DESIGN OF A 28GHZ SINGLE AND 2×1 ARRAY ANTENNA FOR 5G COMMUNICATION

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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DECLARATION

I hereby declare that this project "**DESIGN OF A 28GHZ SINGLE AND 2×1 ARRAY ANTENNA FOR 5G COMMUNICATION**" represents my work which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

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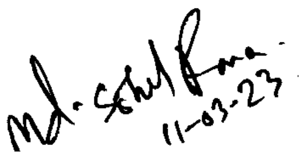
APPROVAL

The project entitled **"DESIGN OF A 28GHZ SINGLE AND 2×1 ARRAY ANTENNA FOR 5G COMMUNICATION"** submitted by **Md.Arifuzzaman (ID:191-33-883) & Md.Mahin-ur Rahman (ID:191-33-836)** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering**
in **March, 2023.**

Signature



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Dedicated

To

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LIST OF ABBREVIATIONS

MIMO	Multiple input Multiple output
SISO	Single input single output
MISO	Multiple input single output
SIMO	Single input single output
WCDMA	Wideband Code Division Multiple Access
LTE	Long Term Evolution
PCS	Personal Communications Service
CPW	Coplanar waveguide
RFID	Radio frequency identification)
PCB	Printed circuit board
FCC	Federal Communications Commission
CST	Computer simulation technology

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LIST OF SYMBOLS

Symbol	Name of the symbol
W	Width of the patch
L	Length of the patch
ΔL	Extended length of an antenna
$\in_{ref}$	Effective dielectric constant

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First of all, we want to give thanks to **Almighty Allah**. With his blessing we are able to complete our work with the best effort.

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ABSTRACT

The design and modeling of two patch antennas working at 28 GHz for use in 5G communication networks are presented in this article. First, we design a single patch antenna for mobile devices, and best results after we design a 2x1 array patch antenna arrangement for base stations. The CST software was used to build and test both antennas.

The patch antenna is 3.29 x 3.26 mm2 in dimension and has a gain of 6.56 dBi. Because of the rectangle patch and partial ground plane used in its construction, it is smaller overall and has a better radiation pattern. Good impedance matching is demonstrated by the simulation's findings, which reveal a return loss of -28.79 dB at 28 GHz.

To create a directional radiation pattern, a microstrip passed into the patches and linked in phase. At 28 GHz, with a 1.5 GHz bandwidth, the modeling results indicate a gain of 5.61 dBi and a return loss29.11 dB.11dB.

Overall, the patch antennas that have been developed work well enough to be used at 28 GHz in 5G communication devices. The single patch antenna is ideal for use in mobile phones due to its small size and high gain, whereas the 2x1 patch antenna array offers a broader frequency and higher gain for use in base stations.

Keywords:

1. Multi-band

2. 5G communication

3. Channel capacity loss

4. Diversity gain

5. MIMO antenna

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CHAPTER 1
INTRODUCTION

1.1 Background / Motivation / Introduction

Millimeter-wave frequency bands have drawn a lot of interest for use in 5G communication networks as the demand for fast wireless communication rises. Due to its abundance and comparatively low atmospheric attenuation, the 28 GHz frequency range stands out as one of the most likely options for 5G transmission.[2][4]

In millimeter-wave transmission devices, patch antennas are frequently used because of their low profile, cheap price, and simplicity of integration with other parts. The construction and simulation of two patch antennas working at 28 GHz are presented in this article. A single patch antenna for mobile devices makes up the first antenna, while a 2x1 patch antenna arrangement for base stations makes up the second.[1]

The single patch antenna is suited for use in mobile phones because of its small dimensions to the single patch antenna, the 2x1 patch antenna array is intended to have a broader frequency and a greater gain, making it ideal for use in base stations. Utilizing CST tools, patch antenna designs are created.[5]

The simulation findings demonstrate the viability of the proposed patch antennas for use in 5G communication systems at 28 GHz by displaying excellent impedance matching, gain, radiation patterns.

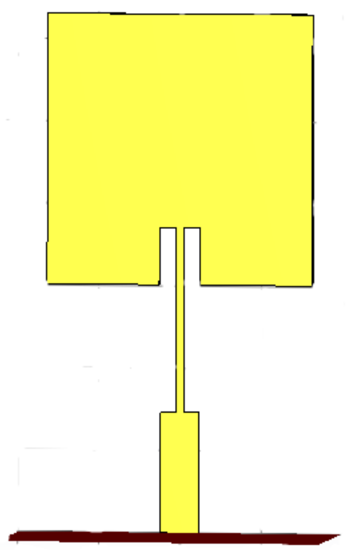

Figure 1.1: Single antenna with inset feed

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A single radiating patch element is located on one side of a dielectric base, and a ground plane is located on the other. This configuration creates a single patch antenna, a subtype of microstrip antenna. The patch is frequently made to resonate at a specific frequency and is typically made of a thin conducting substance, like copper or aluminum.

Due to their small size, low silhouette, and simplicity of integration, singsingle-patcheschs are frequently used in wireless communication systems, such as mobile phones and wireless routers. They have a broad range of uses in many industries, such as satellite communication, radar, and navigation systems, and they are also relatively cheap to produce.[6][8]

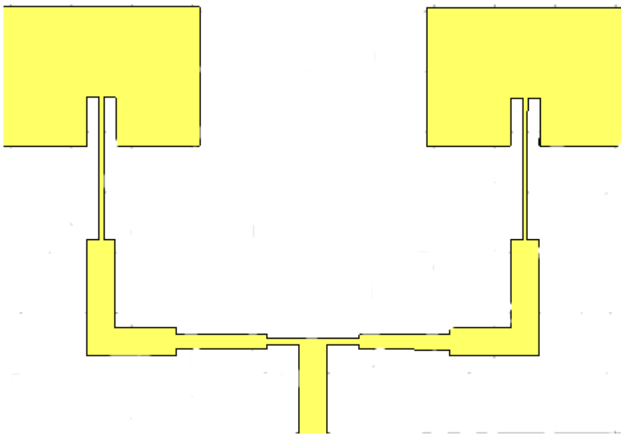

Figure 1.2: 2×1 array antenna with slot

A form of microstrip called a 2x1 array patch antenna is made up of two patch elements arranged in a linear array. The patch components are typically positioned on a dielectric substrate with a ground plane on the other side already material, such as copper or aluminum. The dimensions and material characteristics of the substrate and ground plane, as well as the size, shape, and placement of the patch elements, are all factors in the construction of a 2x1 array patch antenna. Other significant elements that can impact the performance of the antenna include the feeding system and the distance between the patch elements. A 2x1 array patch antenna can provide several benefits over a single patch antenna like increased gain, increased bandwidth, and improved control over the radiation pattern. The antenna can produce directional radiation patterns that are ideal for applications like base station antennas by modifying the distance and phase between the patch elements.[3][5]

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1.2 Problem Statement and Proposed solution

FOR SINGLE ANTENNA

Problem Statement: A single patch antenna's primary drawback is its constrained use in wideband applications due to its small bandwidth.

Proposed solution:

1. To increase the bandwidth, use various feeding methods like inset feed, aperture feed, or proximity coupled feed.
2. Reduce the electrical size of the patch antenna to improve bandwidth by using various substrate materials with low dielectric constant.
3. Use different shapes of patch antennas like circular, and triangulated, which have a wider bandwidth than rectangular patch antenna.[9]

ARRAY ANTENNA

Problem Statement: A 2x1 patch antenna's primary drawback is its intricate design, which can raise the cost of production.

Proposed solution:

1. Use an easy and effective feeding method like a corporate feed, which feeds multiple radiating elements from a single feed line.
2. Instead of using multiple substrates, use a single substrate with numerous radiating components to simplify and lower the cost of production.
3. Use simple geometry, such as a rectangular shape, for the radiating components to minimize design complexity.

