

DESIGN OF WEARABLE ANTENNA WITH METASURFACE FOR 5 GHZ WBAN APPLICATIONS

*A Project report submitted in partial fulfillment of the requirements for
the award of the degree of*

**BACHELOR OF TECHNOLOGY
IN
ELECTRONICS AND COMMUNICATION ENGINEERING**

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

**ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES
(UGC AUTONOMOUS)**

(Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC)

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ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

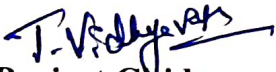
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CERTIFICATE

This is to certify that the project report entitled “DESIGN OF WEARABLE ANTENNA WITH METASURFACE FOR 5 GHZ WBAN APPLICATIONS” submitted by V.Rashmita (319126512124), Y.Kranthi Swaroop (319126512128), Y.Gowthami (319126512127), P.Balaji(319126512105) in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Electronics & Communication Engineering of Anil Neerukonda Institute of technology and Sciences(A), Visakhapatnam is a record of bonafide work carried out under my guidance and supervision.



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ABSTRACT

This letter gives us information about design of Metasurface-equipped wearable Microstrip Patch Antenna for 5 GHz WBAN Applications. Here metasurface is used in order to increase the performance and especially it is meant for size miniaturization. The work made assured that High gain of antenna and metasurface such that its bandwidth has also increased when compared to the antenna without metasurface. Considering the bending as the major challenge and to improve the efficiency within low SAR value the metasurface antenna has geometry of 40mmx40mm. This structure can achieve higher gain and better efficiency over 5GHz WBAN band. This wearable antenna has certain qualities that are suitable for a wide range of wireless body area network applications. Also, the suggested meta surface antenna observes a peak gain of 6.48 dB with a 78% efficiency spanning the 4.44 to 5.85 GHz range, which satisfies the 5 GHz WBAN band. Besides, the results of on-body confirms that the meta surface antenna is appropriate for wearable applications.

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CHAPTER 1

INTRODUCTION

In this chapter, antenna and its types were discussed, also how antenna has its radiation mechanism and different types of parameters that it constitutes. And then microstrip patch antenna and its advantages were discussed. And further how wearable antennas with metasurfaces helps in achieving 5GHz WBAN band and different its applications were discussed.

1.1 History Of Antennas

Heinrich Hertz, a professor at the Technical Institute in Karlsruhe, Germany, created the first radio antennas. Operating at $\lambda = 8 \text{ m}$ in 1886, Heinrich Hertz's end-loaded half-wave dipole transmitting antenna and resonant half-wave receiving loop. The innovation of radio's father and pioneer, Hertz, remained a laboratory curiosity until Bologna, Italy's Guglielmo Marconi, then 20 years old, added tuning circuits, enormous antenna, and ground systems for longer wavelengths, and was able to transmit signals over great distances. He shocked everyone by receiving signals at St. Johns, Newfoundland, from a transmitting station he had built at Poldhu in Cornwall, England, in the middle of December 1901. In 1905, Guglielmo Marconi used a square conical antenna in Poldhu, England, to transmit signals over the Atlantic at wavelengths of thousands of metres is shown in Figure.1.1 below.

Rarely has a technology captivated the attention of the general people like Marconi's wireless did at the turn of the 20th century. Centimeter wavelengths gained popularity and the entire radio spectrum became widely used with the development of radar during World War II. In low, medium, and geostationary orbits, thousands of communication satellites bristling with antennae currently circle the planet..

Similar to the rings surrounding Saturn, the geostationary satellites create an orbital ring around the planet. Day or night, cloudy or clear, a GPS receiver may provide centimetre-level accuracy for latitude, longitude, and elevation anywhere on or above the earth.

The Very Large Array (VLA) is a collection of 27 steerable parabolic dish antennas, each measuring 25 m in diameter, used to observe radio sources located billions of light-years away. In 1980, the array was situated at the National Radio Astronomy Observatory, which is not far from Socorro, New Mexico. With their arrays of antennae, our probes have travelled to planets inside the solar system and beyond, responding to our commands and returning images. Additionally, our radio telescope antennas that operate at millimetre to kilometre wavelengths are able to pick up signals from far-off objects that have taken more than 10 billion years to reach here.

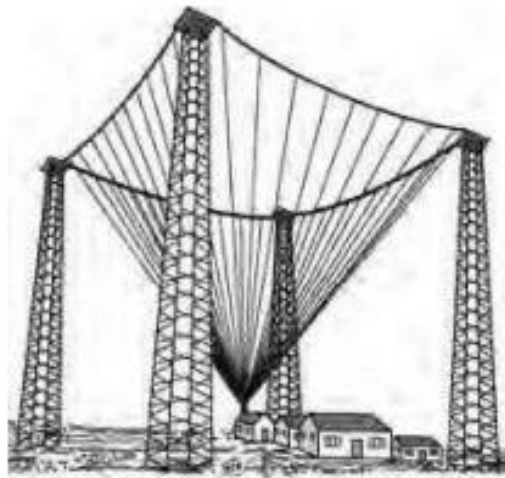


Figure.1.1 Square conical antenna

1.2 Need Of Antenna

Antennas are crucial parts of numerous communication systems and have a number of uses. Here are some reasons why antennas are needed:

Transmitting and Receiving Signals: Antennas are used in a variety of communication systems, including radio, television, satellite, and cellular networks, to transmit and receive signals.

Signal Strength: Antennas are used to increase a transmitted signal's signal strength so that it can reach farther distances.

Directional Reception: Antennas can be made to only pick up signals coming from a specific angle, enabling directional communication and reducing interference from outside sources.

Compactness: In order to be helpful in portable electronic devices like mobile phones, tablets, and laptops, antennas can be made to be very compact.

Wireless Connectivity: Many wireless communication technologies, such as Wi-Fi, Bluetooth, and RFID systems, employ antennas to connect devices to networks and facilitate wireless data exchange.

Overall, antennas play a significant role in current communication systems and are essential to ensuring that humans can efficiently interact wirelessly and across great distances.

1.3 Radiation Mechanism

Electromagnetic radiation is created when electric charges are accelerated. Therefore, the source of radiation is the movement of charges, or current. Here, it should be noted that not all current distributions will result in radiation that is potent enough for transmission. Electromagnetic energy is transmitted, coupled, concentrated, or directed via antennas in the desired or assigned direction. An antenna may be isotropic, unisotropic, directional, or non-directional (omni-directional). Acceptable parameters include the antenna's shape, size, weight, gain, efficiency, impedance, frequency characteristics, and radiation pattern. Above all, these factors determine the antenna's economic feasibility. The main differences in how different frequencies are used are related to price, size, and shape.

For transmitting antennas, high gain and directivity are essential. While low side lobes and a high signal-to-noise ratio are important considerations when choosing receiving antennas. Antenna may vary in size from the order of few millimetres(strip antenna) to thousands of feet (dish antennas for astronomical observations) To give a mathematical equation to it, as we know

$$A = \frac{\mu dl}{4\pi}$$

$$dl \frac{dl}{dt} = dlq \frac{dv}{dt} = dlqa$$

$$E = -\nabla V - \frac{\partial A}{\partial t} = -\nabla V - \frac{\mu dl}{4\pi} \frac{\partial a}{\partial t} = -\nabla V - \frac{\mu dl}{4\pi} qa$$

As shown in these equations, to create radiation (electric field), there must be a time-varying current dI/dt or an acceleration (or deceleration) a of a charge q . No radiation occurs if the wire is straight while a charge is travelling with uniform velocity, but radiation that is unlimited in extent occurs if the wire is curved, bent, discontinuous, or terminated. Therefore, the radiation is produced by the current distribution on the antennas. Usually, transmission lines and waveguides are used to excite these current distributions as shown in the Figure 1.2.

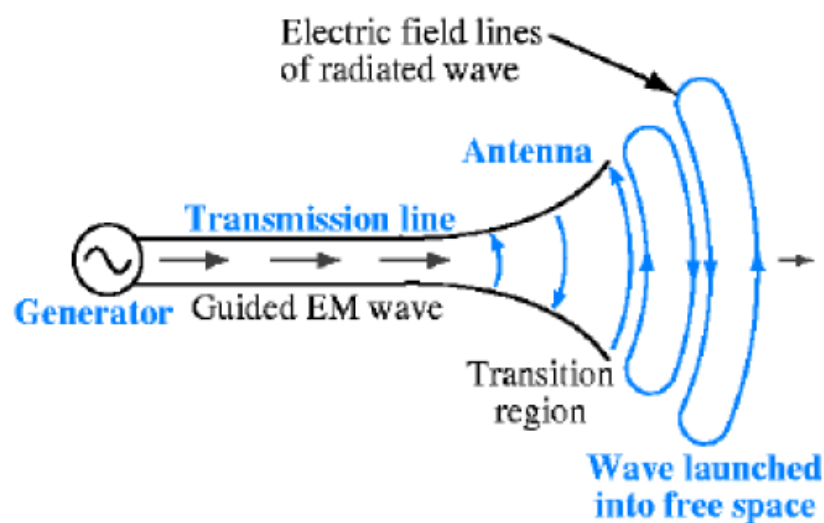


Figure.1.2 Antenna radiation mechanism

1.4 Antenna Parameters

1) The generator's right side is positive and its left side is negative at any given time. According to a physics rule, similar charges repel one another. As a result, electrons will gravitate towards the positive terminal while moving as far away from the negative terminal as they can. The distribution curve reveals that none of the current flows at the ends and that most current flows in the Centre. The current distribution over the antenna

is always the same, regardless of how much or how little current is flowing. However, the quantity of current at any particular location on the antenna varies inversely with the generator's output voltage.

2) The generator creates it after a quarter cycle, at which point the current and voltage reach their minimal values. Although there is no current flowing, there are a minimum number of electrons at the left end and a minimum number at the right end of the line. As the generator's voltage varies, the charge distribution throughout the wire changes as well..

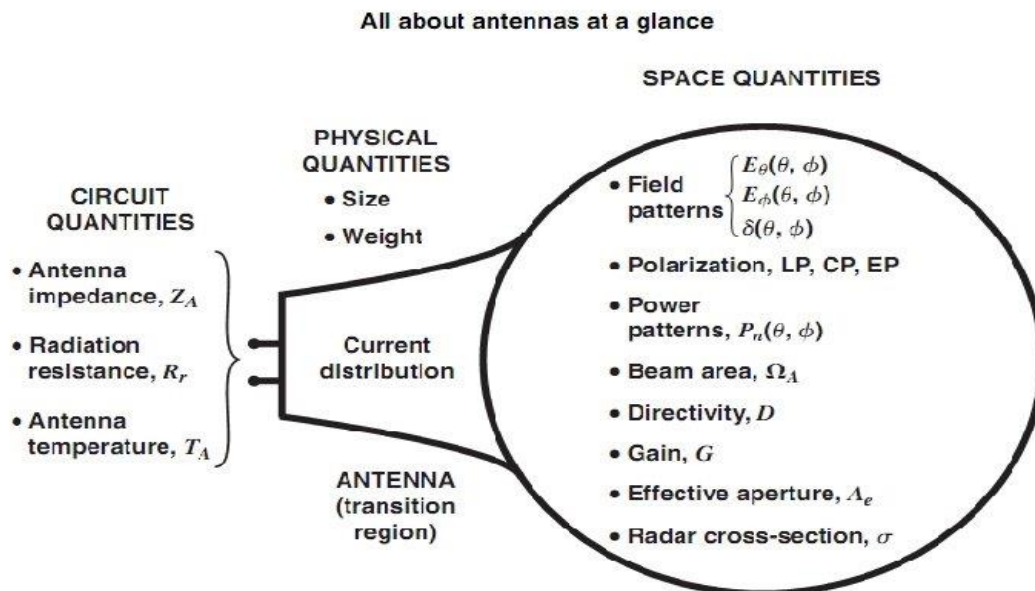


Figure.1.3 Schematic diagram of basic parameters

1.4.1 Gain

Gain is a statistic used to evaluate the directionality of an antenna. A low gain antenna radiates with nearly the same power in all directions, in contrast to a high gain antenna, which preferentially radiates in some directions. In example, the difference between the signal intensity radiated in a given direction by the 11 P antenna at a given distance and the signal intensity radiated in the same distance by a hypothetical isotropic lossless antenna is characterised as the gain, directive gain, or power gain of an antenna. Since

the radiation intensity from a lossless isotropic antenna equals the power into the antenna divided by a solid angle of 4π Steradians,

The gain formula is defined by equation 1.1.

$$Gain = \frac{4\pi \text{ radiation intensity}}{\text{total input(transmitted)power}} \dots\dots\dots(1.1)$$

Although an antenna's gain and directivity are directly related, antenna gain also takes the antenna's efficiency and directional capabilities into account.

1.4.2 Directivity

The radiation intensity from the antenna divided by the radiation intensity averaged over all directions is the definition of the antenna's directivity. The total power radiated by the antenna divided by four determines the average radiation intensity. In other words, the ratio of a non-isotropic source's radiation intensity in a given direction to that of an isotropic source determines the source's directivity. The directivity formula is defined by equation 1.2

$$D = \frac{4\pi U}{P_{rad}} \dots\dots\dots(1.2)$$

1.4.3 Return Loss(S11)

A measure called the Return Loss (RL) shows how much power is sent to the load and does not come back as a reflection. When the transmitter and antenna impedances are not the same, waves are reflected, resulting in the development of standing waves. Consequently, the RL is a parameter to show how well the transmitter and antenna have been matched. The RL is given by equation 1.3.

$$S11(dB) = 10\log_{10} \frac{P_i}{P_r} \dots\dots\dots(1.3)$$

1.4.4 Polarization

When choosing and installing an antenna, antenna polarisation is a key factor. Because an antenna's radiation characteristics depend on its polarization, signals won't be received by the receiving antenna even if the transmitting and receiving antenna's resonance frequencies are exactly matched. The electric field or “E” plane determines the polarization or orientation of the wave. An antenna is vertically linear polarized

when its electric field is perpendicular to the Earth's surface. Antennas with horizontally linear polarisation have an electric field that is perpendicular to the Earth's surface. The plane of polarisation of a circularly polarised antenna revolves in a corkscrew pattern, producing one full rotation for each wavelength. A wave with circular polarisation emits energy in all planes, including the horizontal, vertical, and transverse. Right-hand circular (RHC) polarisation is the sensation that results from a rotation that is clockwise when viewed from the direction of propagation. If the rotation is counter clockwise, the sense is called left-hand-circular (LHC) polarization. Polarization is a significant design factor. Each antenna in a system needs to have its polarisation correctly aligned. When both stations are using the same polarization, the signal between them is strongest.

