F-STRUCTURED UWB MIMO ANTENNA SYSTEM FOR LOWER 5G BANDS

A project report submitted in partial fulfillment of the requirements
for the award of

Bachelor of Technology

In

ELECTRONICS & COMMUNICATION ENGINEERING

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CERTIFICATE

This is to certify that the project titled "**F-STRUCTURED UWB MIMO ANTENNA SYSTEM FOR LOWER 5G BANDS**" is a bonafide record of work done by **V. SAI VENKATA KISHORE (19BQ1A04G3), M. LAKSHMI PRASAD (20BQ5A0410), U. KALYAN (19BQ1A04F8)** and **G. SAI PHANINDRA (19BQ1A04D1)** under the guidance of Mr. **A. SRINAG, Assistant Professor** in partial fulfillment of the requirement of the degree for Bachelor of Technology in Electronics and Communication Engineering, JNTUK during the academic year 2022–23.

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ABSTRACT

In this project a compact 2 × 2 planar F-Structured MIMO antenna system with ultra-wide band capability Antenna system is specifically designed to target lower 5th generation operating bands ranging from 2 GHz to 12 GHz. The design is extremely miniaturized with total structure size of 32 x 32 x 0.8 mm. The return loss values for designed antenna must be less than −10 db. The mutual coupling between both elements is less than −20 dB over the transmission bandwidth. By Using the UWB technology, wireless communication devices can transmit over a very wide range of frequency band while consuming lower powers. Also, the UWB technology-based devices have several other merits including high data-rates, increased bandwidth, and being low in cost.

Multi Input Multi Output is an antenna technology for wireless communications in which multiple antennas are used at both the source and the destination simultaneously over the same radio channel by exploiting multipath propagation. The design of MIMO antennas in the 5G frequency band occupied less space so mutual coupling reduction techniques are required for maintaining the required gain, efficiency, and isolation. This paper is also focused on the mutual coupling reduction techniques and diversity in MIMO antennas. MIMO offers improved signal range, reduced bit errors, lower power consumption, reduced interference. The use of microstrip patch Antenna is increasing in demand due to it slighter in weight, low volume, low cost, low profile, smaller in dimension and ease of fabrication and conformity. Micro strip MIMO is a complex technology by utilizing multiple antennas to overcome multipath fading propagation problem.

OBJECTIVE

We know that 5G is the future of telecommunications, with ever increasing internet traffic and demand for high data rate. with the increasing in the number of user frequency, the allocation is becoming a challenge as the existing frequency bands are getting overcrowded. With the increasing in the number of user frequency, the allocation is becoming a challenge as the existing frequency bands used for 2G, 3G, and 4G are getting overcrowded. So, there is a need for wider bandwidthand higher data rates, to support the transmission of heavy volume data traffic.

As the demand for high data rates is increasing day by day, fifth-generation (5G) becomes the leading-edge technology in wireless communications. The main objectives of the 5G communication system are to enhance the data rates (up to 20 Gbps) and capacity, ultra-low latency (1ms), high reliability, great flexibility, and enhance device to device communication. The mentioned objectives lead to the hunting of the millimeter-wave frequency range which lies from 30 to 300 GHz for 5G wireless communications.

The major parameters associated with an antenna are Reflection coefficient(S11), Gain, Directivity, Return Loss and VSWR and the proposed antenna must improve the gain, directivity and reflection coefficient should be small. The performance of the designed antenna was evaluated in terms of impedance, gain, return loss, VSWR and radiation pattern.

The proposed work is to design a MIMO Antenna that operates at one of the FCC reserved frequency bands for 5G communications. At the same time to show the proposed MIMO network is for future communications. MIMO technology is widely applied due to high transmission rate and stable communication quality.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

In the coming years, the global mobile data traffic is likely to be projected by 45%, this means 10 times increase between the years 2016 and 2022. This massive increase is mainly due to mobile video streaming and implementation of Internet of Things (IoT). This will result in approximately 18 billion IoT out of total 29 billion devices. Due to this reason, the future 5th generation networks would need to overcome the demand of wider spectrum in high frequency range. The key constraint to implement and deploy 5G networks before 2020 is the availability of frequency spectrum; hence both the higher and lower frequency bands are needed for 5G.