1.3 Aims/ Objectives

FOR 2×1 ARRAY ANTENNA

1. Use several radiating components to raise the antenna's gain.
2. To make the radiation distribution better.
3. Increase the bandwidth of the antenna by using multiple resonant elements.
4. Achieve polarization diversity by using elements.

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FOR SINGLE ANTENNA

1. For use in tiny devices or applications where size and weight are most important.

2. Achieve a wide bandwidth to cover multiple frequency bands.

3. Achieve a high radiation efficiency by minimizing losses in the antenna structure

As a result, we have a wide range of applications, such as those for

1. Satellites
2. Missiles
3. Mobile radio
4. And wireless communication.

Microstrip antennas also have the advantage of being easy and cheap to produce. Direct printing of these low-profile antennas onto a circuit board is an option.

1.4 Brief Methodology / Technologies/ Procedures

1. **Requirements Gathering:** Determine the patch antenna's particular requirements, such as operating frequency, bandwidth, radiation pattern, polarization, size, and weight.
2. **Design:** Create the patch antenna with simulation software, taking into account the substrate material, patch shape, and feeding method.
3. **Fabrication:** Fabricate the patch antenna and assemble the components using the chosen manufacturing technique, such as PCB technology.
4. **Testing:** Measure the patch antenna's characteristics, such as return loss, radiation pattern, and gain, with suitable test equipment. If the outcomes fall short of the mark, revise the design and repeat steps 2-4.
5. **Integration:** Integrate the repair antenna into the finished product, making sure it complies with all specifications and performs as intended.[10]

1.5 Implementation Schedule

Single Antenna Implementation Schedule:

1. Research and gather information on single antenna design and performance - 1 week

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2. Determine antenna specifications and design parameters - 1 week
3. Procure necessary materials and components for the antenna - 2 weeks
4. Construct the antenna and perform initial testing - 2 weeks
5. Analyze the performance of the antenna and make necessary adjustments - 1 week
6. Finalize the design and test the antenna in real-world applications - 2 weeks
7. Document the design process and results in the thesis paper - 1 week

Total Time: 10 weeks

2×1 Array Antenna Implementation Schedule:

1. Research and gather information on array antenna design and performance - 2 weeks
2. Determine array antenna specifications and design parameters - 2 weeks
3. Procure necessary materials and components for the antenna - 4 weeks
4. Construct the array antenna and perform initial testing - 4 weeks
5. Analyze the performance of the array antenna and make necessary adjustments - 2 weeks
6. Finalize the design and test the array antenna in real-world applications - 4 Week.
7. Document the design process and results in the thesis paper - 2 weeks

Total Time: 20 weeks

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CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Patch antennas are becoming more and more common because they are inexpensive, lightweight, and low profile. They are extensively used in many different uses, including RFID systems, wireless local area networks, satellite communication, and mobile communication systems. A straightforward and effective radiating element that is readily designed and manufactured on various substrates is the patch antenna. The purpose of this review of the literature is to give a broad overview of the studies on single and 2×1 patch antennas.

The simplest type of patch antenna is the single patch antenna, which comprises of a patch t is either rectangular or circular that is placed over a ground plane. A coaxial cable that is connected to the patch at a particular location supplies the antenna. The patch antenna being inexpensive, lightweight, and low profile. With a small beam width, it also offers good gain and directivity. The single patch antenna's comparatively small bandwidth, however, restrict in several studies have been done by researchers to improve the single patch antenna single-patch Different feeding methods, adding slots or notches to the patch, and using various substrate materials are a few of the tactics used. One such example is the coplanar waveguide (CPW) feeding method for a single patch antenna. The design of a single patch antenna with a triangular slot produced an increased impedance match and a broad bandwidth.[2][11]

The 2×1 patch antenna is an array of two patch antennas that are fed by a single coaxial cable. A specified distance separates the two patch antennas, which are positioned parallel to one another. In comparison to a single patch antenna, the 2×1 patch antenna has a broader bandwidth, a higher gain, and better directivity. Additionally, it offers a broadside emission pattern, which makes it appropriate for a variety of uses. Several studies have been done by researchers to improve the efficiency of the 2×1 patch antenna. Changes in the distance between the two patches, the addition of slots or notches, and various feeding strategies are a few of the methods used. For instance, a meandering line feeding method was suggested for a 2×1 patch antenna, which produced a wider bandwidth and improved radiation characteristics. Broad bandwidth

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and better impedance matching were achieved by designing a 2×1 patch antenna with an inverted T-shaped slot.[7]

By conducting a literature review, researchers and engineers can gain insight into the latest advancements and techniques used in the design and optimization of these antennas. This information can help them to improve the performance of existing antennas or to develop new and innovative antenna designs for specific applications.

2.2 Related Research/ Works

Single antenna: A Compact Microstrip Patch Antenna at 28 GHz for 5G wireless Applications.

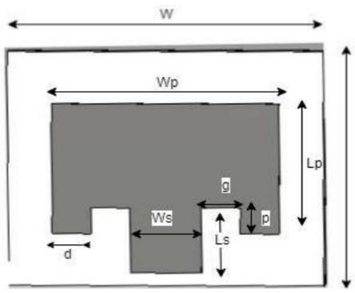

Figure 2.1: Single patch antenna for related works

Table 2.1: Parameter list for single antenna

Parameter	**Value(mm)**
W	**5.5**
L	**4.5**
Wp	**3.96**
Lp	**2.5**
Ws	**1.24**
Ls	**1.25**
g	**0.68**
p	**0.5**
d	**0.68**

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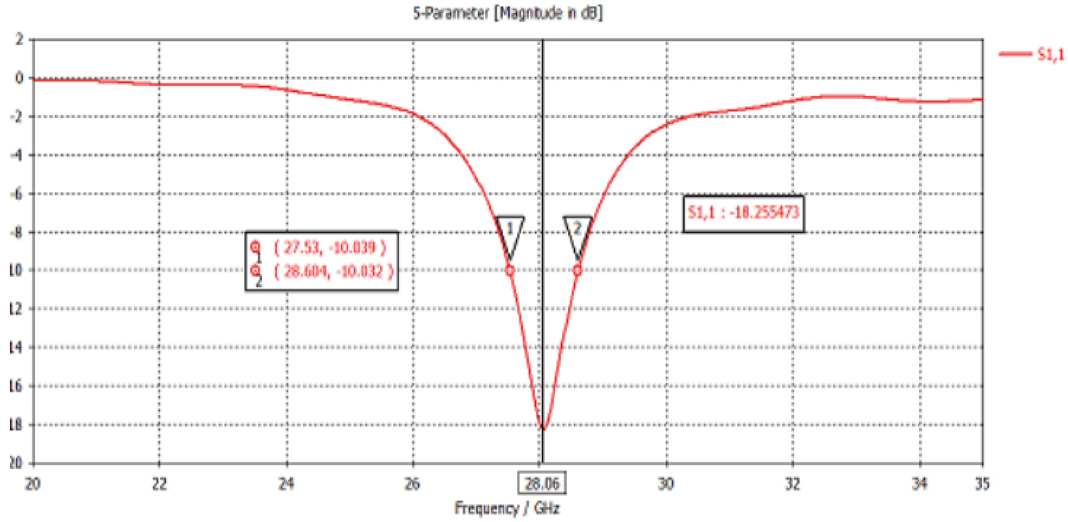

Figure 2.2: S-parameter for related work

2.3 Compare and Contrast

Table 2.2: Compare with Related Works and Proposed antenna

References	Size	Return loss	VSWR	Bandwidth	Gain	Directivity	Efficiency
Related Works	4.5×5.5	-18.25	1.27	1.1	6.83	7.9	87%
Proposed	7.8×8	-28.79	1.07	0.71	6.56	7.50	87%

2.4 Summary

In the related work section, we would review existing literature on single antenna design and performance. This could include studies on antenna radiation patterns, impedance matching, and signal transmission. You would discuss the strengths and weaknesses of different designs and highlight any gaps in the literature that our proposed work aims to address. We might also discuss the applications of single antennas in various fields, such as telecommunications, radar, and remote sensing.

