage standing ratio is defined which measures how efficiently RF power is delivered from the source to load through transmission line.

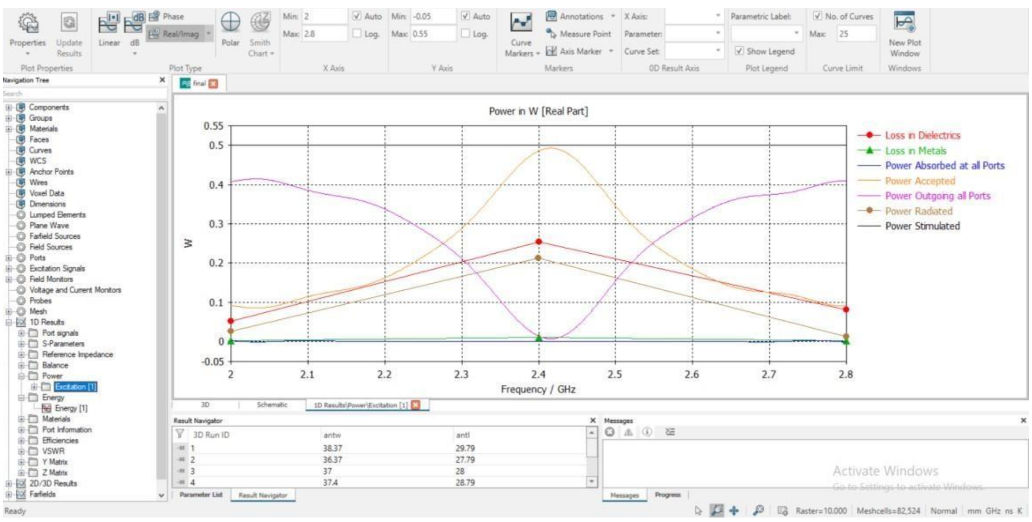

Fig:9

The radiated energy of an antenna is represented as power. It is used to supply power to an antenna and it is shown in Fig:9

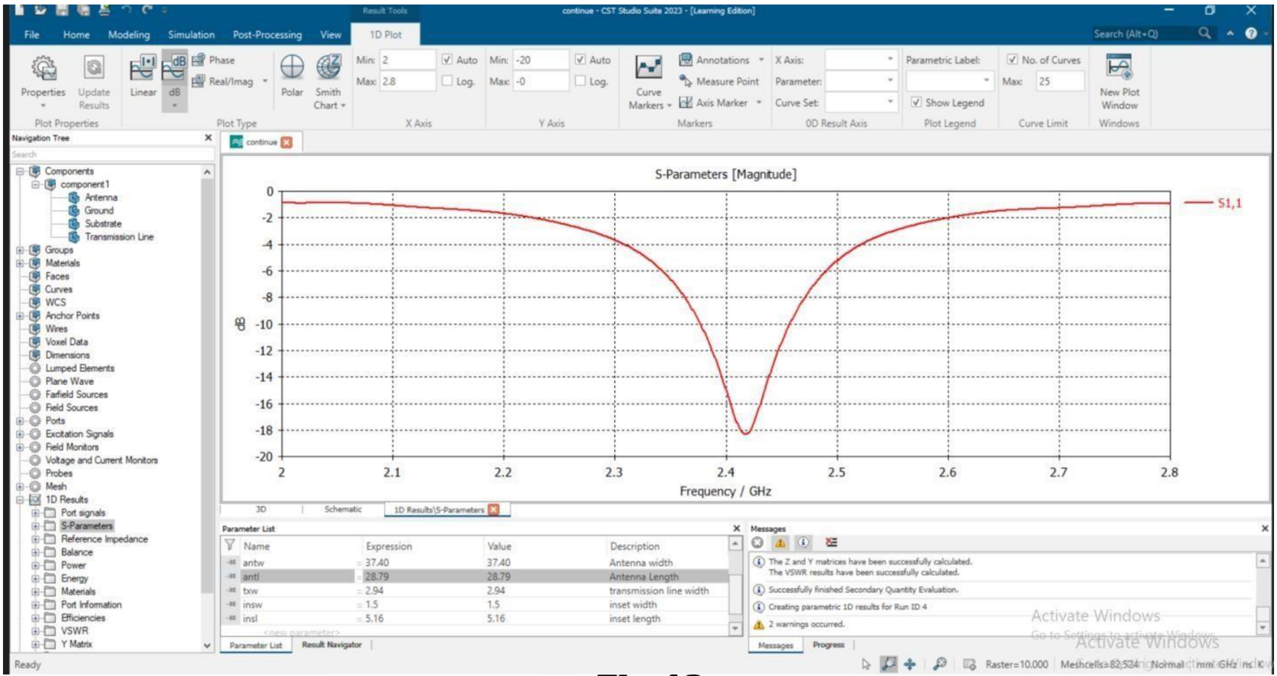

Fig:10

S-parameters (also called S-matrix or scattering parameters) represent the linear characteristics of RF electronic circuits and components.