1.4.5 Voltage Standing Wave Ratio(VSWR)

Electromagnetic waves may experience variations in impedance at each interface as they pass through the many components of the antenna system, from the source through the feed line to the antenna and finally to free space. Standing waves in the feed line are caused by a portion of the wave's energy reflecting back to the source depending on the impedance match. The voltage standing wave ratio (VSWR), which may be measured, is the ratio of the wave's maximum power to its minimum power. A VSWR of 1:1 is ideal. A VSWR of 1.5:1 is considered to be marginally acceptable in low power applications. The VSWR value will be decreased, and power transfer through each component of the system will be maximized, by minimizing impedance differences at each interface. The VSWR can be defined as shown in equation 1.4.

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|} \quad \dots\dots\dots(1.4)$$

1.4.6 Bandwidth

The antenna operating frequency band within which the antenna operates as intended is known as the bandwidth. The ratio of the higher to lower operating frequencies can be used to define the bandwidth of a broadband antenna. In other words, the frequency over which the antenna will perform satisfactorily i.e. it's one or more characteristics

have acceptable values between the bandwidth limits. The absolute bandwidth (ABW) is defined as the difference of the two edges and the fractional bandwidth (FBW) is designated as the percentage of the frequency difference over the Centre frequency, given as shown in equation 1.5.

$$\begin{aligned}
 ABW &= f_L - f_H \\
 FBW &= 2 \frac{f_H - f_L}{f_H + f_L} \quad \dots\dots\dots (1.5)
 \end{aligned}$$

1.4.7 Radiation Pattern

As "a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates," the radiation pattern of an antenna is described. The radiation pattern is typically determined in the far field region and is shown as a function of the directional coordinates. Power flux density, radiation intensity, field strength, directivity, phase, and polarisation are examples of radiation qualities. The term "lobe" refers to a variety of radiation pattern elements. Major, minor, side, and back lobes are the several subtypes of lobes. The definition of a major lobe, also known as the main beam, is "the radiation lobe containing the direction of maximum radiation." Any lobe that is not a major lobe is a minor lobe. A side lobe is "a radiation lobe in any direction other than the intended lobe." (Usually a side lobe is adjacent to the main lobe and occupies the hemisphere in the direction of the main beam.) "A radiation lobe whose axis makes an angle of about 180° with respect to the beam of an antenna," according to the definition, is a rear lobe. The radiation pattern in 3D plane is shown in the Figure.1.4.

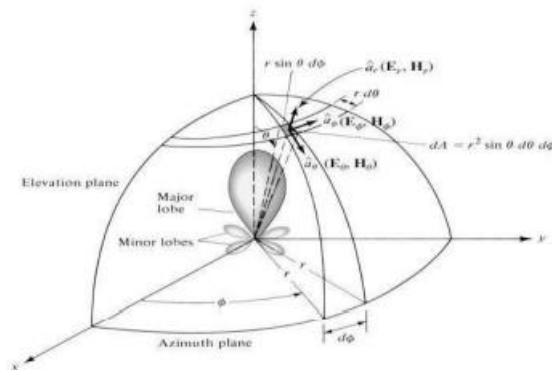


Figure.1.4 Radiation pattern in 3D plane of an antenna

1.5 Types of antennas

1.5.1 Wire Antennas

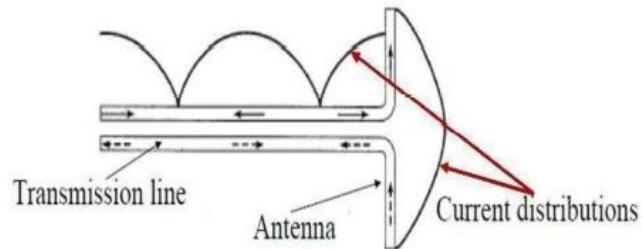


Figure.1.5 Wire antennas

Dipole, monopole, loop antenna, helix antennas:- These were shown in Figure.1.5 and are typically utilised in vehicles, structures, ships, airplanes, and spaceships for personal use.

1.5.2 Aperture Antennas

Horn antennas, waveguide opening Aperture antennas are typically utilised in aircraft and spacecraft because they can be flush mounted. These are shown in Figure.1.6



Figure.1.6 Aperture antennas

1.5.3 Reflector Antennas

Parabolic reflectors, corner reflectors :- High gain antennas like this are typically employed in satellite tracking, microwave transmission, and radio astronomy. The reflector antennas are shown in Figure.1.7



Figure.1.7 Reflector antennas

1.5.4 Lens Antennas

Convex-plane, convex-convex , convex-concave and concave-plane lenses o These antennas are usually used for very high frequency applications.

1.5.5 Microstrip Antennas

Rectangular, circular etc. shaped metallic patch above a ground plane :- Micro strip antennas have a modest profile.A metal patch mounted at a ground level with a dielectric material in-between constitutes a **Microstrip** or **Patch Antenna**. These are

very low size antennas having low radiation. Used in aircraft, spacecraft, satellites, missiles, cars, mobile phones etc and are shown in Figure.1.8.



Figure.1.8 Microstrip antennas

1.5.6 Array Antennas

Yagi-Uda antenna, slotted waveguide array, aperture array, and microstrip patch array- Used for applications requiring very high gains with the benefit of a controlled radiation pattern.

1.6 WBAN band

Wearable and implanted device communication is made possible by a sort of wireless network called a Wireless Body Area Network (WBAN). To monitor different physiological signals like heart rate, blood pressure, body temperature, and other health indicators, these devices are worn or implanted on the body. The WBAN technology is frequently used in healthcare applications like telemedicine, mobile health, and remote patient monitoring. WBANs use low-power wireless communication protocols including Bluetooth, ZigBee, and Wi-Fi as their foundation. Data can be sent between devices using these protocols, as well as between devices and a central monitoring facility. The information is often gathered by sensors implanted inside or attached to the body, and it is relayed wirelessly to a receiver or gateway device.

The capacity of WBANs to continuously monitor the wearer's health is one of their main benefits. As a result, healthcare professionals may remotely monitor patients with chronic diseases and take appropriate action if necessary, which can be especially helpful for those patients. WBANs also have the potential to improve patient

outcomes by enabling early detection of health issues, and providing timely intervention before a condition becomes serious. The low power consumption of WBANs is another benefit. The WBAN devices can be powered by small, long-lasting batteries because they are made to function at extremely low power levels. This is crucial for wearable technology, which has to be portable and unobtrusive. However, there are certain issues with WBANs as well.

Ensuring the security and privacy of the data exchanged between the devices is one of the main issues. It is crucial to make sure that the data carried by WBANs is secured against unauthorised access because it frequently contains sensitive health information. Keeping many systems and devices interoperable is another difficulty. Since WBANs frequently include hardware from several manufacturers, it's critical to make sure that all of the devices can properly interact with one another. This necessitates the creation of universal communication standards and protocols that many manufacturers can use. WBANs are predicted to become more significant in the healthcare industry as technology advances.

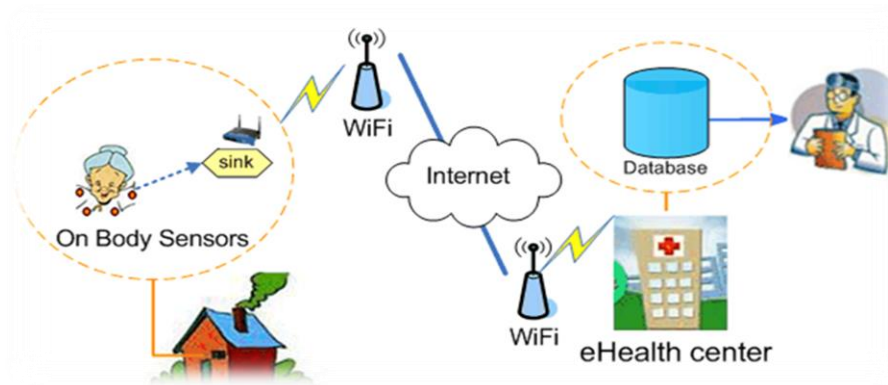


Figure.1.9.Usage of WBAN band

1.6.1 Main components of WBAN

Wireless Body Area Networks (WBANs) are a type of wireless network that comprises tiny sensors worn or implanted on the human body to monitor various physiological data. The main components of a WBAN include:

1.6.1.1 Wearable Sensors: These are tiny electronic devices for monitoring various physiological parameters, including heart rate, blood pressure, temperature, and oxygen saturation. They can be implanted beneath the skin or linked to the body. These sensors can interact with other WBAN devices via wireless communication protocols like Bluetooth or Zigbee.

1.6.1.2. Processing Unit: The data gathered by the wearable sensors is gathered, processed, and analysed by the processing unit. This component may be housed on the wearable device or a different gadget like a laptop or smartphone.

1.6.1.3. Communication Module: The communication module is in charge of sending the information gathered by the worn sensors to other WBAN devices or to a distant server. Depending on the needs of the application, this module may employ Bluetooth, Zigbee, or Wi-Fi among other wireless communication protocols. Power Source: The power source is in charge of providing electricity to the processing and communication components, as well as the wearable sensors. The power source may be a battery, a solar cell, or a wireless charging system, depending on the kind of gadget and the application.

1.6.1.4. Sensor Nodes: The gadgets that are in charge of gathering physiological information from the human body are called sensor nodes. They frequently have various kinds of sensors built into them to track various physiological indicators, whether they are worn or implanted on the body. Low-power devices are built into sensor nodes, which employ wireless connection to provide information to the gateway node..

1.6.1.5. Gateway Nodes: The devices known as gateway nodes are used to process, aggregate, and compress data once it has been received from sensor nodes. They are in charge of running the network and ensuring reliable and efficient data transmission. Additionally, gateway nodes are capable of more complex data processing jobs including pattern recognition, data fusion, and signal processing. They can also put in place a number of security measures to guard the information from unauthorised access or interception.

1.6.1.6. Wireless Communication Technologies: Between the sensor nodes and the gateway node, WBANs communicate data using a variety of wireless communication protocols. Bluetooth, Zigbee, and Wi-Fi are a few of the wireless technologies that are frequently utilised in WBANs. Depending on variables like data rate, range, power consumption, and interference, a wireless technology is chosen. Since WBAN sensor nodes function in close proximity to the human body, low-power devices must be created for them to reduce the amount of energy used. To save power and lengthen the battery life, power management strategies such as duty cycling, sleep modes, and energy harvesting are used.

1.6.2. WBAN Applications

- **Health Monitoring:** Vital indicators including blood pressure, heart rate, and blood sugar levels can be tracked and monitored for health using WBANs. People with chronic diseases or elderly people who need ongoing monitoring may find this to be extremely helpful.
- **Sports and Fitness:** WBANs can be used to monitor an athlete's or fitness enthusiast's performance. The heart rate, body temperature, and mobility can all be tracked using sensors that can be applied to different body areas. This can assist people in making the most of their workouts and avoiding injury.
- **Medical Diagnostics:** WBANs can be used in medical diagnostics to find irregular heartbeats or breathing patterns, for example. WBAN sensor data can be analysed to look for patterns that could point to underlying health problems.
- **Assistive Technology:** The development of assistive technology for people with disabilities can utilise WBANs. For instance, sensors mounted on wheelchairs can identify obstructions and warn the user to steer clear of them.
- **Military Applications:** WBANs can be used for military purposes, such as keeping track of soldiers' vital signs while they are in active combat. This can aid medical professionals in more swiftly locating and treating ailments.
- **Ambient Assisted Living:** Elderly people can live independently at home for longer periods of time with the help of WBANs. In order to notify carers or emergency services of falls or other crises, sensors can be used.

1.7. Wearable Antennas

In order to enable wireless communication, wearable antennas are a particular category of antenna that can be incorporated into clothing or worn on the body. With the popularity of wearable technologies such as smartwatches and fitness trackers, they have increased. Some examples of wearable antennas are:

- Patch Antennas: These are flat antennas that are simple to wear on the body or incorporate into garments. They can be made to work at different frequencies and have a low profile.
- Textile Antennas: These antennas are constructed from conductive materials and weaved into garments. They may be made to fit to the body since they are flexible.
- Whip Antennas: These thin, flexible antennae can be worn on the wrist or on a bracelet. They can be made to be waterproof and work at different frequencies.
- PIFA Antennas: Another low-profile antenna that can be included into clothes is a planar inverted F antenna (PIFA). They are simple to make and may be made to work at different frequencies.
- Flexible PCB Antennas: These are antennas that can be easily incorporated into clothing or wearable technology because they are printed onto a flexible printed circuit board (PCB). They can be made waterproof and engineered to work at different frequencies.

Wearable antennas have a wide range of possible uses, such as wireless communication for monitoring fitness and health, emergency response, and worker communication in dangerous areas. They can also be applied to virtual and augmented reality applications, as well as entertainment and gaming.