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CHAPTER 3
MATERIALS AND METHODS [OR PROJECT/SYSTEM DESIGN] [OR DESIGN PROCEDURE]

3.1 Introduction

The Materials and Methods section for a single and 2×1 patch antenna describes the materials used and the methods employed to design, fabricate, and test the antennas. This section should provide enough detail so that the reader can replicate the experiment or simulation.

For a single patch antenna, the Materials and Methods section may include the following:

Materials:

- Substrate material
- Conductive patch material
- Feed line material
- Coaxial connector
- Soldering material

Methods:

- Design of the antenna using simulation software, such as CST or HFSS
- Fabrication of the antenna, including cutting the substrate to size, depositing the patch material, and attaching the feed line and coaxial connector
- Measurement of the antenna's impedance matching, radiation pattern, and gain using a vector network analyzer (VNA) and an anechoic chamber

For a 2×1 patch antenna array, the Materials and Methods section may include the following:

Materials:

- Substrate material
- Conductive patch material
- Feed line material
- Coaxial connector
- Soldering material
- Phase shifter

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Methods:

- Design of the array using simulation software, such as CST or HFSS
- Fabrication of the array, including cutting the substrate to size, depositing the patch material, attaching the feed line, coaxial connector, and phase shifter, and adjusting the spacing between the two elements
- Measurement of the array's impedance matching, radiation pattern, and gain using a vector network analyzer (VNA) and an anechoic chamber
- Evaluation of the array's performance under different phase shifter settings to optimize the radiation pattern

3.2 Methods and Materials or System Design and Components

Table 3.1: Design Requirements

Frequency(f)	28 GHz
Dielectric constant	4.4
Dielectric height	0.244
Substrate	fr-4 (lossy)
Ground	copper
Feed line	50Ω, 70Ω, 100Ω

Antenna design calculation

1. $W=\frac{Vo}{2fr}\sqrt{\frac{2}{\epsilon r+1}}$

2. $L=\frac{Vo}{2fr\sqrt{\epsilon reff}}-2\Delta L$

3. $\epsilon_{ref}=\frac{\epsilon r+1}{2}+\frac{\epsilon r-1}{2}\left[1+\frac{2h}{W}\right]^{-\frac{1}{2}}$

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

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Where, W=Width of the patch

L=Length of the Length

$\in_{ref}$= **Effective dielectric constant**

ΔL=Extended length of an antenna

Table 3.2: Parameters list of the single antenna

Length of the patch	3.29 mm
Width of the patch	3.26 mm
Length of the quarter wave	1.467 mm
Width of the quarter wave	0.466 mm
Length of the feed line	1.55 mm
Width of the feed line	0.10 mm
Length of the inset feed	0.7 mm
Width of the inset feed	0.20 mm
Length of the Substrate	8 mm
Width of the substrate	7.9 mm
Thickness	0.035 mm

Table 3.3: Parameters list of the 2×1 array antenna

Length of the patch	3.26 mm
Width of the patch	2.30 mm
Length of the quarter wave	1.55 mm
Width of the quarter wave	0.0820 mm
Length of the feed line (50Ω,70Ω,100Ω)	1.467, 1.50, 1.54 mm
Width of the feed line(50Ω,70Ω,100Ω)	0.466, 0.25, 0.1081 mm
Length of the inset feed	0.8 mm
Width of the inset feed	0.2 mm
Length of the Substrate	8 mm
Width of the substrate	11 mm
Thickness	0.035 mm

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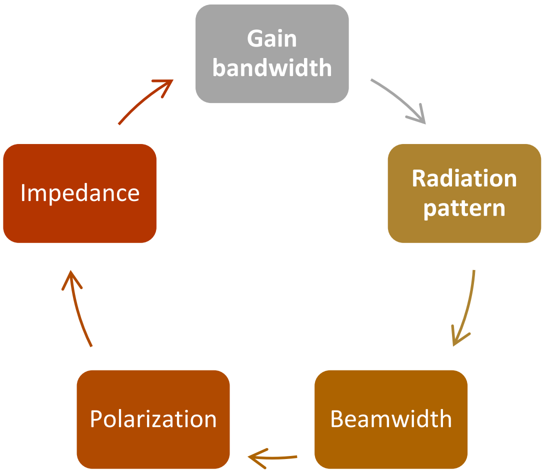

Figure 3.1: Typical thee meters of antenna

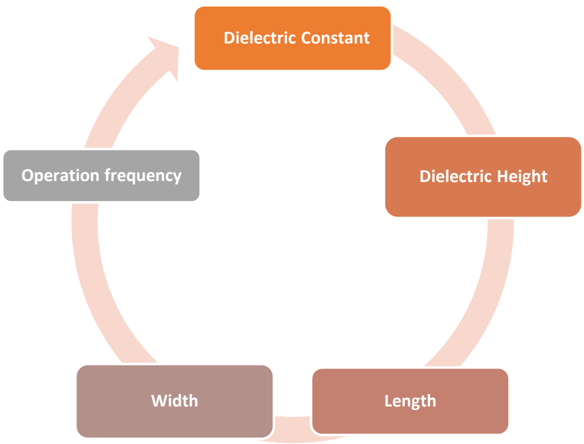

Figure 3.2: Antenna calculation parameter

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3.3 System Analysis or Design Analysis

System Analysis: Understanding the needs and limitations of the antenna system is the aim of system analysis. The system characteristics, such as the frequency range, bandwidth, polarization, gain, radiation pattern, and impedance matching, are defined in this process.

For a single antenna, the system analysis may entail finding the ideal physical size and shape of the antenna element. The analysis may also take into account where the antenna is placed of the antenna.

For a 2×1 array antenna, the system analysis may entail calculating the ideal distance between the two components, their phase differences, and the array's overall radiation pattern. The need for impedance matching and the impact of the components' mutual coupling may also be taken into account during the analysis.

Design Analysis: The next stage is to design the antenna system after the system's needs and limitations have been determined. Choosing the proper elements and parts, such as the antenna element, feed network, and matching network is part of this process.

For a single antenna, the design analysis for a single antenna may include choosing the type of antenna element, such as a dipole or patch antenna, as well as designing the feed network and matching network to achieve the desired performance characteristics.

For a 2×1 array antenna, the design analysis for a 2×1 array antenna may include determining the suitable spacing between the two elements, designing the feed network to ensure the correct phase difference between the elements, and designing the matching network to ensure that both elements have the same impedance.

3.4 Simulation/Experimental Setup [or Implementation]

A high-performance 3D EM analysis software package called CST Studio is used for developing, analyzing, and optimizing electromagnetic (EM) systems and components. CST Studio Suite contains electromagnetic field solutions for applications across the EM spectrum in a single user interface.

To set up a simulation or experiment for a single and 2×1 array antenna in CST (Computer Simulation Technology), the following steps can be followed:

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Geometry Creation:

The first stage is to use CST to create the antenna's 3D geometry. The antenna components, feed network, and matching network must all be created. The geometry of a single antenna will consist of a single antenna element and the related feed and matching networks. The geometry of a 2×1 array antenna will comprise two antenna elements, a feed network connecting the two elements, and a matching network matching the impedance of both elements.