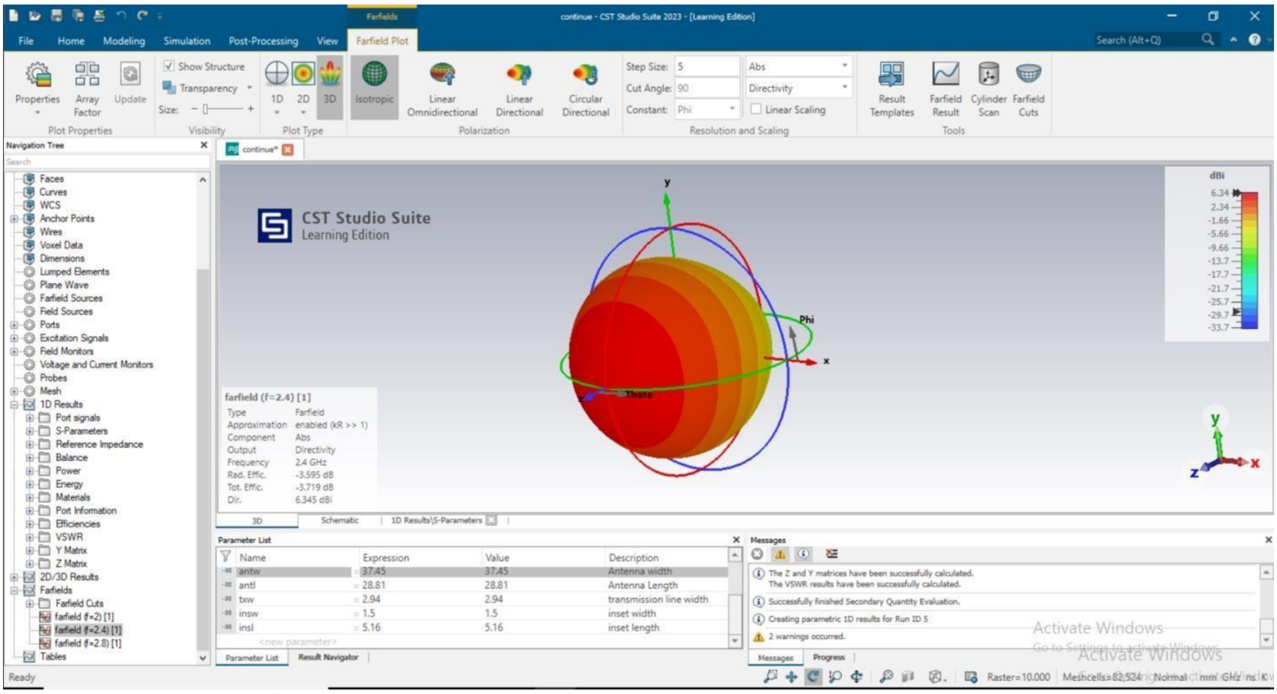

Fig:11

The far-field distance is the distance from the transmitting antenna to the beginning of the region, or far field. Antennas emit electromagnetic waves when an alternating current flows through them. In the near-field region, which is closer to the antenna, the electromagnetic fields are more complex and have significant reactive components. These fields decay rapidly with distance and do not propagate as waves.