1.8. Metamaterials

1.8.1. Introduction

A type of synthetic materials called metamaterials is created to have characteristics that are not present in materials that occur naturally. They often consist of periodic arrangements of subwavelength-sized structures, which gives them their special features. These structures can be designed to manipulate electromagnetic waves, sound

waves, or other types of waves in ways that are not possible with conventional materials. Since its initial introduction in the late 1990s, metamaterials have drawn a lot of interest from researchers across a variety of disciplines, including physics, engineering, and materials science. One of the most important characteristics of metamaterials is their capacity for negative refractive indices, which allows them to bend light in the opposite direction from that of ordinary materials. A wide range of potential uses, such as lenses, cloaking devices, and superlenses that can resolve features smaller than the wavelength of light, have been made possible by this ability. Metamaterials are appealing for use in the aerospace and other industries because they may be manufactured to have exceptional mechanical properties, including a negative Poisson's ratio or a high stiffness-to-weight ratio. Furthermore, specialised frequency response, gain, efficiency, and other characteristics that are crucial for a variety of applications can be engineered into metamaterials. Metamaterials are often created using time- and money-consuming nanofabrication methods, such as electron beam lithography or 3D printing. However, improvements in manufacturing methods and materials science are making it possible to make metamaterials more successfully and affordably, which is anticipated to spur the creation of new applications in the upcoming years.

1.8.2.Properties of metamaterials

Metamaterials have the potential to revolutionize many areas of science and technology. Here are some more examples of their potential applications:

- 1.Antennas: Antennas with high gain, low profile, and wide bandwidth can be made using metamaterials. Many different applications, including wireless communication and radar systems, can make use of these antennas.
- 2.Cloaking devices: It is possible to create metamaterials that will bend light around an item, rendering it invisible to the observer. Both practical uses like concealing ugly objects and potential military applications can be made of this characteristic.
- 3.Solar cells: By absorbing more light and collecting a larger range of the solar spectrum, metamaterials can be utilized to increase the efficiency of solar cells.

4.Sensors: Highly sensitive sensors for a variety of substances, from chemicals to biological molecules, can be made using metamaterials. Numerous applications, such as environmental monitoring and medical diagnostics, are possible with these sensors.

5.Terahertz imaging: Terahertz imaging, which can be used to find hidden weapons and other things, uses metamaterials to construct lenses and other components.

6.Soundproofing: Materials with bad acoustics can be made using metamaterials, and these materials can be utilized to muffle sound and lessen noise pollution.

7.Negative refractive index: It is possible to create metamaterials with negative refractive indices, which can refract light in the opposite direction from that of natural materials. Because of this characteristic, metamaterials can be utilized to create cloaking devices and lenses, among other things.

8.Electromagnetic properties: It is possible to design metamaterials to have particular electromagnetic properties, such as conductivity, permeability, or permittivity that is high or low. They are therefore advantageous for uses such as antennas, sensors, and electromagnetic shielding.

9.Acoustic properties: Metamaterials are advantageous for applications like soundproofing and noise reduction because they may be created to have certain acoustic characteristics, including negative acoustic impedance.

10.Mechanical properties: Metamaterials can be designed to exhibit peculiar mechanical properties including tunable elasticity, a negative Poisson's ratio, and high stiffness-to-weight ratios. They are therefore suitable for usage in robotics, aircraft, and other fields.

11.Frequency response: Metamaterials are advantageous for applications like filters and sensors because they may be made to have a specific frequency response, such as resonant or non-resonant behaviour.

12.Thermal properties: Metamaterials are advantageous for applications like thermoelectric devices and thermal management because they may be manufactured to have certain thermal properties, such as high or low thermal conductivity.

1.9. Metasurfaces

1.9.1. Introduction

Two-dimensional metamaterials called metasurfaces have the ability to precisely and precisely control electromagnetic waves. They are thin, planar structures that typically include a number of scatterers that are smaller than a wavelength organised in a particular way. These surfaces can alter the amplitude, phase, and polarisation of the entering electromagnetic waves because to their distinctive design. Metasurfaces can be used to focus, shape, and steer the waves of light in a variety of ways. They are very helpful when designing optical parts like polarizers, beam splitters, and lenses. Metasurfaces, which are much thinner and more compact than conventional bulky optical components, can have the same effect as those components by precisely adjusting the phase of incoming light. Holography is one of the most fascinating fields in which to use metasurfaces since it allows for the creation of high-resolution 3D images. A 3D image that appears to be floating in space can be produced by using metasurfaces to alter the phase of the incoming light. Potential uses for this method include virtual reality, entertainment, and medical imaging. The creation of novel detectors and sensors also makes use of metasurfaces. Metasurfaces can improve the sensitivity and resolution of sensors, enabling them to detect incredibly small changes in the environment by altering the characteristics of the incoming electromagnetic waves. With potential uses in a variety of sectors, including optics and sensing, telecommunications, and information technology, metasurfaces constitute an interesting new area of research in the science of metamaterials.

1.9.2. Properties of metasurfaces

Metasurfaces are appealing for a variety of applications due to their distinctive characteristics. Some of these properties include:

- High precision control of electromagnetic waves: With the ability to precisely regulate the amplitude, phase, and polarisation of electromagnetic waves, metasurfaces may manipulate light in previously unimaginable ways.

- **Thin and lightweight design:** Metasurfaces are frequently thin and light, making it simple to integrate them into current systems and equipment. They are perfect for use in miniature devices since they are smaller than conventional optical components.
- **High efficiency:** Metasurfaces are highly effective in controlling electromagnetic waves, which enables them to carry out challenging tasks with little energy loss.
- **Broadband operation:** Some metasurfaces are able to alter light from many sources and at various wavelengths because they can function over a wide range of frequencies.
- **Versatility:** Metasurfaces can be created to carry out a variety of tasks, such as polarizing, filtering, and concentrating light.
- **Compatibility with existing fabrication techniques:** Many metasurfaces can be produced at scale using currently available methods, such as electron-beam lithography or laser patterning.

CHAPTER 2

LITERATURE REVIEW

C. A. Balanis' "Antenna Theory: Analysis and Design" [1] is a comprehensive textbook that covers the fundamental principles and practical applications of antenna engineering. Aperture antennas, array antennas, broadband antennas, radiation pattern analysis, antenna parameters—just a few of the many topics it covers—include the fundamentals of electromagnetic theory.

In 2014, W. G. Whittow et al,[2]has reported a novel method of fabricating wearable antennas using inkjet printing. With the addition of the second layer of ink, the performance of the totally cloth patch antennas was enhanced. According to simulations and SEM measurements, this second layer of ink had two purposes: 1) improving the consistency of the surface; and 2) extending the skin depth of the conducting layer, which has a conductivity of around 1 MS/m.

In 2017 , X. M. Hu, S. Yan, and G. A. E. Vandenbosch, [3]proposed a new type of dual-band button antenna for WLAN 2.45 and 5 GHz applications,simulated, fabricated and measured. The suggested antenna has consistent far-field characteristics, a good and robust dual operating bandwidth performance, and a relatively small size. For use in on-body and off-body communication, the 2.4 GHz and 5 GHz bands, respectively, have both a monopole and a broadside type radiation pattern.

In 2014,S. Agneessens and H. Rogier,[4] proposed a dual-band wearable antenna based on a novel half-diamond shaped HMSIW topology, fabricated using textile materials and brass eyelets. By using a mix of a ground plane and SIW technology to produce a half-open chamber, the design was specifically created to display robust behaviour when worn by a human. In an anechoic environment, the antenna underwent extensive testing in both free-space and on-body settings. Impedance matching and radiation performance in free space show very excellent agreement between simulations and observations.

In 2017, D. Ferreira, P. Pires, R. Rodrigues, and R. F. S. Caldeirinha,[5] reported the effect of bending on the performance of a rectangular microstrip textile-patch antenna for WBAN tuned at 2.4 GHz. The antenna's conducting material was composed of copper and nickel mixed together with polyester fibre and denim as the substrate. The bending impact on performance caused by the placement of the antenna at three general locations—the chest, arm, and wrist—was investigated under the assumption that a textile antenna for WBAN may be included into clothing.

In 2018, G. P. Gao, B. Hu, S. F. Wang, and C. Yang,[6] proposed a wearable PIFA with dual band characteristics . The antenna gain and SAR are improved by the rectangular ring-shaped EBG. The suggested antenna is stable when bent and operates within the 2.4/5.8 GHz WLAN frequency spectrum. The EBG structures produce unidirectional radiation, which can lower the radiation energy to the human body, according to measured radiation patterns. The suggested antenna is excellent for use with WBAN applications.

In 2017, N. W. Liu, L. Zhu, and W. W. Choi,[7] proposed a novel low-profile planar PIFA with enhanced bandwidth under the dual-resonance operation of two radiative resonant modes, i.e., $TM_{0,1/2}$ and $TM_{2,1/2}$ modes. An antenna prototype is fabricated and tested to validate the predicted performance. The results shows that the bandwidth of the PIFA has gained a tremendous increment up to 15.3% with two in-band attenuation poles.

In 2009, S. Zhu, and R. Langley,[8] proposed a dual-band coplanar patch antenna integrated with an electromagnetic band gap substrate. The antenna configuration uses the 2.45 and 5 GHz wireless bands and is constructed from standard clothing textiles. The coplanar antenna design, the band gap substrate design, and their integration are presented. Despite having only 3x3 elements, the band gap array decreases radiation entering the body by over 10 dB and increases antenna gain by 3 dB. The performance of the antenna when bent and when mounted on a person's body are shown.

In 2009, Q. Bai and R. Langley,[9] presented the performance of a dual band textile CPW antenna under different bending and crumpling conditions. The performance of the antenna is presented together with an electromagnetic band gap material (EBG) to

improve the wearable antenna performance. At 2.45 GHz and 5.8 GHz, the input impedance and radiation pattern are examined using numerical and experimental techniques.

In 2012, Q. Bai and R. Langley,[10] proposed of a PIFA textile antenna under different crumpling conditions. At 2.4 GHz, input impedance, efficiency, and radiation patterns are examined using numerical and experimental techniques. The resonance frequency, bandwidth, and radiation from textile antennas can all be significantly impacted by crumpling.

In 2014, Z. H. Jiang, D. E. Brocker, P. E. Sieber and D. H. Werner,[11] proposed compact conformal wearable antenna that operates in the 2.36–2.4 GHz medical body-area network band. The antenna is made possible by putting a planar monopole underneath a highly truncated metasurface made up only of a two by two array of I-shaped pieces. The exhibited antenna has a small form factor compared to other wearable antennas that have been proposed in the past. It also achieves a gain of 6.2 dBi, a front-to-back ratio of more than 23 dB, and a 5.5% impedance bandwidth.

In 2016, Yan S, Vandenbosch.G,[12]proposed a pattern reconfigurable wearable antenna is designed based on a metamaterial structure. The patch antenna can resonate at the zeroth-order mode or the +1 mode by rearranging the transmission line's dispersion curve, producing a broadside or omnidirectional radiation pattern, respectively. Fabricated for wearable applications, the antenna is made of cloth. In both operational modes, the impedance bandwidth spans the 2.4 GHz industrial, scientific, and medical (ISM) band.

Comparison Table of References:

Ref.No.	Area Profile size (mmxmm)	Frequency (GHz)	BW (GHz)	Peak gain (dBi)	S11 (dB)	Efficiency	Application
[6]	40.11x40.15	5.81	0.371	0	-13	86.1%	WBAN application
[7]	73x42	5.80	0.22	3.15	-18	78.5%	WBAN application
[8]	39.85x39.79	5.83	0.71	6.55	-24	84%	WBAN application
[9]	30x30	5.33	0.57	5.11	-19	89.6%	WLAN health care application
[10]	41x48	5.80	0.29	1.11	-25	82.3%	WBAN
[11]	55x55	2.45/5	5.51-5.6	6.41	-38	75.5%	WBAN application
[12]	55x55	2.45/5.8	0.76-0.61	5.2	-25	64.3%	To design wearable antennas

Table 2.1 Comparison table of References

CHAPTER 3

CST STUDIO SUITE

3.1.Introduction

Engineers and researchers use antenna designing software as a specialised tool to design and optimise various types of antennas for certain applications. These computer programmes analyse the performance of the antenna under various conditions and offer suggestions on how to enhance the design using complex algorithms and simulations. Some of the popular antenna designing software programs available in the market include:

1.HFSS (High-Frequency Structure Simulator): Antennas, microwave circuits, and other high-frequency electronic systems are designed and analysed using this potent electromagnetic simulation software tool.

2.CST Studio Suite: This software package comprises tools for the analysis of microwave and RF circuits as well as for electromagnetic simulation, antenna design, and optimisation.

3.FEKO: A wide variety of antennas, including microstrip, patch, and helix antennas, can be designed and analysed using this complete electromagnetic simulation software suite.

4.ANSYS HFSS: Another electromagnetic simulation software tool, such as microstrip, patch, and slot antennas may all be designed and examined using this programme.

These software programs can significantly streamline the antenna design process, allowing engineers to quickly evaluate different designs and optimize their performance. They can also reduce the cost and time required for prototyping and testing, making them an essential tool for antenna design and development.

Table 3.1 Comparison table between CST Studio Suite and some other popular antenna design and simulation software programs:

Feature	CST Studio Suite	HFSS	FEKO
Electromagnetic simulation capabilities	Comprehensive package with a wide range of simulation tools for designing and analyzing a broad range of antennas, including complex structures such as arrays and metamaterials.	High-frequency electromagnetic simulation software that is widely used for designing and analyzing antennas, microwave circuits, and other high-frequency electronic systems.	Comprehensive electromagnetic simulation software package that can be used for the design and analysis of a wide range of antennas, including microstrip, patch, and helix antennas.
User interface	Intuitive and user-friendly interface that makes it easy to set up simulations and analyze results.	User interface can be complex for new users, but it is highly customizable and can be tailored to specific needs.	User interface can be complex for new users, but it is highly customizable and can be tailored to specific needs.
Optimization algorithms	Includes advanced optimization algorithms that can be used to quickly and efficiently optimize antenna designs for specific performance metrics.	Includes advanced optimization algorithms that can be used to quickly and efficiently optimize antenna designs for specific performance metrics.	Includes advanced optimization algorithms that can be used to quickly and efficiently optimize antenna designs for specific performance metrics.