Material Selection:

The materials used in the antenna system, including the dielectric base, conductive elements, and any other components, are then model for the antenna's performance.

Frequency Setup:

After deciding on the geometry and materials, the next stage is to define the frequency range and bandwidth for the simulation. This determines the frequency range at which the antenna can work, and it is critical to select a range that corresponds to the antenna's intended use.

Simulation Parameters:

The simulation parameters, such as the mesh size and time step, should be set up to ensure accurate simulation results.

Boundary Conditions:

The simulation's boundary conditions must also be defined. This involves configuring the antenna's excitation source, such as a voltage source, as well as the simulation region's boundary conditions.

Simulation Run:

The simulation can now be executed and the outcomes analyzed. The study of a single antenna may include evaluating the antenna's radiation pattern, gain, and impedance matching. The analysis of a 2×1 array antenna may include assessing the array's radiation pattern, the impact of mutual coupling between the elements, and the overall performance of the array.

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CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results/ Observations

The results and observations for a single and 2×1 patch antenna can vary depending on various parameters such as the design of the antenna, the operating frequency, and the material We know that the input voltage reflection coefficient is lower than -10 dB.

FOR SINGLE ANTENNA

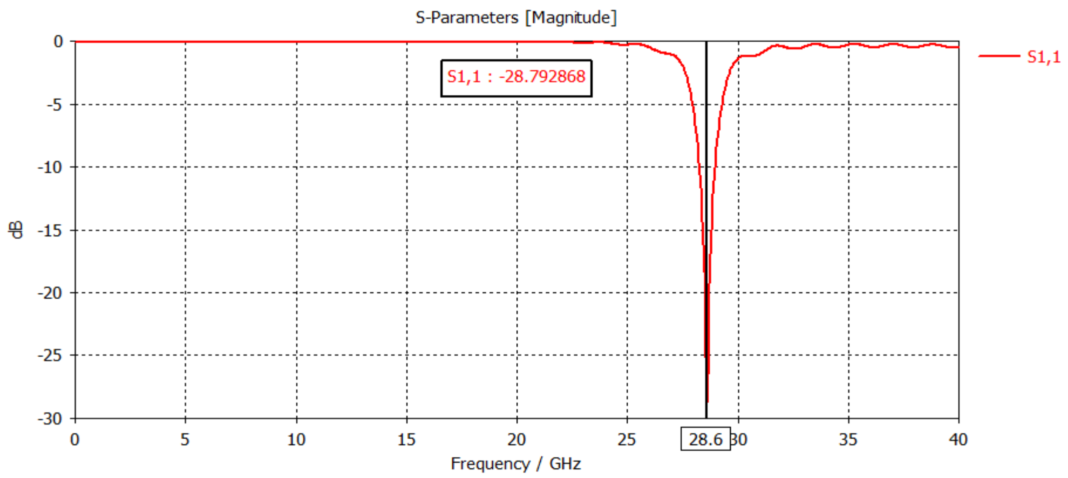

Figure 4.1: Single antenna return loss carve

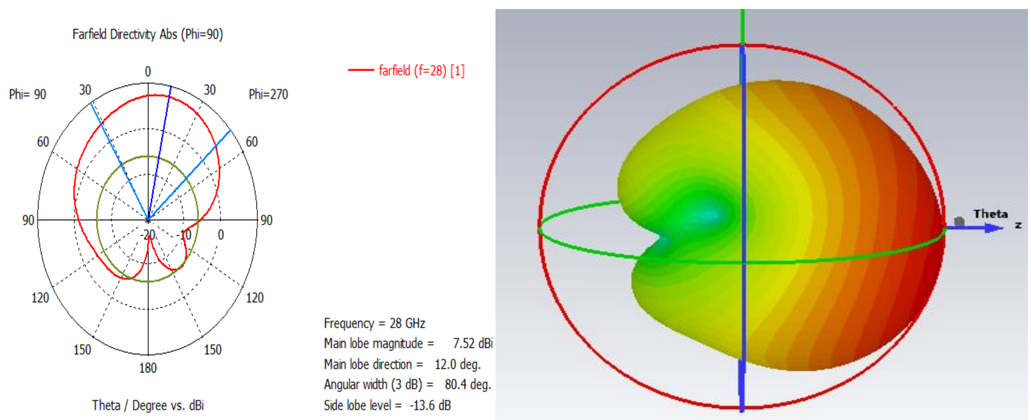

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Figure 4.2: 2D and 3D radiation pattern for single antenna