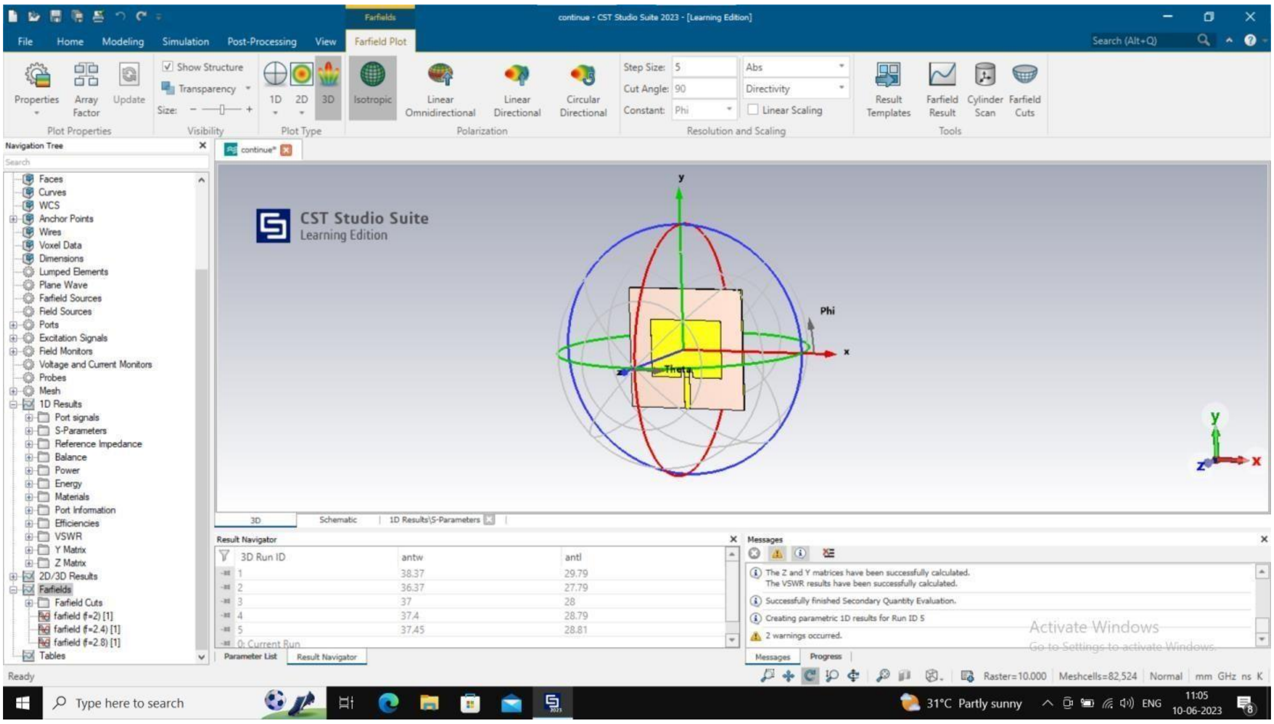

Fig:12

The radiation pattern of a microstrip patch antenna is influenced by several factors, including the shape and size of the patch, the feed mechanism, and the substrate material. However, microstrip patch antennas typically exhibit a broad radiation pattern in the plane of the patch, with a narrower pattern in the perpendicular plane. To design and analyze the radiation pattern of a microstrip patch antenna, various numerical methods and software tools are used, or commercial electromagnetic simulation software like CST Studio Suite.

Future Scope

Future scope of microstrip patch antennas holds great potential for advancements and applications in various fields. Here are some potential areas where microstrip patch antennas can contribute:

1.5G and Beyond: As wireless communication networks continue to evolve, microstrip patch antennas can play a crucial role in the development and implementation of 5G and future generations of communication systems. Their compact size and ability to operate at high frequencies make them suitable for deployment in small cell networks, Internet of Things (IoT) devices.
2.Millimeter-wave Communication: Microstrip patch antennas can be designed to operate at millimeter-wave frequencies, which are increasingly being explored for high-speed wireless communication. With the demand for high data rates and low latency, microstrip patch antennas can enable the deployment of millimeter-wave communication systems for applications such as wireless backhaul, autonomous vehicles, and ultra-high-definition video streaming.

3.Smart Antenna Systems: Microstrip patch antennas can be integrated into smart antenna systems, enabling beamforming and spatial diversity techniques. By using multiple patch elements and sophisticated signal processing algorithms, smart antenna systems can enhance signal quality, increase coverage, and mitigate interference. This is particularly relevant for wireless communication in urban environments and crowded areas.

4. Wearable and IoT Devices: The compact size and planar structure of microstrip patch antennas make them suitable for integration into wearable devices, such as smartwatches, fitness trackers, and smart clothing. They can also be utilized in IoT devices for wireless connectivity and sensing applications, enabling seamless communication and data exchange in the expanding network of interconnected devices.

5.Satellite Communication: Microstrip patch antennas are commonly used in satellite communication systems due to their low profile and lightweight characteristics. As the demand for satellite-based services grows, there is a need for smaller, more efficient, and multi-band antennas. Microstrip patch antennas can continue to play a vital role in enabling satellite communication for various applications, including remote sensing, navigation, and broadband connectivity.

6.Advanced Materials and Manufacturing Techniques: The development of novel materials, such as metamaterials and graphene, can further enhance the performance of microstrip patch antennas by enabling properties like tunability, miniaturization, and improved radiation efficiency. Additionally, advancements in manufacturing techniques, such as additive manufacturing (3D printing) and flexible substrates,can facilitate the production of customized and conformal microstrip patch antennas for specific applications.

Conclusion

In this paper we studied about the design methodology of a microstrip patch antenna using a particular shape. The methodology for design and development of microstrip patch antenna depends on various techniques used to simulate different parameters of the antenna. The proposed antenna was designed using FR4 substrate. The major performance parameters such as antenna gain, bandwidth were observed. The simulation was performed using CST software. The results indicate significant improvement in the desired performance parameters. The performance can be further improved for target parameters depending on the application.

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