Integration with other design tools	Can be seamlessly integrated with other design tools, such as CAD software and PCB layout software, making it easier to incorporate antenna designs into larger systems.	Can be seamlessly integrated with other design tools, such as CAD software and PCB layout software, making it easier to incorporate antenna designs into larger systems.	Can be seamlessly integrated with other design tools, such as CAD software and PCB layout software, making it easier to incorporate antenna designs into larger systems.
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3.2. Advantages of CST software:

1. Comprehensive electromagnetic simulation capabilities: A comprehensive software suite with a variety of electromagnetic simulation tools is called CST Studio Suite. As a result, it may be used to construct and analyze a wide variety of antennas, including those with complicated features like arrays and metamaterials.
2. User-friendly interface: Simulator setup and result analysis are made simple using CST Studio Suite's user-friendly interface. When it comes to intricate designs, in particular, this can save a lot of time and work.
3. Advanced optimization algorithms: Advanced optimisation techniques are included in the programme that may be used to quickly and effectively optimise antenna designs for particular performance metrics. Engineers may be able to improve performance with fewer iterations as a result.
4. Integration with other design tools: Antenna designs can be more easily included into bigger systems thanks to CST Studio Suite's seamless integration with other design tools including CAD and PCB layout software.
5. Comprehensive support and training: For new users or those working on complicated projects, the software vendor offers a wealth of support and training options, including webinars, user forums, and documentation.

- Although there are numerous software programmes available for antenna design and simulation, CST Studio Suite is a popular choice for many engineers and researchers due to its extensive electromagnetic simulation capabilities.

3.3. Overview of the User Interface

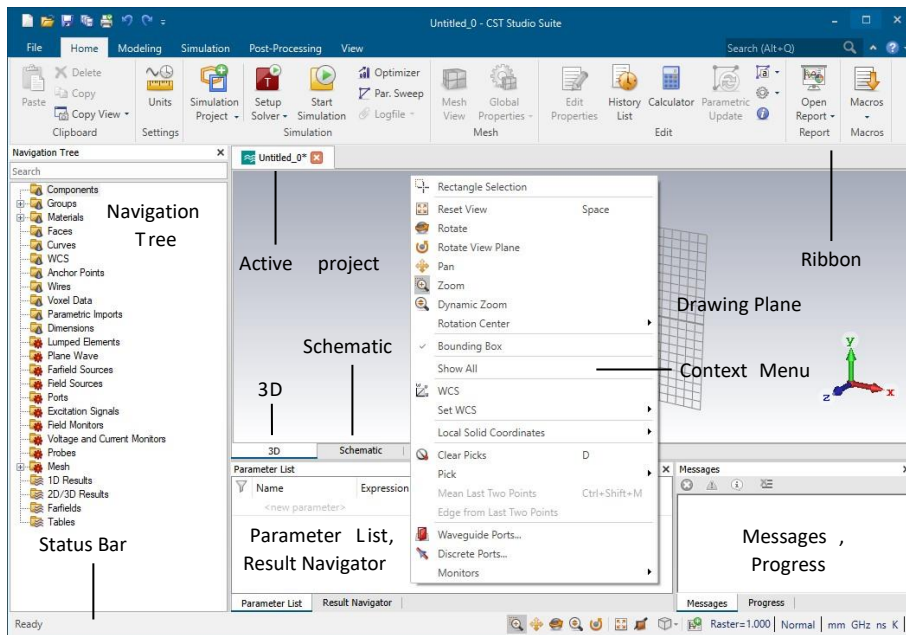


Figure 3.1. various user interface elements

3.3.1 Ribbon

The Ribbon command bar organizes all user interface controls in a series of tabs. It is a replacement for the classical menus and toolbars:

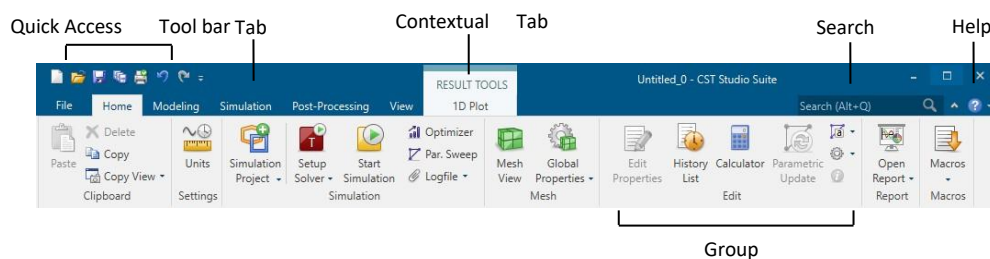




Figure 3.2. Ribbon command bar

All commands in a Ribbon tab are organized in groups, which are labeled. Besides tabs and groups, the Ribbon consists of:

- A Quick Access Toolbar. This is a small customizable toolbar that displays commands, that displays frequently used commands.

- Core tabs are the tabs, which are always visible. When switching from 3D to Schematic the core tabs change, because each mode has its own set of individual controls.
- Contextual tabs are activated only when a particular object is selected or special view is active.
- The File tab consists of a set of commands related to file handling. General application options and additional help can also be found here.
- A *Search* field to quickly find commands, examples or search in the help.
- A *Help*  button to access the online help and the support account. In addition, the *Quick Start Guide* can be started here if a CST Microwave Studio project or a project of a similar type is active.
- The *Minimize the Ribbon (Ctrl+F1)*  button can be used to hide all the Ribbon groups. Instead, only the tab labels are permanently visible.

3.4.Simulation workflow

There following are the steps for designing an antenna followed by its simulation:

1.Start the application by selecting the CST Studio Suite entry in the Windows Start menu's CST Studio Suite 2020 folder. You will see the main window of the CST Studio Suite user interface:

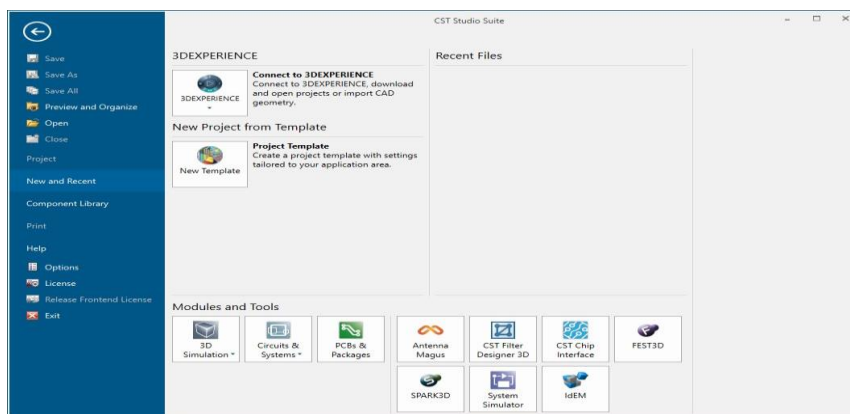


Figure.3.3. Main window

2. By selecting the New Template button on the New and Recent tab, a new project can be started. By pressing this, the template wizard will launch, leading you through a series of questions to define the application domain for your new project.

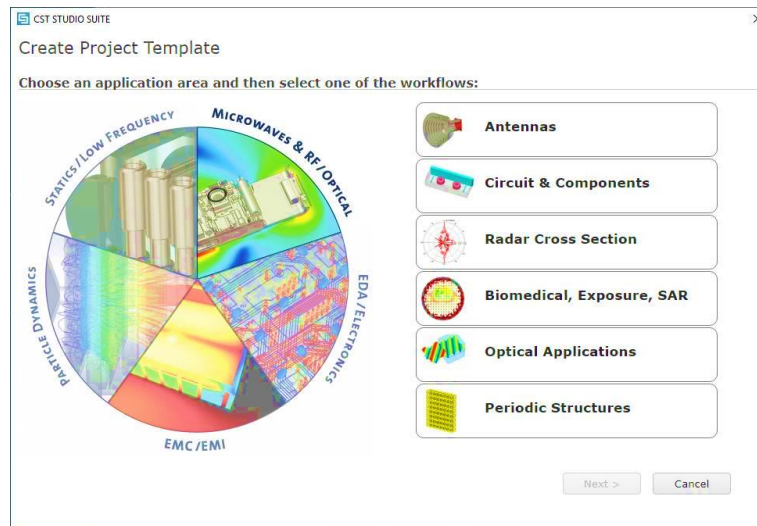


Figure 3.4. Project template wizard

3. We don't need any unique project settings for this introduction, so simply choose MW & RF & OPTICAL and Antennas, then repeatedly press the Next button without making any changes. On the summary page, which follows the project definition, you can confirm your selections. Change the project template's name on this page if necessary:

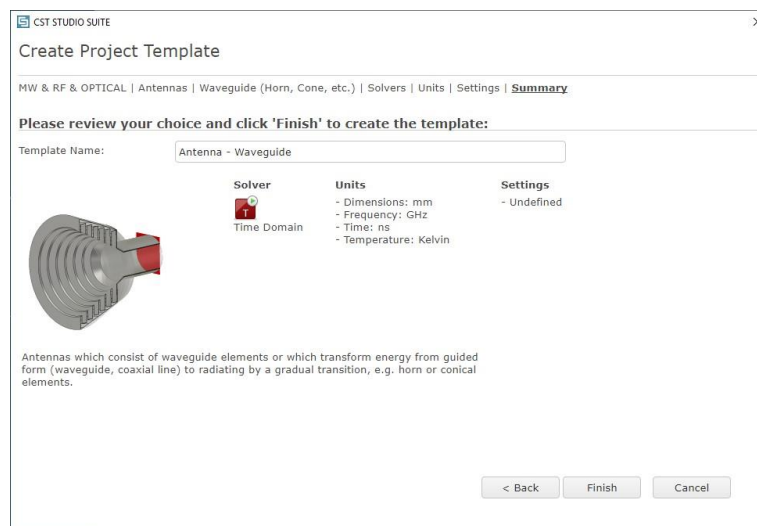



Figure.3.5. Template wizard

Finally press the *Finish* button to start the appropriate module. In this case, this is the high frequency module CST Microwave Studio.

4. Create a First Brick

- Use the *Modeling* tab and activate the Brick tool by using *Modeling: Shapes > Brick* . You are able to select the first point of the brick's base in the drawing plane (see the text line in the upper left corner of the main window).
- Double-clicking a spot on the drawing plane will allow you to specify a starting point.
- You can now double-click on the opposite corner of the brick's foundation to pick it on the drawing plane.
- Next, adjust the brick's height by dragging the mouse. To adjust the brick's height, double-click.
- Finally, a dialogue window displaying all of the coordinate places you have entered's numerical values will popup. To save the settings and produce your first primitive, click OK. You can choose an existing material from the list in this dialogue box or define a new one by choosing [New Material...] from the options. Afterward, a new dialogue box will appear:

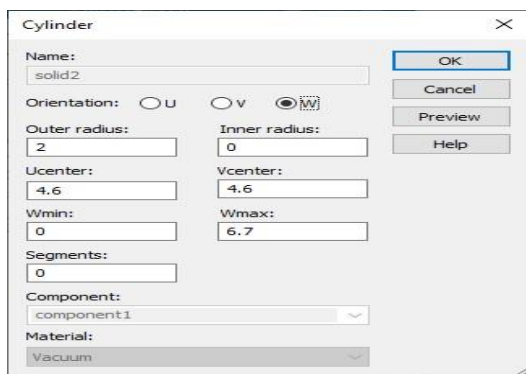


Figure.3.6.Brick window

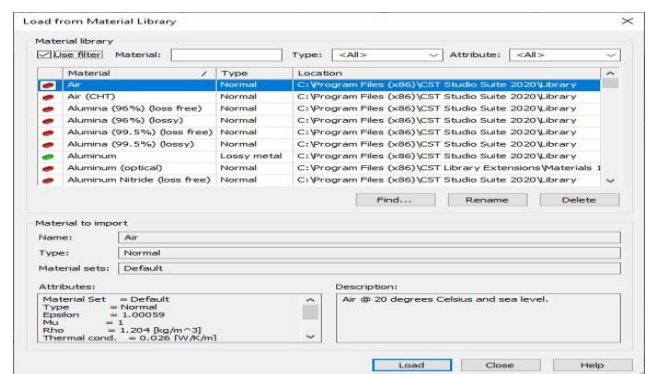


Figure.3.7.Material Library

5. A shape is automatically categorised in the navigation tree once it has been defined. Every shape is contained in the Components folder. You can find all defined forms in a subfolder called component1 if you enter this folder. When a shape is produced, the

final shape dialogue box is where each primitive's name is allocated. The names that are used by default begin with "solid" and then an increasing number: solid1, solid2, etc.

6. The first port will be assigned to the antenna's front face in the following step. Picking the port face first by using the Pick Face tool is the simplest method, followed by a double-click on the selected face. By clicking the "Define waveguide port" icon after the port's face has been selected, you can access the waveguide port dialogue box. The bounding box of any previously selected elements (faces, edges, or points) will be used to automatically specify the extension and location of the port in the waveguide port dialogue box.