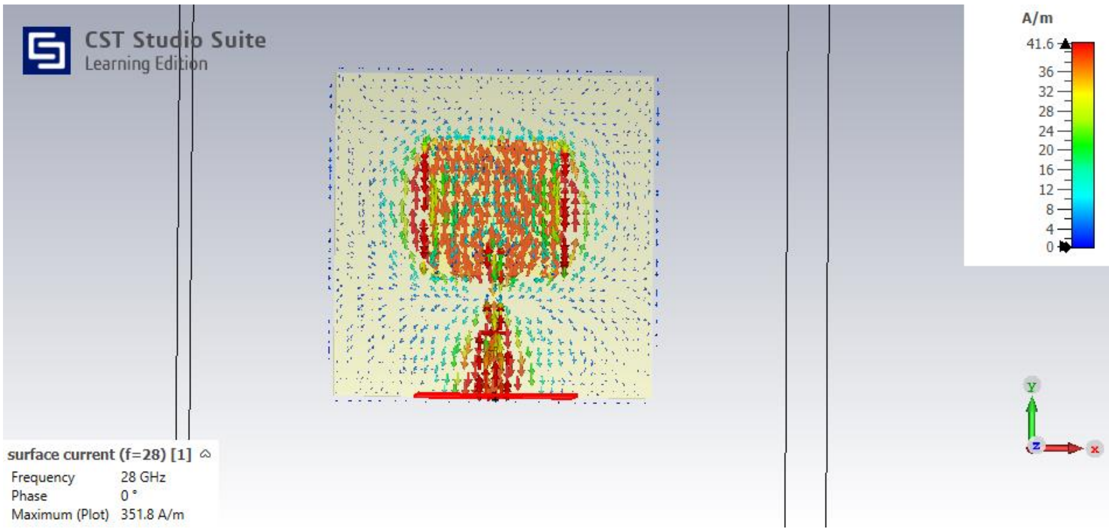

Figure 4.3: Surface current of this single antenna

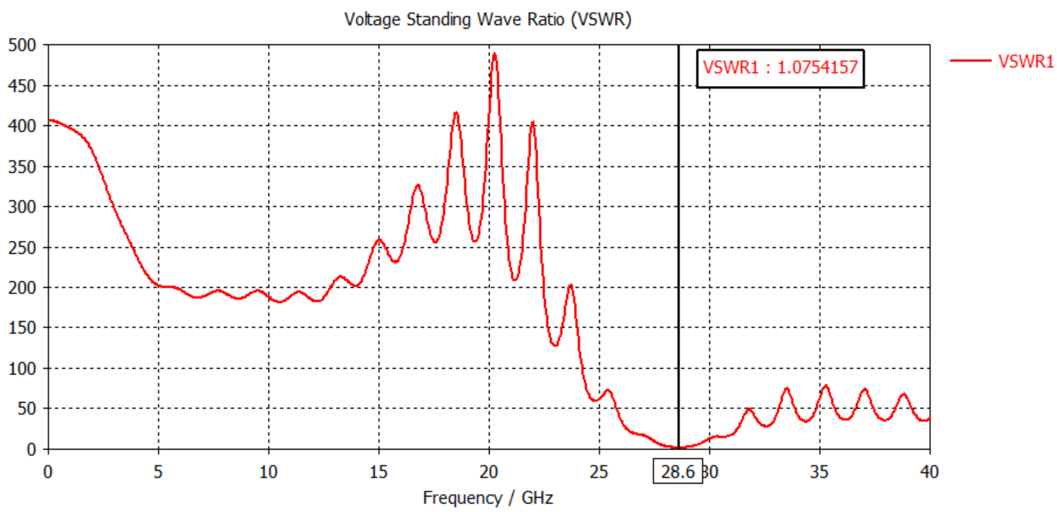

Figure 4.4: VWSR of this single antenna

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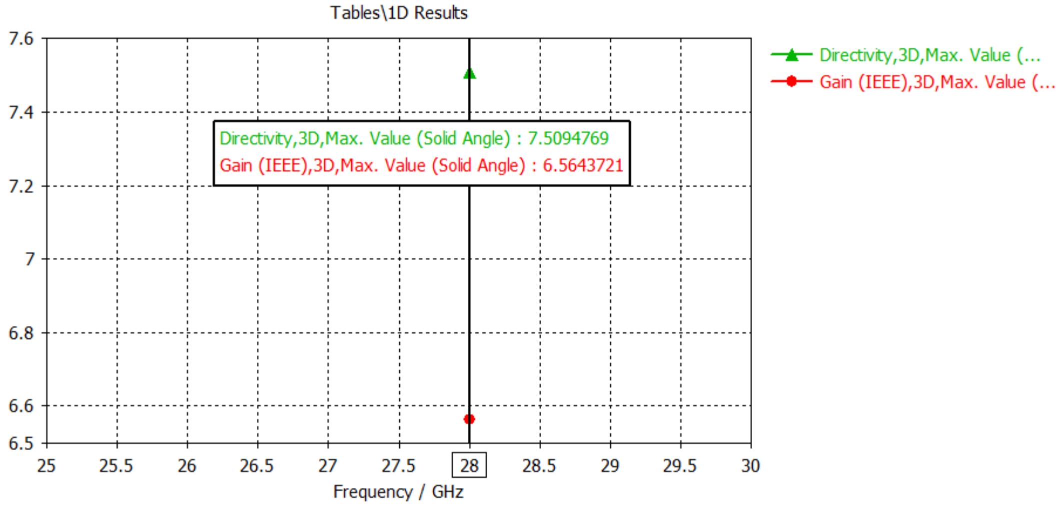

Figure 4.5: Gain and directivity plot of this single antenna

FOR 2×1 ARRAY ANTENNA

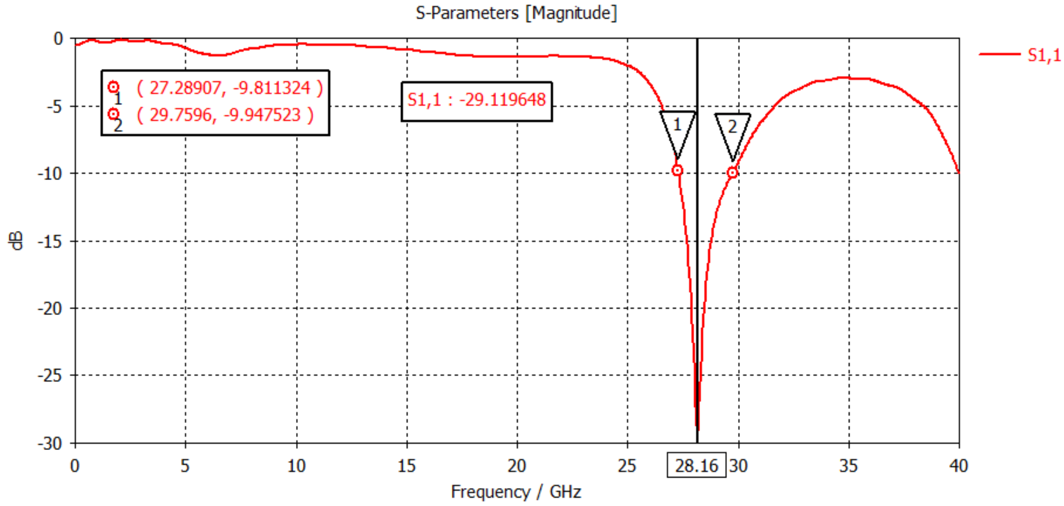

Figure 4.6: 2×1 array antenna return loss carve

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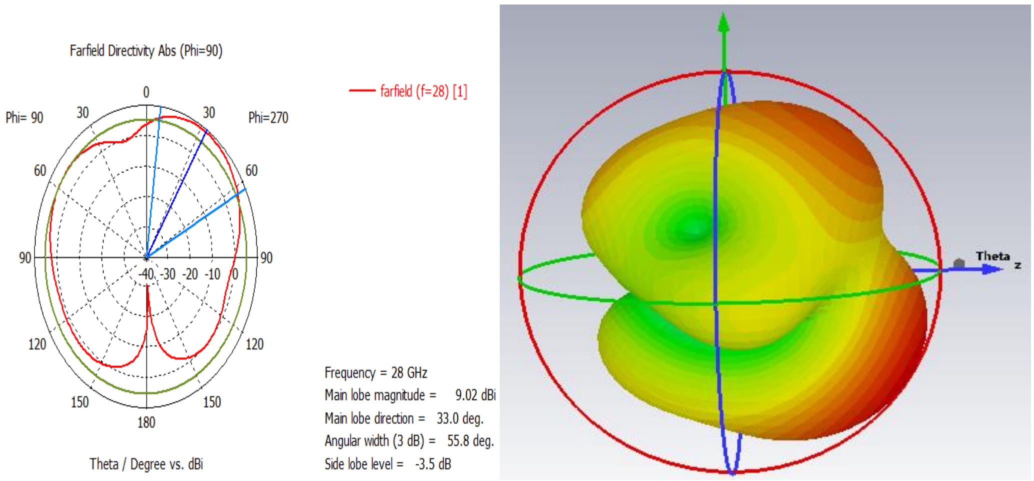