7. After specifying the ports and necessary frequency range, click the start simulation button to begin the simulation.

8. Results from a simulation are often displayed in the navigation tree once it is finished. The result curves for the current parameter values will be displayed, for instance, when a result is selected from the navigation tree:

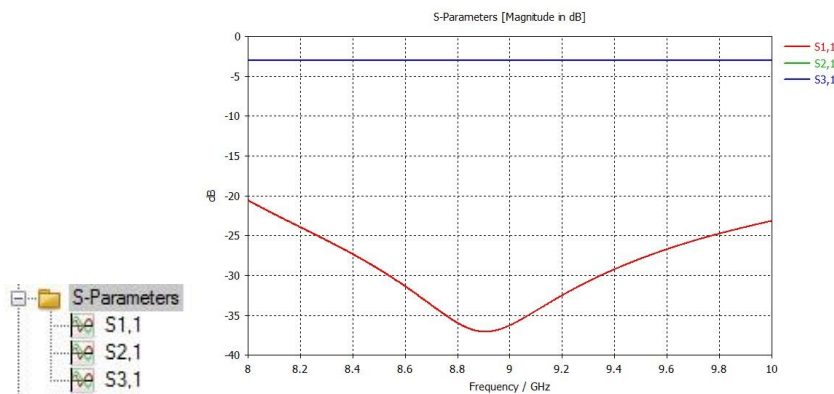


Figure.3.8. S-parameters

9. The Post-Processing Templates allow for flexible processing of 2D/3D Fields, 1D Signals, or scalar values (0D Results).

Typical examples for Post-Processing Templates are 1D results such as the following:

- Z, Y versus frequency

- Farfield 1D plots at a single frequency
- Broadband farfield values
- Group delay times
- 1D Plots of 2D/3D results along arbitrary curves
- FFT of existing time signals
- Exchange excitations and TDR functionality
- Mixture of any of these 1D-results using an analytic formula ..etc

10. After getting the desired output save the file with extension .cst and export the images of the proposed antenna model.

CHAPTER 4

ANTENNA DESIGN

4.1.Introduction

A wireless network of wearable computer devices is known as the Wireless Body Area Network (WBAN). The implants are portable and can be carried by hands or in clothing because they are placed on the body's surface. This body area network offers long-term, continuous monitoring over or inside the human body and sends things like speech and video. We employ antennas in today's technology because they offer an easy way to transport signals or data. The only method of communication is wireless, and antennas are the entry point. Due to its appealing qualities and potential applications, such as affordable, portable wireless communication and sensing, wearable antennas have recently attracted a lot of attention. Different types of wearable antennas are made for reliable functioning when positioned on body tissue and subjected to bending. Although small bandwidth presents a significant challenge for antennas, the process of increasing bandwidth by using several resonances. However, despite the size being raised, the procedure still did not produce the required gain. Dielectric superstrate can be placed on the antenna to increase gain and minimise size, but it is unmanageable. Instead, an EBG (Electronic Band Gap) structure can be employed as a superstrate that functions as a stop band to block electromagnetic waves, but the results do not meet expectations. In order to do this, the 2-dimensional periodic structure Metasurface (MS), which consists of an array of unit cells and works as a band limit filter, is used. These metasurfaces are capable of blocking or absorbing the electromagnetic waves that are mostly used to reduce size. Typically, this metasurface is positioned above or below the antenna. Additionally, it has been noted that the antenna size decreased and the impedance bandwidth decreased. Regarding the design and performance is discussed in the following sections.

4.2. Construction Of Antenna Using CST

Firstly, the Microstrip patch antenna is designed. The basic structure of the antenna consists of ground, substrate, patch, feed.

The following are the steps to be followed to design the antenna:

- **Ground plane:** A ground plane is a crucial part of an antenna system because it gives the antenna a reference point and enhances its performance. The radio waves are reflected back towards the antenna by the ground plane, which boosts the radiation's effectiveness. Typically, a big, flat metal surface known as the ground plane is used in conjunction with an antenna. The size and shape of the ground plane can have a significant impact on the antenna's performance, as it affects the antenna's impedance, radiation pattern, and efficiency. Draw the outline of the ground plane using the sketch tool. The ground plane is usually a rectangular shape, but it can also be a custom shape.

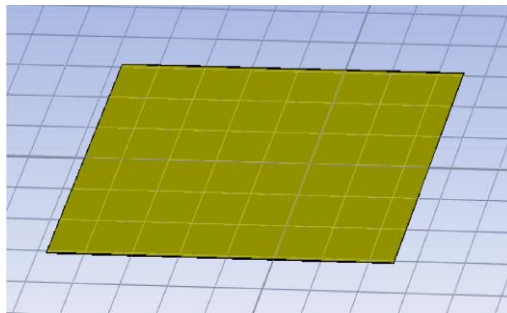


Figure.4.1.Ground plane

- **Loading Substrate:** The substrate is a key component in many antenna designs since it supports the antenna's structural integrity and affects its electromagnetic characteristics. In antenna design, the substrate is the material on which the antenna is constructed or mounted. The substrate material is an important consideration when building an antenna since it can affect the antenna's radiation effectiveness, bandwidth, and other performance characteristics. The substrate is constructed of FR4 material, which has a 1.6mm thickness and dimensions of Lg and Wg.

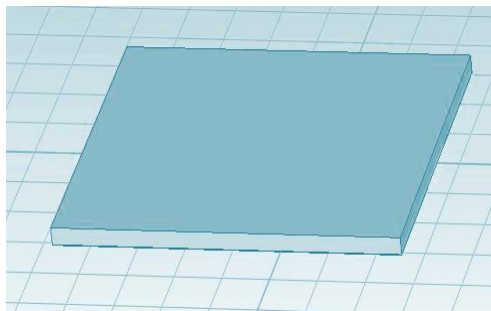


Figure.4.2.Substrate on ground plane

- **Loading Patch:** In contemporary communication systems, patches are a common type of antenna. A patch antenna is a kind of antenna that consists of a flat metal surface that is either rectangular or circular and is often positioned above a ground plane. Typically, a coaxial cable or microstrip line connected to a transmitter or a receiver feeds the patch. Because they are very simple to develop, manufacture, and incorporate into complicated systems, patches are widely used. They may be made to have a relatively large bandwidth and are low-profile, making them appropriate for a variety of applications. For the ease of changing the dimensions the square shape is opted. Being a square patch the current distribution among the sharp edges is not much easy, so the corner is cut in this design upto 1mm on the patch. The material of the patch used is copper.
- **Etching slot out of the patch:** In antenna design, cutting a slit out of a patch might be helpful. A discontinuity in the current flow caused by the slot, which is basically a hole in the patch, can change how the antenna emits electromagnetic waves. Slot has been provided in order to decrease the patch size without altering the proportions. By lengthening the patch's electrical connection, the frequency changes automatically. On the patch, a rectangular slit with dimensions L_s and W_s is etched out.
 - a) To improve the bandwidth of the antenna: A slot can increase the frequency range that an antenna operates over, which can be advantageous in some applications.
 - b) To create a directional antenna: By designing the slot in a specific way, it is possible to create a directional antenna that radiates more power in direction than another. This can be useful for applications like point-to-point communication.
 - c) To reduce the size of the antenna: Etching a slot out of a patch can reduce the overall size of the antenna, which can be beneficial in applications where space is limited.
- **Shortening of pins:** An antenna's resonance frequency can be changed by shortening the pins inside the device. Shortening a pin reduces the antenna's radiating element's length, which in turn alters the resonance frequency of the

antenna. The frequency at which an antenna generates the strongest electromagnetic field is known as the resonant frequency. It is possible to change the antenna's resonance frequency to a desired frequency by modifying the radiating element's length by shortening the pins. Two shorting pins with 1mm diameter at a distance $D1$ are loaded on the patch for the bandwidth enhancement.

- **Giving feed:** Different feed types are received by the antenna. Transmission line feed and coaxial feed are the two most common feed types. Without a metasurface, the antenna's (Antenna1) core houses the feeding point. Since the metasurface was included, it has changed. Transmission line feed is not supported due to the patch's additional layer. It uses coaxial feed at 50 ohm. The feeding location serves as the basis for the impedance matching. The position must be on the patch for the return loss to be accurate. With the aid of a rectangular transmission line with dimensions L_f and W_f for the feed position, the patch is stretched..

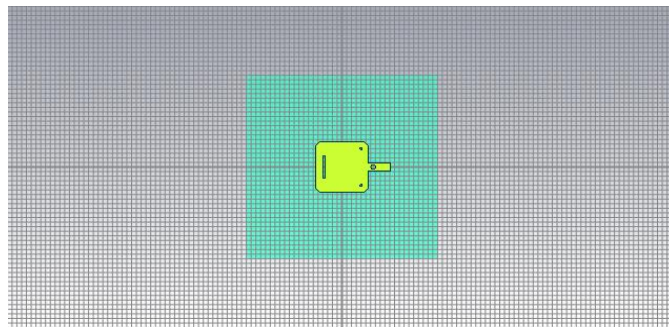


Figure.4.3.Antenna without metasurface(Antenna 1)

- **Loading Metasurface:** The superstrate, which is made of the FR4 material and has a 1.6mm thickness, is loaded onto the antenna, and the metasurface is installed on top of it. L_g Width and W_g Length describe the superstructure. The potential of metasurfaces as a method for miniaturizing and integrating optical components into compact, light devices has enabled the creation of metasurface-based photonic circuits and metasurface-assisted optoelectronic devices. In this instance, the metasurface is composed of a 5x5 array of unit cells.. Utilizing

more cells on the metasurface increases the gain. 25 cells are created with a size L_2 for the metasurface's specified dimensions. The G-value between the cells is important and crucial. Figures depict the microstrip antenna both with and without a metasurface. The antenna with metasurface (Antenna2)'s complete set of specifications is presented in the table 4.1 given below.

Table 4.1.Parameters of metasurface antenna

Parameter	Dimension (mm)
L_g	40
W_g	40
L_p	11
W_p	11
L_f	4.5
W_f	1.8
L_s	5
W_s	0.5
D1	8
L_2	6
G	0.2
L_3	30.8

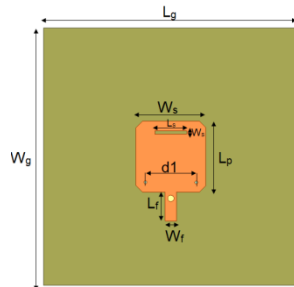


Figure.4.4.Top side of substrate

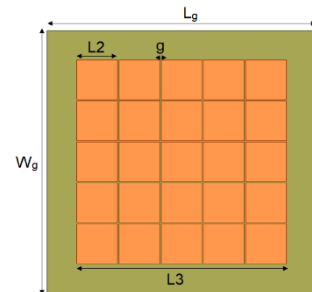


Figure.4.5.Top side of Superstrate

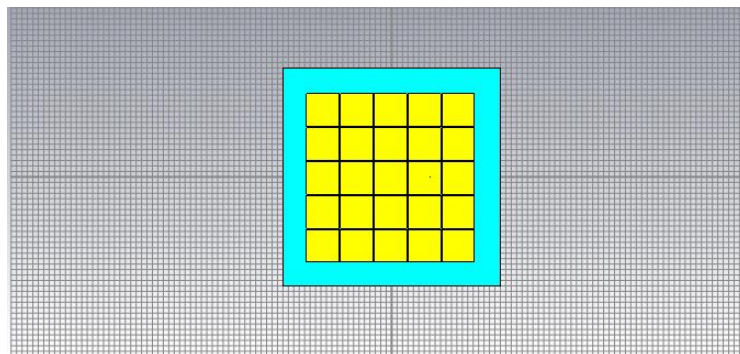


Figure.4.6.Metasurface Antenna(Antenna 2)(Front view)

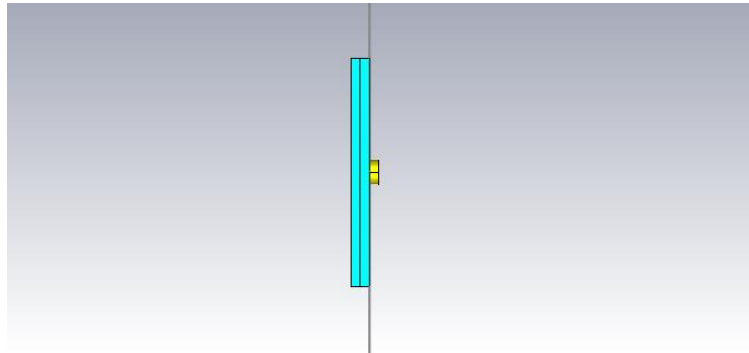


Figure.4.6.1.Right side view

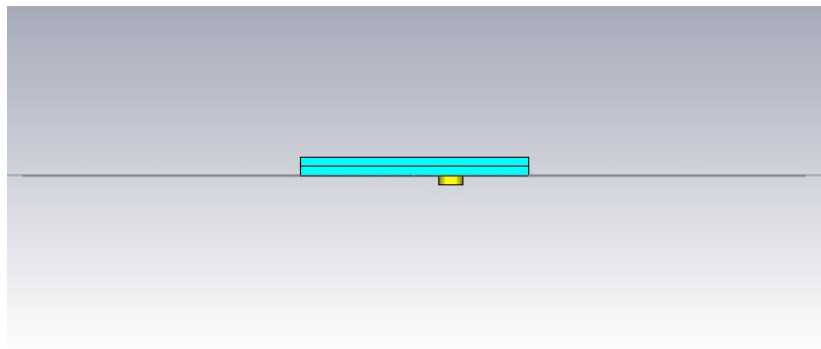


Figure.4.6.2.Bottom view

- **Loading metasurface antenna on the human body:** The suggested Metasurface antenna ought to be safe for people to use. The CST microwave studio had a cube with a three-layer human tissue accessible. Antenna was consequently positioned 5 mm above human tissue.