Figure 4.7: 2D and 3D radiation pattern for 2×1 array antenna

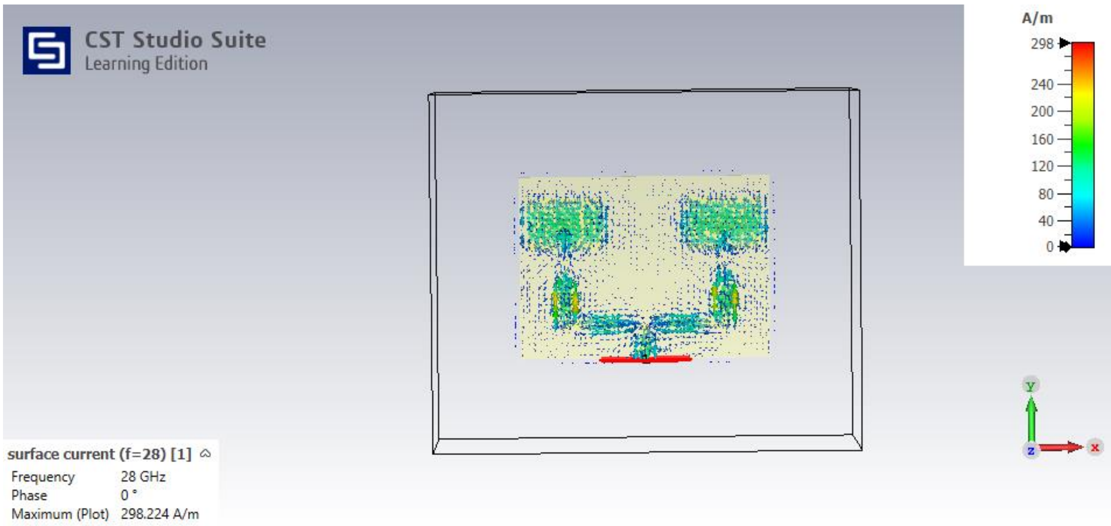

Figure 4.8: Surface current of this 2×1 array antenna

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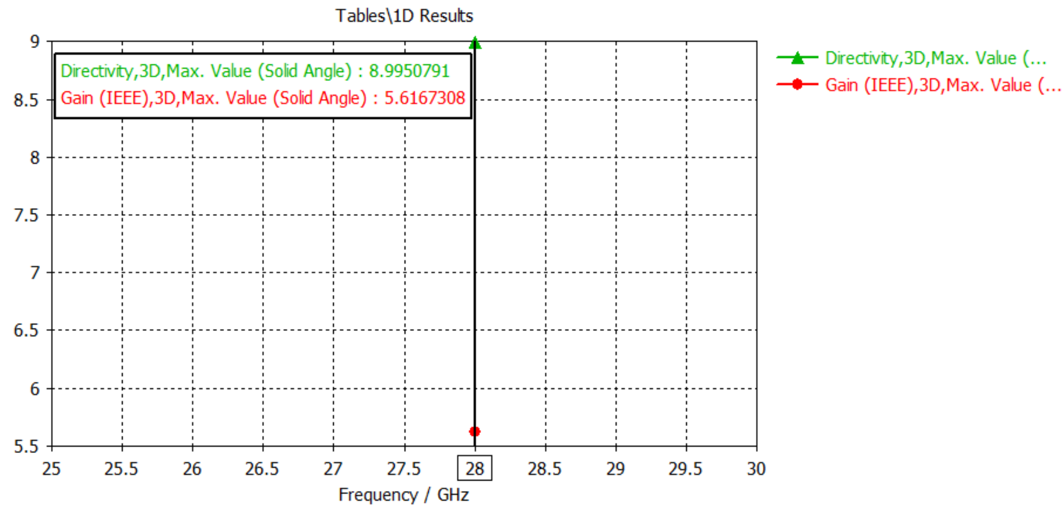

Figure 4.9: Gain and directivity plot for 2×1 array antenna

Table 4.1: Result sheet for single and 2×1 array antenna

Parameters	**Single antenna**	**2×1 array antenna**
Return loss(dB)	-28.79	-29.11
VSWR	1.07	1.07
Power Accepted	0.49	0.49
Power radiated	0.25	0.22
Gain(dB)	6.56	7.61
Directivity(dB)	7.50	8.99
Efficiency	87%	84%

4.2 Discussions

The single and 2×1 array antenna properly works for 28GHz and returns a loss of -28.79 dB and -29.11 dB as shown in Figures 4.1 and 4.6. The voltage standing wave ratio for single and 2×1 array antennae is 1.07 as shown in Figure 4.4. The gain and directivity for single are 6.56, 7.50 as shown in Figure 4.5.

The gain and directivity for the 2×1 array antenna are 7.61, 8.99 as shown in Figure 4.9. The single and 2×1 array antenna efficiency is 87% and 84%.

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CHAPTER 5
PROJECT MANAGEMENT

5.1 Task, Schedule Mil, stones

FOR SINGLE PATCH ANTENNA

Task 1: Design patch antenna using CST

- **Schedule:** 1 week
- **Milestone:** Completed antenna design

Task 2: Fabricate the antenna patch and feed

- **Schedule:** 1-2 weeks
- **Milestone:** Completed antenna patch and feed

Task 3: Test the antenna patch and feed

- **Schedule:** 1-2 weeks
- **Milestone:** Completed antenna testing

Task 5: Prepare a report and documentation on the antenna design and performance

- **.Schedule: 1 week**
- **Milestone: Completed report and documentation**

FOR 2×1 ARRAY PATCH ANTENNA

Task 1: Design patch antenna using CST

- **Schedule:** 2-4 weeks
- **Milestone:** Completed antenna design

Task 2: Fabricate the antenna prototype

- **Schedule:** 2-4 weeks
- **Milestone:** Completed antenna prototype

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Task 3: Test the antenna prototype

- **Schedule:** 2-3 weeks
- **Milestone:** Completed antenna testing

Task 4: Analyze and optimize antenna performance based on test results

- **Schedule:** 2-3 weeks
- **Milestone:** Completed antenna optimization

Task 5: Prepare a report and documentation on the antenna design and performance

- **Schedule:** 1-2 weeks
- **Milestone:** Completed report and documentation

5.2 Resources and Cost Management

1. **DESIGN RESOURCE**

Simulation software: We will require antenna simulation software, such as CST software like CST, and HFSS.

And Antenna design guidelines: Here are a few rules and recommendations for creating patch antennas. It is crucial to review these recommendations and apply them to OUR planning process.

Antenna design experience: A patch antenna is a specialized talent that calls for knowledge and experience in antenna design.

2. **MANUFACTURING RESOURCES**

PCB fabrication: Printed circuit board (PCB) technology can be used to create a patch antenna. To create your antenna, you will need access to a PCB fabrication center.

Material selection: The material we use for our patch antenna is critical to its function. To accomplish the desired performance, the substrate material as well as the conductive material used for the patch and ground plane should be carefully selected.

Manufacturing experience: Manufacturing a patch antenna requires experience and expertise in PCB fabrication and antenna manufacturing.

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My project is not hardware-based. It’s a software-based project. I used the CST student version. The student version is available online. So, no external cost don’t need for this project.

But, if we were to build the hardware below is a list of our expenses.

5.3 Lesson Learned

Radiation pattern: A single-patch antenna has a unidirectional radiation pattern, which means it radiates the majority of its energy in one way. A 2×1 patch antenna, on the other hand, has a bidirectional radiation pattern, which means it emits energy in two opposite directions. As a result, the 2×1 patch antenna is ideal for applications requiring coverage in both ways, such as point-to-point communication links.

Gain: When compared to a single patch antenna, a 2×1 patch antenna has gain. This is so that a stronger signal in the intended direction can be produced by the two two-phase elements. The 2×1 patch antenna's greater gain may be useful in applications that call for longer-range communication.

Cost: A single patch antenna is generally less expensive compared to a 2*1 patch antenna, as the latter requires additional components such as a power divider and additional feed lines. Therefore, a single single-patch more cost-effective solution for certain applications.

Size: In comparison to a 2×1 patch antenna with the same gain, a single patch antenna may be smaller. This is because the 2×1 patch antenna needs extra parts, which can make the antenna's overall size larger. Therefore, for single-patches choices, a single-single-patches choice.

I needed to familiarize myself with a variety of sources while working on this project. I need a different kind of parameter and here. To project's vision reality changes had to be made. I could relate to the practical themes with the book's theoretical subjects.

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CHAPTER 6
IMPACT ASSESSMENT OF THE PROJECT

6.1 Economical, Societal, and Global Impact

A single and 2x1 patch antenna for 28 GHz can have several economic, societal, and global impacts. Here are some potential impacts:

1. **Economic impact:** At 28 GHz, patch antenna use has the potential to significantly affect the economy. In 5G networks, which are predicted to change how we use the internet, these antennas are frequently used. Due to faster data speeds and reduced latency, the use of 5G networks is anticipated to result in increased economic development and productivity. Companies have chances to create new goods and services thanks to the creation and rollout of 5G networks.

2. **Societal impact:** The use of patch antennas at 28 GHz can also have a significant societal impact. These antennas are used in a wide range of uses, including mobile phones, satellite communication, and self-driving cars. The use of 5G networks, in particular, can allow new applications such as telemedicine, remote education, and smart city infrastructure. This can result in better access to healthcare and education, as well as better transportation and public protection.

3. **Global impact:** The use of patch antennas at 28 GHz may have a global effect as well. 5G network deployment is expected to be a major enabler of the Fourth Industrial Revolution, which is defined by the convergence of physical, digital, and biological technologies. Manufacturing, transportation, and healthcare are among the sectors that could benefit from this. Furthermore, the use of 5G networks can help to bridge the digital gap by giving high-speed internet access to communities that currently lack it.

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6.2 Environmental and Ethical Issues

The use of a single and 2x1 patch antenna for 28 GHz can also raise some environmental and ethical issues, including:

1. **Environmental impact:** Patch antenna production, deployment, and disposal can all have an environmental effect. The fabrication of these antennas necessitates the use of materials such as copper, which can have negative environmental consequences if not disposed of correctly. Furthermore, the installation of a large number of antennas may require the effectual of 5G networks.

2. **Ethical issues:** The deployment of 5G networks generates ethical concerns about privacy and surveillance. Because these networks allow the collection of massive amounts of data, it is critical to ensure that this data is used responsibly and ethically. Furthermore, the deployment of 5G networks has the potential to exacerbate current social and economic inequalities by leaving communities behind. There is also ongoing discussion about the potential health consequences of being exposed to electromagnetic radiation from 5G networks and related patch antennas. While scientists agree that exposure to these frequencies is not harmful, some individuals and organizations are concerned about possible health risks.

6.3 Utilization of Existing Standards or Codes

1. **IEEE 802.11ad:** This is a wireless local area network (WLAN) standard that operates at 60 GHz, which is near the GHz frequency. The standard specifies design and operation rules for WLANs, including the use of directional antennas such as patch antennas.
2. **3GPP:** This is a set of standards for mobile communication systems that incorporates 5G networks. In the design and implementation of 5G networks, 3GPP specifications call for the use of different frequency bands, antenna types, and modulation schemes. FCC guidelines: In the United States, the Federal Communications Commission (FCC) controls the use of radio free radio

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frequency (RF) spectrum sections Commission (FCC) has set rules and guidelines for the use of the 28 GHz band, including maximum power limits and interference standards.

3. **Building codes:** Patch antenna installation may necessitate adherence to local building codes and regulations in some instances. These codes may include structural support requirements, electrical safety requirements, and aesthetic factors.

Designers and operators of patch antennas at 28 GHz can guarantee that their systems are safe, reliable, and interoperable with other systems by adhering to established standards and codes. Compliance with these standards can also help to guarantee that the deployment of these systems does not cause harmful interference to other RF spectrum users.

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CHAPTER 07

7.1 Conclusions

Finally, the use of a single and 2x1 patch antenna for 28 GHz has the potential to have major economic, social, and environmental consequences. These antennas are frequently used in 5G networks, which are anticipated to revolutionize internet usage and enable new applications such as telemedicine, remote education, and smart city infrastructure. The deployment of these systems, however, poses significant ethical, environmental, and health concerns that must be carefully considered. It is critical to observe established standards and codes such as IEEE 802.11ad, 3GPP, FCC regulations, and building codes to guarantee the safe and responsible deployment of patch antennas at 28 GHz. By adhering to these guidelines, designers and o, operators of these systems can ensure that their systems are safe, reliable, and interoperable with other systems, while also minimizing negative environmental and societal effects. Overall, the use of 28 GHz patch antennas represents a significant technological development with the potential to transform industries and better people's lives. However, before deploying these systems on a wide scale, it is critical to proceed with caution and carefully consider the potential consequences.[11]

7.2 New Skills and Experiences Learned

1. **Technical knowledge:** A strong basis in wireless communication, electromagnetic theory, and antenna design are necessary to comprehend patch antenna principles and operation as well as their function in 5G networks. Individuals can develop their technical knowledge in these fields. People must do extensive research on patch GHz to compose a on the subject. This entails looking for and assessing reliable sources, putting information together, and finding knowledge gaps that require additional research.

2. **Communication skills:** One of the most important skills for anyone working in the wireless communication industry is the ability to communicate technical information clearly and concisely. It to both technical and non-technical readers, one must write a paper on patch antennas at 28 GHz.

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3. **Collaboration:** It may be necessary to work with other researchers or professionals in related areas to conduct research on patch antennas at 28 GHz. People who work together often develop ideas and viewpoints that they might not have on their own.

4. **Awareness of societal and environmental issues:** As mentioned earlier, the deployment of patch antennas at 28 GHz raises ethical, environmental, and health concerns that must be considered.

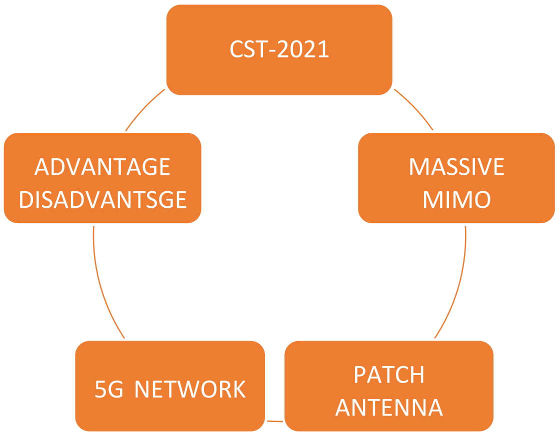

Figure 7.1: New learning things

7.3 Future Recommendations

Future Recommendations of a single and 2×1 patch antenna for 28 GHz for papers

Here are some future recommendations for papers related to single and 2×1 patch antennas for 28 GHz:

1. **Performance Comparison:** Future studies may find it helpful to compare the performance of single and 2×1 patch antennas at 28 GHz in detail. Numerous factors, including gain, radiation pattern, polarization, and impedance matching, can be used to base this analysis. This can assist in determining the benefits and drawbacks of each antenna type for various uses.
2. **Antenna Optimization:** The potential for antenna optimization to improve efficiency at 28 GHz is still very large. Future research can concentrate on various methods to enhance antenna performance, including the use of metamaterials,

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fractal shapes, and various feed structures. These papers can be a great resource for learning how to build 28 GHz patch antennas that are optimized for different uses.

3. **Antenna Integration:** In contemporary communication networks, integrating antennas with other components is becoming increasingly crucial. The integration of single and 2×1 patch antennas with additional parts like filters, amplifiers, and transceivers can be the subject of future studies. These articles can shed light on creating and improving 28 GHz antenna-integrated systems.
4. **Antenna Array Design;** Compared to single antennas, antenna arrays can provide greater gain and better performance. The construction and optimization of single-layer and multilayer 28 GHz patch antenna arrays can be the subject of upcoming papers. These articles can shed light on how to create high-performance 28 GHz antenna arrays for a variety of uses.
5. **Antenna Testing:** To guarantee the best performance in practical situations, testing and measurement of 28 GHz patch antennas are essential. Future studies could concentrate on different testing methods like near-field and far-field readings, as well as the effects of various environmental conditions on antenna performance. These studies can shed light on the evaluation and verification of 28 GHz patch antennas for various uses. In conclusion, there is still a great deal of room for study and development in the area of 28 GHz patch antennas, and upcoming papers may offer insightful information about designing and refining these antennas for a range of uses.