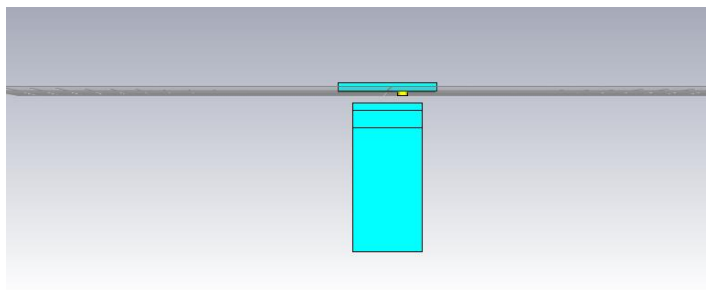


Figure.4.7.Metasurface antenna placed on human tissue

CHAPTER 5

RESULTS

5.1.Introduction

The outcomes of CST simulation offer insightful knowledge regarding the behaviour of electromagnetic fields and the functionality of various parts or systems. By examining their performance under various operating situations, the simulation findings can be utilised to optimise the design of antennas, filters, transmission lines, and other electronic devices.

5.2. S11 parameters

The S11 parameter can be used to optimize the impedance matching of the antenna system. By analyzing the reflection coefficient at the input port, we can adjust the dimensions of the antenna, add matching networks, or modify the transmission line to improve impedance matching and reduce reflection. The results of S11 parameters of the antenna with meta surface and without metasurface had been shown in the below figures 5.1 and 5.2 respectively. The bandwidth of $S_{11} < -10\text{dB}$ for the antenna without metasurface is 5.39-5.53 GHz. Whereas for the antenna with metasurface is 4.44-5.85 GHz. Here we can observe the bandwidth has widened. The simulated bands cover the 5GHz WBAN band (is 5.15-5.825GHz).

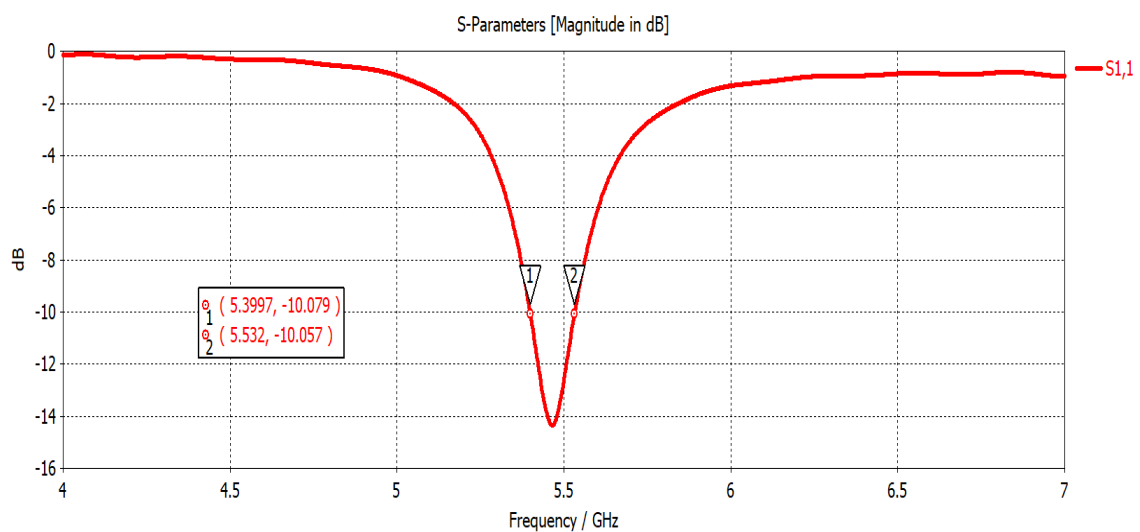


Figure.5.1.S11 parameter of patch antenna without metasurface

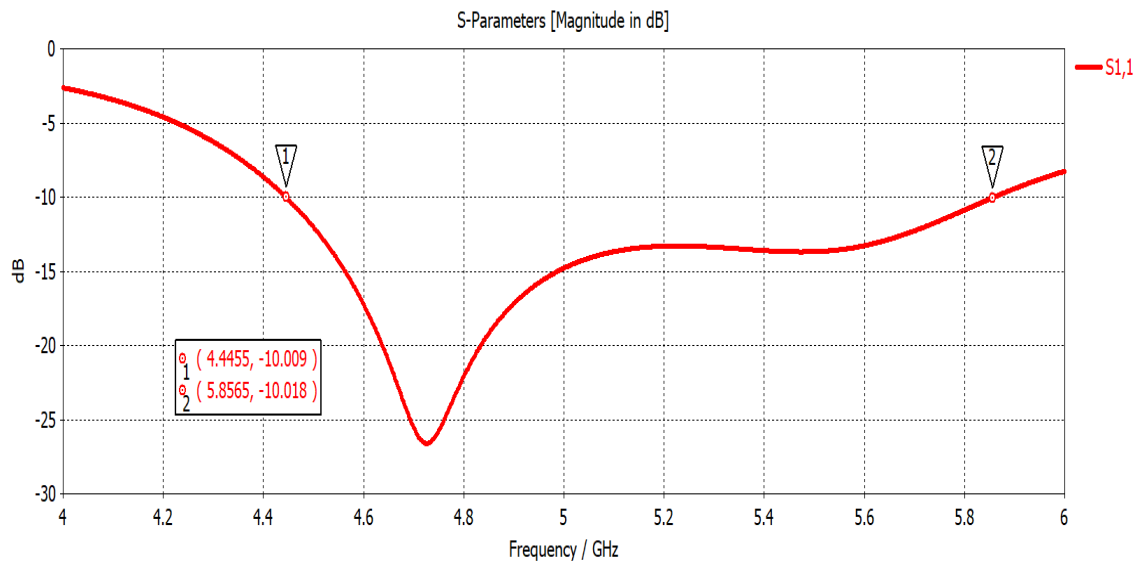


Figure.5.2. S11 parameter of patch antenna with metasurface

5.3.Frequency vs Gain

A graph that depicts the relationship between the frequency of the signal and the antenna's gain is called the frequency vs. gain of an antenna. An antenna's gain, which is commonly represented in decibels (dB), is a measurement of how well the antenna transforms input power into radiated power in a specific direction.

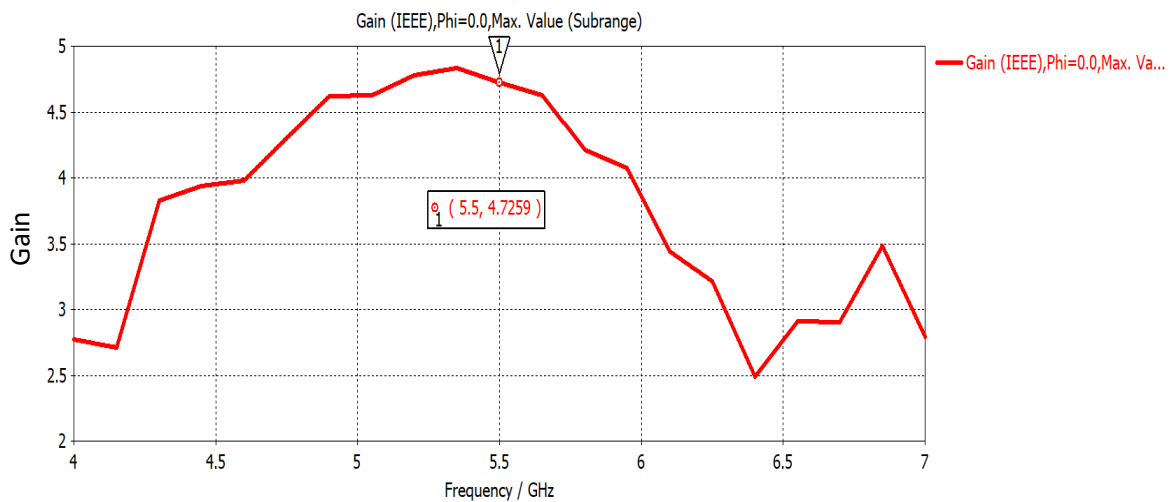


Figure.5.3. Frequency vs gain of patch antenna without metasurface(Antenna 1)

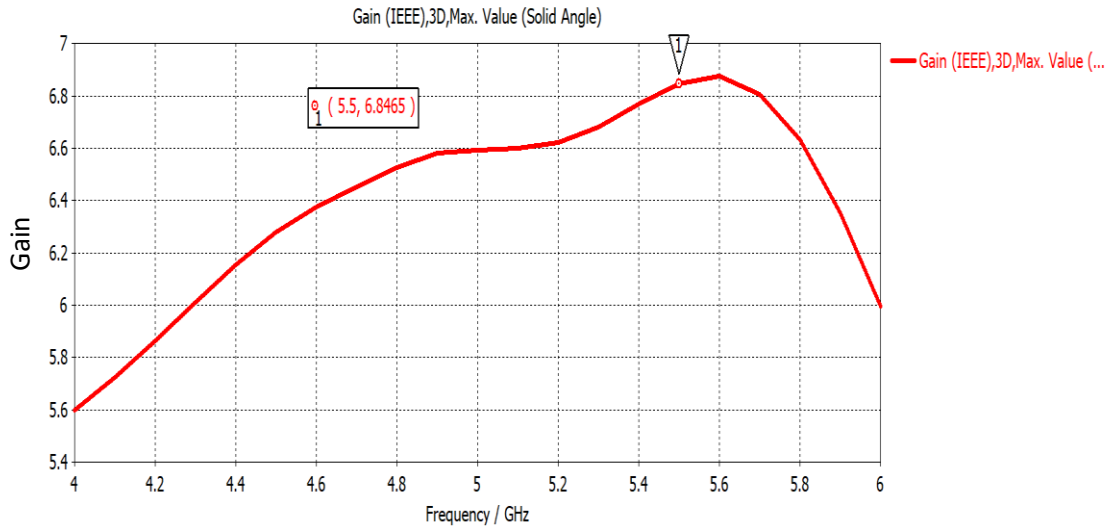


Figure.5.4.Frequency vs gain of patch antenna with metasurface(Antenna 2)

The first antenna to be developed without a metasurface has a gain of 4.7 dB. The frequency was shifted down in the antenna after pins were shorted. Once more, the antenna's size needs to be decreased in order to operate at the appropriate frequency. The gain will automatically decrease if the antenna's size is reduced. In order to increase gain, the antenna is loaded with the metasurface. The gain enhancement method is revealed by comparing the radiation patterns of Ant 1 (an antenna without Metasurface) and Ant 2 (an antenna with Metasurface) at 5.5 GHz. When compared to Ant 1, Ant 2's peak gain at 5.5 GHz is improved by about 2.1 dB. By this we can say that Metasurface creates the additional resonance such that the gain will be enhanced. when compared with Ant 1.

5.4.Radiation patterns

Antennas with higher gain are often used in applications where a stronger signal is required, such as in long-range communication or in applications with low signal strength. However, a higher gain antenna may also have a narrower beamwidth, which means that it may be more difficult to aim it accurately towards the desired receiving antenna or to cover a large area. The radiation pattern of an antenna is a graphical

representation of the directional properties of its radiation. It is a plot of the relative strength of the radiated field in different directions from the antenna.

Either a two-dimensional or three-dimensional radiation pattern is possible. An antenna's physical properties, such as its size and form, as well as its operating frequency, define the radiation pattern of the antenna. Radiation patterns vary among various types of antennas. For instance, the radiation pattern of a dipole antenna is brightest perpendicular to the wire, whereas the radiation pattern of a patch antenna is strongest in a certain direction known as the "boresight" direction. The radiation is shown as a function of angle and separation from the antenna in a three-dimensional radiation pattern. The antenna is typically placed in the centre of a spherical plot to represent the pattern. The radiated field's strength is depicted as the color or intensity of the plot.