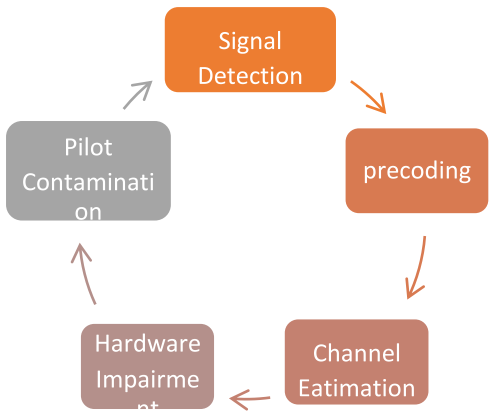

Figure 7.2: Challenging issue

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APPENDIX A

COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
P1	Range of resources	Textbooks, Research papers, Online courses, Simulation software, Online tutorials and articles, Webinars, and workshops.
P2	Level of interaction	For simple single-patch antennas, the interaction required may be minimal. The designer can use basic equations and design rules to calculate the dimensions of the patch, the feed location, and other key parameters. Commercial software tools can also be used to simulate the antenna performance and optimize the design. For more complex single and 2×1 patch antennas, more interaction may be required. The designer may need to use advanced simulation tools such as full-wave electromagnetic simulators to model the antenna performance accurately. This may involve adjusting the dimensions of the patch, the feed network, and other components to achieve the desired performance specifications.
P3	Innovation	There have been several innovations in the design and applications of single and 2×1 patch antennas. Here are a few examples: Dual-band and multi-band patch antennas, Reconfigurable patch antennas, Wearable patch antennas, Metamaterial patch antennas.

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P4	Consequences of society and environment	The use of single and 2×1 patch antennas can have both positive and negative consequences for society and the environment. Here are a few examples: Positive consequences: 1. Improved wireless communication: Single and 2×1 patch antennas are commonly used in wireless communication systems, such as cell phones, Wi-Fi routers, and satellite communications. These antennas can improve the quality and range of wireless communication, making it more reliable and accessible. 2. Enhanced safety and security: Single and 2*1 patch antennas are also used in radar and surveillance systems, which can enhance safety and security in various applications, such as aviation, maritime, and military operations. 3. Reduced energy consumption: Patch antennas are often designed to be small and lightweight, which can reduce the energy consumption of wireless communication devices, such as cell phones and laptops. Negative consequences: 1. Electronic waste: With the rapid advancement of wireless communication technology, there has been a growing concern over electronic waste generated by

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		discarded devices that contain patch antennas. These devices can contain hazardous materials that can harm the environment if not disposed of properly. 2. Electromagnetic radiation: There have been concerns over the potential health effects of exposure to electromagnetic radiation emitted by wireless communication devices that use patch antennas. While there is no conclusive evidence linking patch antennas to adverse health effects, it remains an area of ongoing research and concern. 3. Interference with other devices: Patch antennas can emit electromagnetic radiation that can interfere with other electronic devices, such as medical equipment, navigation systems, and broadcasting systems. This can cause disruptions in critical applications and services.
P5	Familiarity	The design of single and 2×1 patch antennas requires a certain level of familiarity with antenna theory, electromagnetic field theory, and microwave engineering. Here are some of the key concepts and skills that are necessary for designing these types of antennas: Understanding of antenna parameters, Knowledge of electromagnetic field theory, Familiarity with microwave engineering, Proficiency with simulation software,

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		Practical skills for prototyping and testing
P6	Extent of stakeholder involvement and conflicting requirements	The extent of stakeholder involvement and conflicting requirements for the design of single and 2*1 patch antennas will depend on the specific application and context of the antenna design. Here are some factors that may influence the level of stakeholder involvement and conflicting requirements: 1. Application requirements: The requirements for the antenna will vary depending on the application. For example, a patch antenna designed for use in a satellite communication system will have different requirements than one designed for use in a Wi-Fi router. The stakeholders involved may include engineers, product managers, marketing teams, and customers, among others. 2. Regulatory requirements: Antennas used in certain applications, such as aviation or medical devices, may be subject to regulatory requirements and standards that must be met. This may involve additional stakeholder involvement, such as regulatory agencies and certification bodies. 3. Cost considerations: The cost of the antenna may be a factor in the design process, and may involve trade-offs between performance and cost. This may involve stakeholders such as procurement teams and finance departments.

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		4. Environmental considerations: The impact of the antenna on the environment, such as the use of hazardous materials or the potential for electronic waste, may be a factor in the design process. This may involve stakeholders such as environmental and sustainability teams
P7	Interdependence	The design of a single and 2×1 patch antenna is highly interdependent on several factors that must be taken into consideration in order to achieve the desired performance characteristics. Here are some of the key interdependencies involved in the design of these antennas: 1. Antenna size and shape. 2. Substrate material and thickness. 3. Feed mechanism. 4. Ground plane. 5. Manufacturing tolerances. 6. Environmental factors

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Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
A1	Depth of knowledge required	The design of a single and 2×1 patch antenna requires a solid of electromagnetic theory, antenna design principles, and RF circuit design. Here are some specific areas of knowledge that are important for designing a patch antenna: 1. Electromagnetic theory 2. Antenna design principles 3. RF circuit design 4. Substrate material properties 5. Manufacturing techniques
A2	Range of conflicting requirements	The design of a single and 2×1 patch antenna requires balancing a range of conflicting requirements. Here are some examples of conflicting requirements that must be considered: 1. Size vs. frequency 2. Gain vs. directivity 3. Bandwidth vs. efficiency 4. Impedance matching vs. bandwidth 5. Polarization vs. application requirements 6. Environmental factors vs. performance
A3	Depth of analysis required	The depth of analysis required for the design of a single and 2×1 patch antenna depends on the specific requirements and performance specifications of the antenna. Here are some examples of the depth of analysis required for various aspects of patch antenna design: 1. Electromagnetic simulation 2. Feed mechanism analysis 3. Substrate analysis 4. Manufacturing analysis 5. Environmental analysis

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A4	Familiarity of issues	The familiarity of issues for the design of a single and 2×1 patch antenna design depends on the expertise and experience of the designer or design team. Here are some of the issues that a designer should be familiar with when designing a patch antenna: 1. Antenna theory and principles 2. Electromagnetic simulation tools 3. Substrate materials 4. Feed mechanisms 5. Manufacturing processes 6. Environmental factors 7. Regulatory requirements
A5	The extent of the applicable extent	The applicable extent for the design of a single and 2*1 patch antenna design depends on the intended application and performance requirements. Here are some examples of the applicable extent for different types of patch antenna designs: 1. Mobile communications 2. Aerospace and defense 3. Automotive 4. Medical

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APPENDIX B

DATASHEET OF COMPONENTS

Frequency(f)	*28 GHz*
Dielectric constant	*4.4*
Dielectric height	*0.244*
Substrate	*fr-4 (lossy)*
Ground	*copper*
Feed line	*50Ώ, 70Ώ, 100Ώ*

Parameters list of the single antenna

Length of the patch	*3.29 mm*
Width of the patch	*3.26 mm*
Length of the quarter wave	*1.467 mm*
Width of the quarter wave	*0.466 mm*
Length of the feed line	*1.55 mm*
Width of the feed line	*0.10 mm*
Length of the inset feed	*0.7 mm*
Width of the inset feed	*0.20 mm*
Length of the Substrate	*8 mm*
Width of the substrate	*7.9 mm*
Thickness	*0.035 mm*

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Parameters list of the 2×1 array antenna

Length of the patch	*3.26 mm*
Width of the patch	*2.30 mm*
Length of the quarter wave	*1.55 mm*
Width of the quarter wave	*0.0820 mm*
Length of the feed line (50Ώ,70Ώ,100Ώ)	*1.467, 1.50, 1.54 mm*
Width of the feed line(50Ώ,70Ώ,100Ώ)	*0.466, 0.25, 0.1081 mm*
Length of the inset feed	*0.8 mm*
Width of the inset feed	*0.2 mm*
Length of the Substrate	*8 mm*
Width of the substrate	*11 mm*
Thickness	*0.035 mm*

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