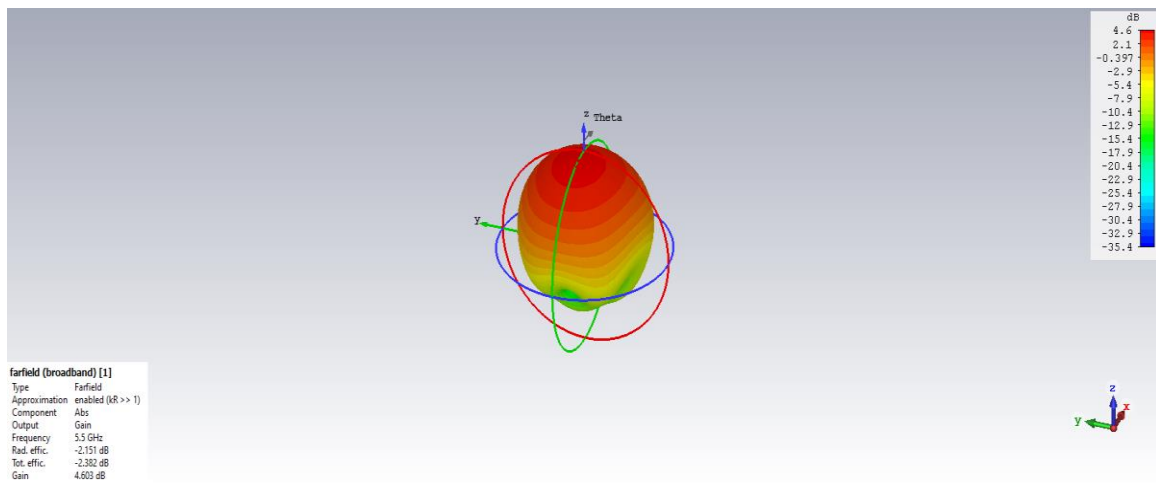


Figure 5.5.3D Gain Without Metasurface at 5.5 GHz

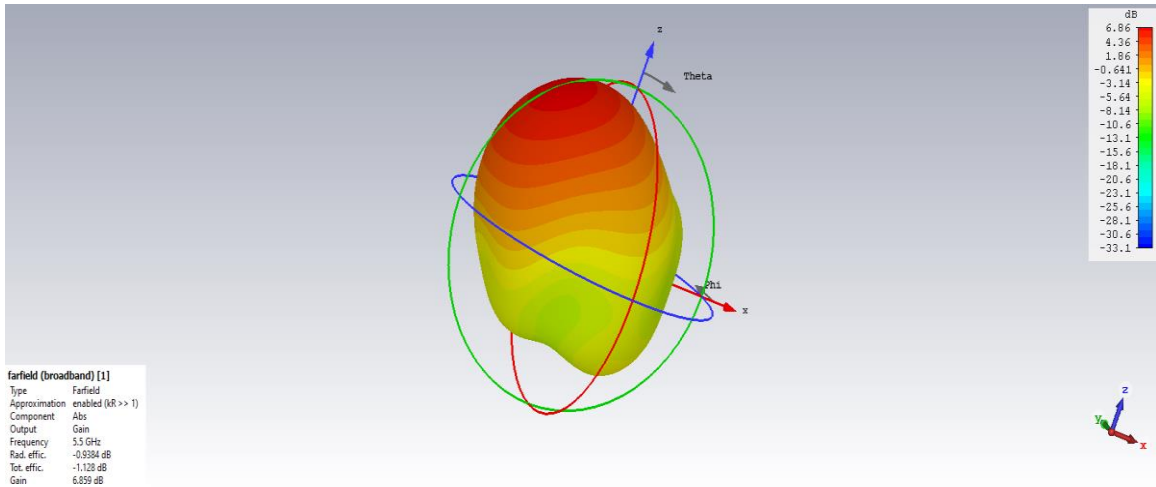


Figure.5.6.3D Gain plot With Metasurface at 5.5 GHz

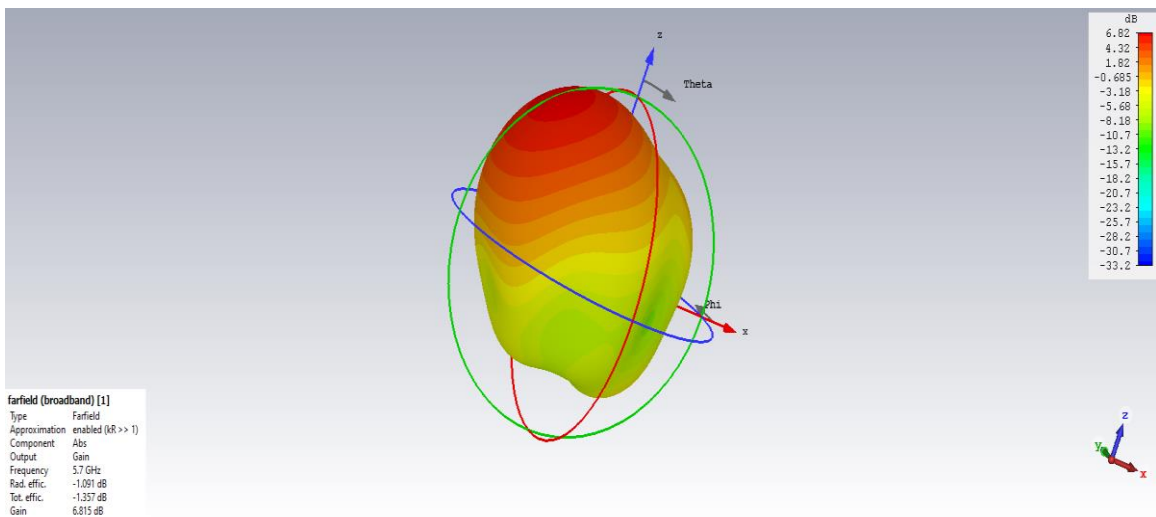


Figure.5.7. 3D Gain plot With Metasurface at 5.7 GHz

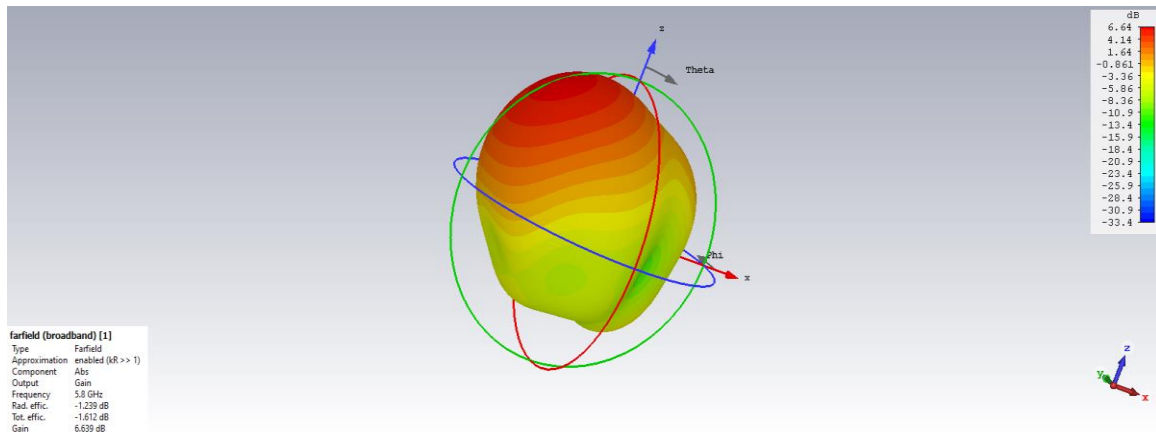


Figure.5.8. 3D Gain plot With Metasurface at 5.8 GHz

The measured radiation patterns at 5.5,5.7 and 5.8GHz compared with the simulations are shown in the following figures. The simulations and measurements are there accord to the selected frequencies. The comparison indicates the radiation Patterns of 5.5,5.7 and 5.8GHz are similar.The radiation patterns in H-plane as well as in E-plane are given below.

An antenna's radiation pattern plays a key role in determining whether it is appropriate for a given application. For instance, point-to-point communication may utilise an antenna with a directed radiation pattern, whereas broadcasting may use an omnidirectional antenna.

The radiation is shown as a function of angle around the antenna in a two-dimensional radiation pattern. A polar plot, with the antenna at the origin and the radiation angle on the x-axis, is typically used to display the pattern. The distance from the origin represents the strength of the radiated field.

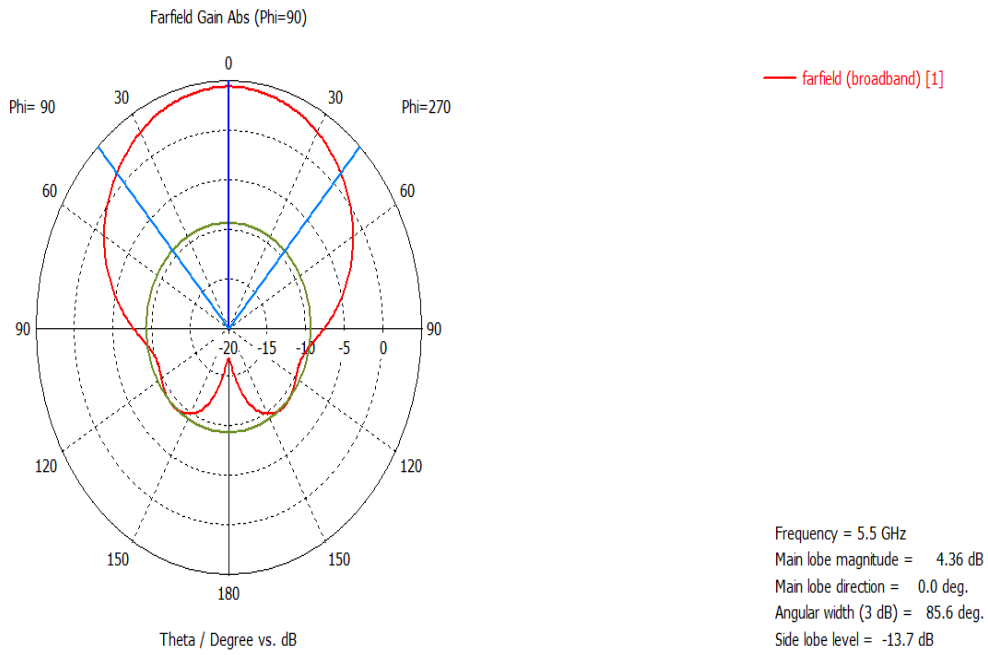


Figure.5.9. Radiation pattern Without Metasurface at 5.5 GHz in H-Plane

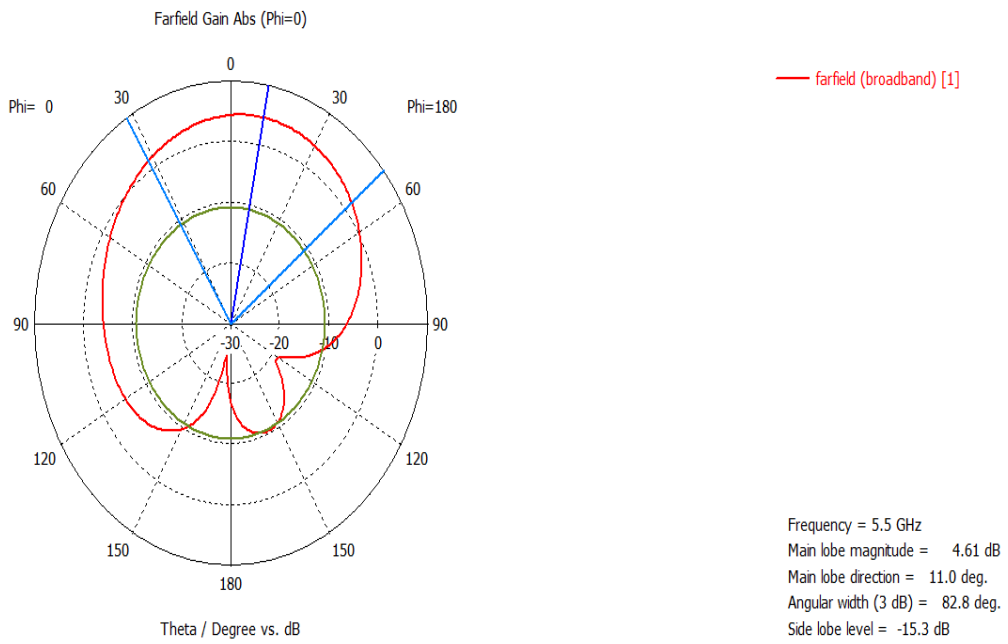


Figure.5.10. Radiation pattern With Metasurface at 5.5 GHz in E-Plane

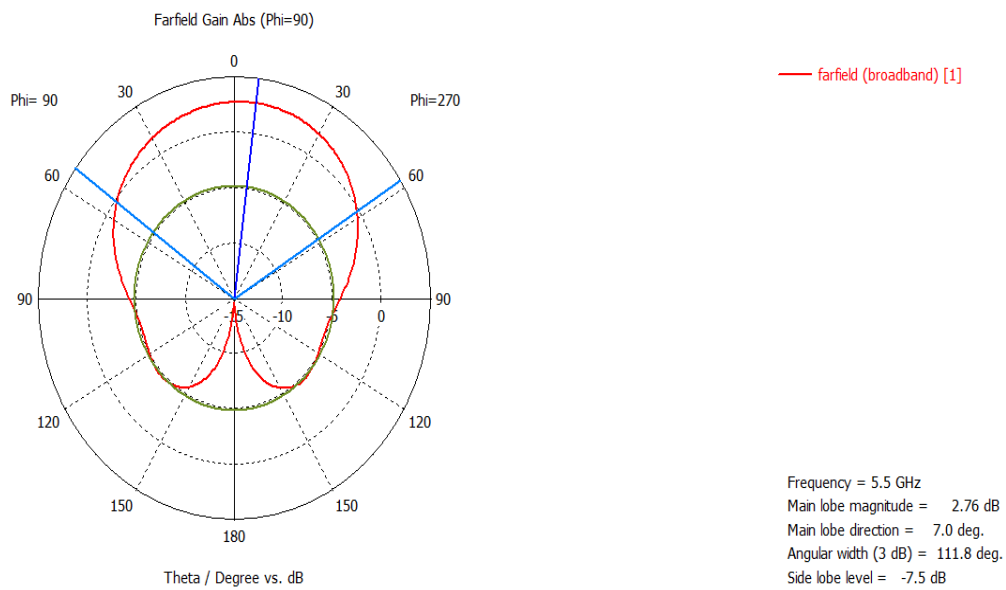


Figure.5.11. Radiation pattern With Metasurface at 5.5 GHz in H-Plane

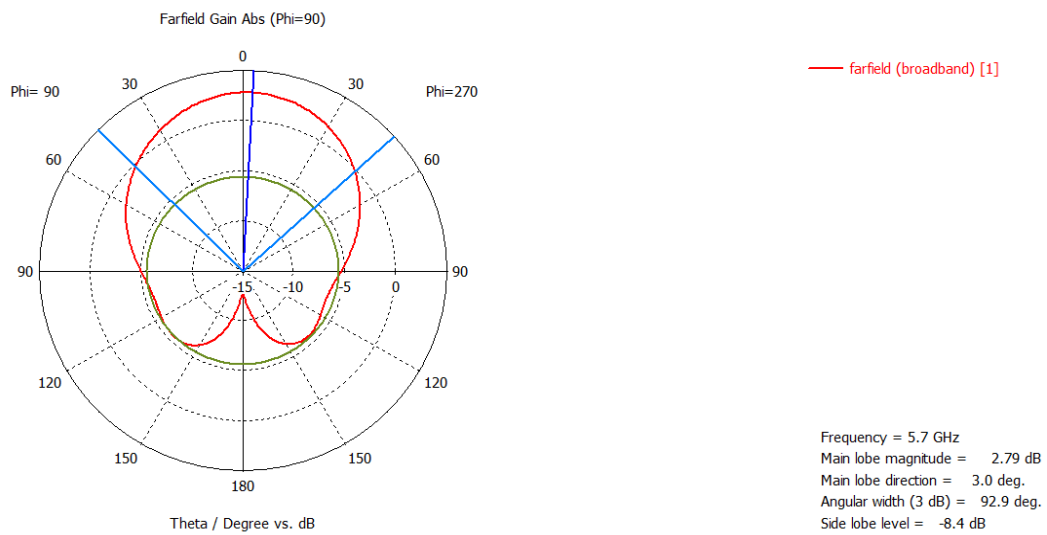


Figure.5.12. Radiation pattern With Metasurface at 5.7 GHz in H-Plane

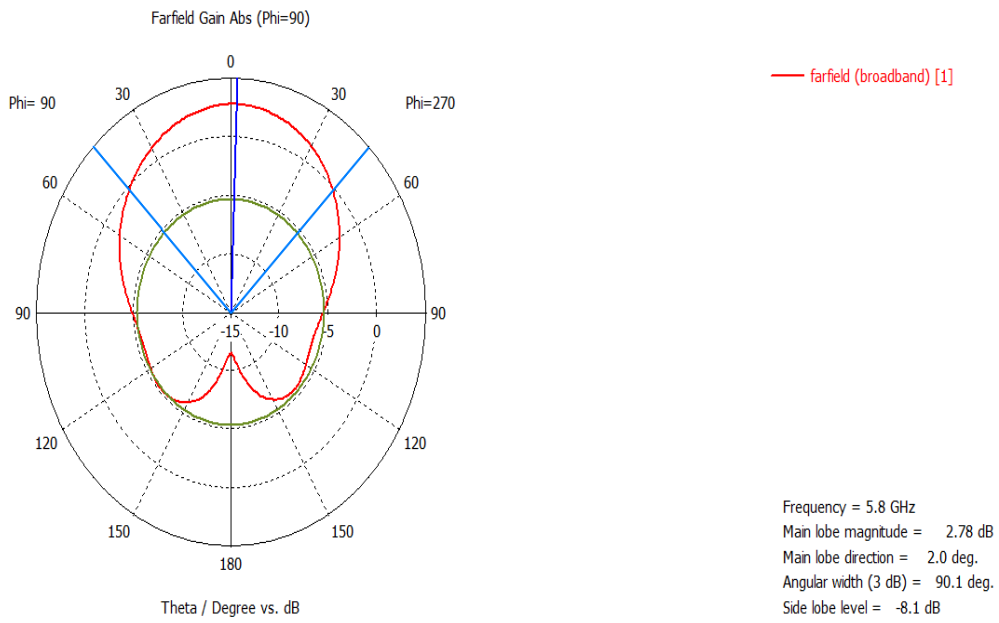


Figure5.13. Radiation pattern With Metasurface at 5.8 GHz in H-Plane

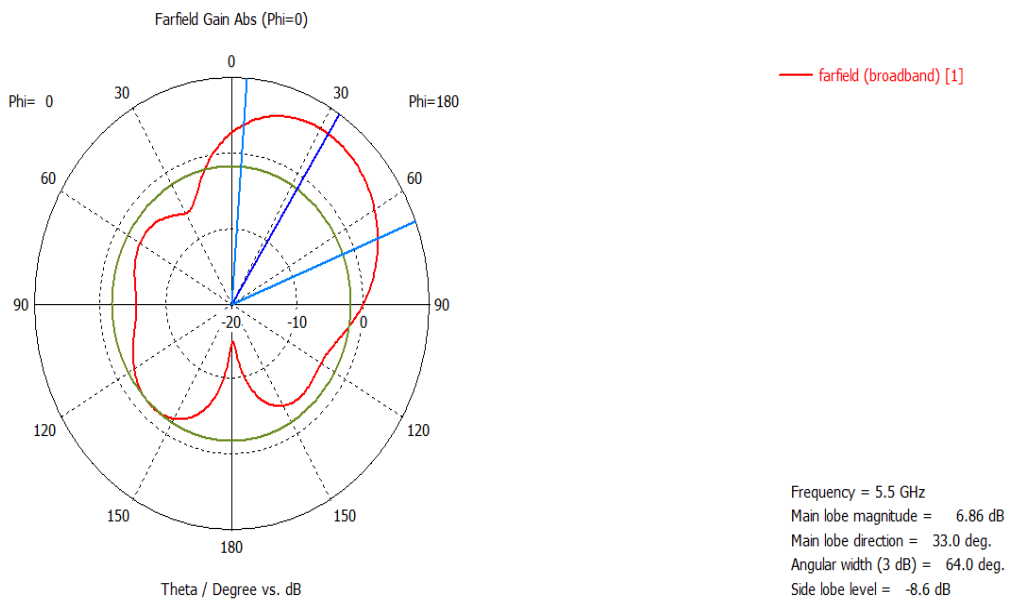


Figure5.14. Radiation pattern With Metasurface at 5.5 GHz in E-Plane

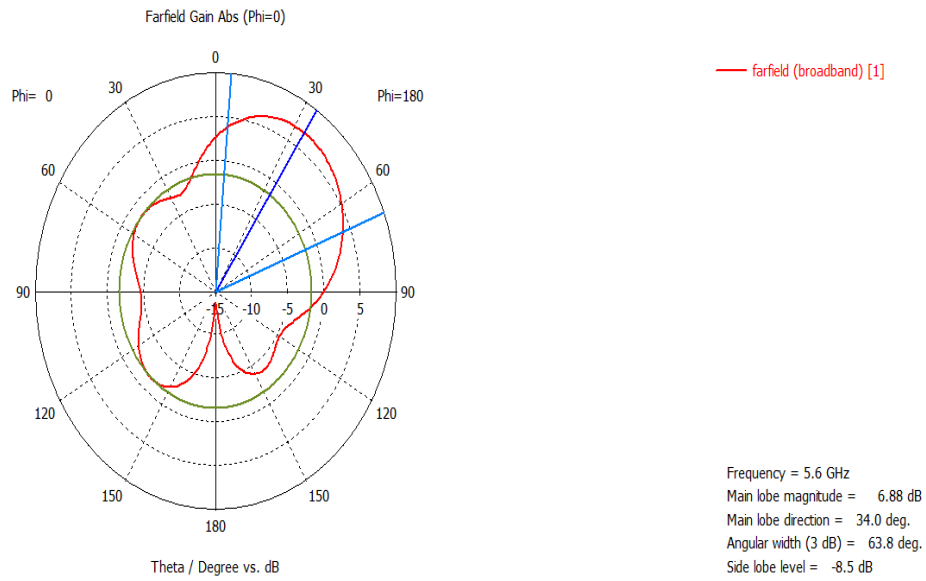


Figure.5.15. Radiation pattern With Metasurface at 5.7 GHz in E-Plane

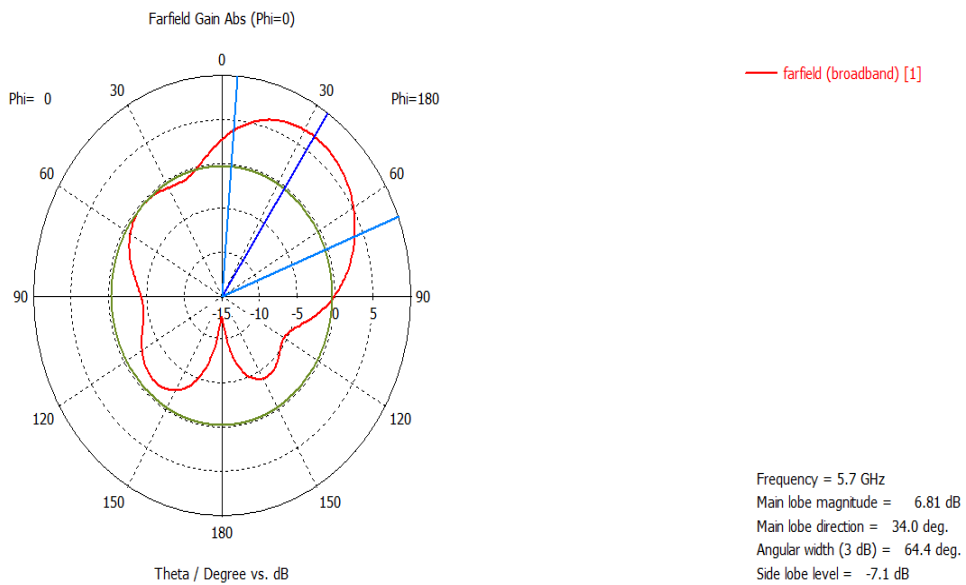


Figure.5.16 . Radiation pattern With Metasurface at 5.8 GHz in E-Plane

CONCLUSION

In this letter, a wearable Metasurface antenna for 5GHz WBAN applications is designed. In table II, the Metasurface antenna is contrasted with other antennas operating in the 5GHz WBAN band. As a result, the antenna with Metasurface increases gain and widens bandwidth. The Metasurface antenna's higher peak gain is 6.84 dB. 78% efficiency is the average. After being positioned on body tissue, this antenna exhibits reliable performance and has an average low SAR value of $1.060 \text{ w/kg} < 1 \text{ g}$, which is safe. Therefore, a variety of wearable applications in the 5GHz WBAN are appropriate for the developed meta surface antenna. The outcomes highlight Metasurface antennas' potential for wearable applications in the future, notably in the 5GHz WBAN. Wearable antennas can perform better and be more suitable for a variety of applications by utilising Metasurface technology. It is a desirable option for wearable devices that demand dependable and effective wireless connection due to its improved performance and reduced SAR value. The developed Metasurface antenna is, all things considered, a viable solution for enhancing the effectiveness and security of wireless communication in wearable devices. The ability of wearable antennas to work near to the body allows them to deliver more accurate and dependable data for monitoring a variety of physiological and physical characteristics. For example, wearable antennas can be used to monitor heart rate, temperature, and blood pressure, which can be useful for detecting medical conditions such as arrhythmia or hypothermia.

FUTURE WORK

As they offer a method of dependable and effective wireless communication between wearable devices and other devices in the network, wearable antennas are becoming more and more crucial for Wireless Body Area Network (WBAN) applications. Future WBAN applications for a range of industries, including healthcare, sports, the military, and entertainment, are predicted to heavily rely on wearable antennas.

Additionally, wearable antennas can offer real-time communication across wearable gadgets, allowing them to collaborate and share data with one another in a smooth and effective way. This is crucial for military applications because real-time communication and action coordination amongst soldiers is required. In general, it is anticipated that wearable antennas will be crucial to the future development of WBAN applications. Wearable antennas are projected to become increasingly effective, dependable, and able to provide more precise and relevant data as technology develops for a range of applications. Future WBAN applications are anticipated to make significant use of wearable technology, which offers a non-invasive and practical means to monitor and gather data on a variety of physiological and physical characteristics, enabling real-time feedback and communication, and improving the overall well-being and performance of individuals in various fields.

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I'm enclosing here with a manuscript entitled "The Design of Wearable Antenna with Metasurface for WBAN applications" for publication in ACES for possible evaluation. The corresponding author of this manuscript are V.Rashmitha(319126512105),P.Balaji(319126512105),Y.Swaroop(319126512128),y.Gowthami(319126512127).The Project Was conducted under the supervision of Dr.T.Vidhyavathi (Associate Professor).

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Design Of Wearable Antenna with Meta surface for 5GHz WBAN Applications

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Abstract – This letter gives us information about design of wearable microstrip patch antenna with a Metasurface for 5 GHz WBAN applications. Here Metasurface is used in order to increase the performance and especially it is meant for size miniaturization. The work made assured that the gain of the antenna along with the Metasurface is high such that its bandwidth has also increased when compared to the antenna without Metasurface. Considering the bending as the major challenge and to improve the efficiency within low SAR value the Metasurface antenna has geometry of 40mmx40mm. This structure can achieve higher gain and better efficiency over 5GHz WBAN band. This wearable antenna secures various characteristics which meets many wireless body area network applications. Also, the proposed Metasurface antenna notices a peak gain of 6.48 dB with efficiency of 78% which operates over 4.44 to 5.85 GHz range that meets the 5 GHz WBAN band. Besides, the results of on-body confirms that the Metasurface antenna is appropriate for wearable applications.

Index terms –Metasurfaces, Wearable Antenna, Wireless Body Area Network.

I. INTRODUCTION

Wireless Body Area Network (WBAN) is a wireless network of wearable computing devices. The devices are implanted on the body surface and are portable in such a way that humans can carry in clothes, by hands. This body area network provides continuous monitoring over or inside human body for long period and transmits such as voice, videos. In this modern technology we use antennas because they provide simple way to transfer the signals or data. Wireless communication is the only way and antennas are gate way for that. Now a days wearable antennas have gained much attention due to their attractive features and possibilities like low cost, and portable wireless communication and sensing[1]-[2]. Various kinds of wearable antennas are designed for

stable performance when placed on body tissue under bending conditions [3]-[4]. Although one of the main challenges for antennas is narrow bandwidth. The way of using many resonances to improve bandwidth has been told in [5]. But the method still did not meet the desired gain and the size has been increased[6]-[10]. In order to improve gain and reduce the antenna size, one can place dielectric superstrate upon the antenna but it is unmanageable. Instead EBG(Electronic Band Gap) structure can be used as superstrate which acts as a stop band to block electromagnetic waves, yet the output is not satisfying the desired output. So, Metasurface(MS) a 2-dimensional periodic structure which acts a band limit filter and consists array of unit cells is used. These Metasurfaces have unique abilities to block or absorb the electromagnetic waves mainly used for miniaturization of size[21]-[22]. This Metasurface is generally placed either above or below the antenna[23]-[24]. It is also observed that impedance bandwidth gets lowered as well as the antenna size got reduced [25]. Regarding the design and performance is discussed in the following sections.

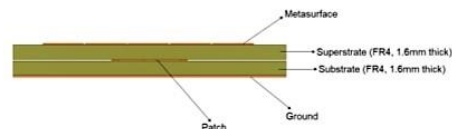


Fig.1. Proposed Metasurface antenna side view



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