In the past few years, there has been remarkable progress in the field of wireless communication. As the world is progressing by leaps and bounds, therefore it is evident to cope up with the data rate challenges faced by the telecommunication sector. With the increase in the number of user frequency, theallocation is becoming a challenge as the existing frequency bands are getting overcrowded. There is a certain limit of users that a single bandwidth channel canaccommodate. An increase in the number of users also gives rise to co-channel interferences. Evolved video technologies like High Definition (HD) and Quadruple High Definition (QHD) resolutions require very high data rates, whichare difficult to be handled by 4G Technologies.

So, there is a need for wider bandwidth and higher data rates to support the transmission of such kind of heavy volume data traffic. To cope with this problem, 5G reserved frequency bands are under research. The 5G provides the luxury of wider bandwidths and higher data rates and a greater number of frequency channels as compared to 3G and 4G; therefore, 5G would be more suitable for the users who demand greater data rates and wider bandwidths.

Despite many desirable features, 5G has a serious low penetration power problem that signal fades away on the reaching to the receiver side from the transmitter side using one antenna. Multiple Input Multiple Output (MIMO) toolhas proven to be a savior in this regard. MIMO technology is widely applied duetothe high transmission rate and stable communication quality.

Lower 5G bands are ideal for early deployment, due to their advantageous properties including wave propagation and available bandwidth. The main spectrum bands between 2 GHz and 6 GHz are in the ranges from 3.3 GHz to 4.2 GHz and from 4.4 GHz to 4.990 GHz.

These bands are presently being considered for initial trials of 5G networks in number of countries.

Region	Frequency range (GHz)
Europe	3.4–3.8
China	3.4-3.8, 4.4–4.5, 4.8–4.99
Japan	3.6–4.2, 4.4–4.9
Korea	3.4–3.7
USA	3.1–3.55, 3.7–4.2

Fig 1.10: Regions and their lower 5G bands

1.1.1 WHAT IS 5G?

5G is the term defined as Fifth-Generation wire-Less iteration of cellular technology. Unlike 4G, which requires large, high-power cell towers to radiate signals over longer distances, 5G wireless signals are transmitted through large numbers of small cell stations located on places like light poles or building roofs.

Fifth-generation wireless (5G) is the latest iteration of cellular technology, engineered to greatly increase the speed and responsiveness of wireless networks. With 5G, data transmitted over wireless broadband connections can travel at multigigabit speeds, with potential peak speeds as high as 20 gigabits per second

(Gbps) by some estimates. These speeds exceed wireline network speeds and offer latency of below 5 milliseconds (ms) or lower, which is useful for applications that require real-time feedback. 5G will enable a sharp increase in the amount of data transmitted over wireless systems due to more available bandwidth and advanced antenna technology.

5G networks and services will be deployed in stages over the next several years to accommodate the increasing reliance on mobile and internet-enabled devices. Overall, 5G is expected to generate a variety of new applications, uses andbusiness cases as the technology is rolled out.

1.1.2 ADVANTAGES OF 5G

- High resolution and bi-directional large bandwidth shaping.
- Technology to gather all networks on one platform.
- More effective and efficient.
- Technology to facilitate subscriber supervision tools for the quick action.
- Most likely, will provide a huge broadcasting data (in Gigabit), which will supportmore than 60,000 connections.
- Easily manageable with the previous generations.
- Technological sound to support heterogeneous services (including privatenetwork).
- Possible to provide uniform, uninterrupted, and consistent connectivity across the world.

1.1.3 FOR IOT TECHNOLOGY

The Internet of Things (IOT) is already gaining pace, but the introduction of 5Gwill provide the infrastructure to connect billion more devices to the internet. The increasing number of IOT devices in the home provides a big opportunity for hardware manufacturers but the real potential lies in industrial IOT.

This technology is already revolutionizing a diverse range of sectors includingmanufacturing, agriculture, and retail in the future, 5G will enable a host of new innovations such as remote robotic surgery and personalized medicine.

1.1.4 NEED OF 5G

At present 4G is the widely used wireless communication system. Up to now we havecompleted 4 generations such as 1G,2G,3G,4G. Each generation of wireless cellular network has introduced to increase bandwidth speed and network capacity. Right now, we are using 4G communication system, It is better over 3G because 4G users get speed up to 100MBPS where 3G provides speed of 14MBPS. As there are advantages in 4G compared to 3G there are some dis-advantages, so we need to overcome those by moving to 5G.

1 Gb = 1,000 Mb = 1,000,000 kb = 1,000,000,000 Bits   UPDATE

Technology	1G	2G	3G	4G	5G
Year	1979	1991	2001	2009	2019
Use Cases	Analog System, Dropped Calls, Giant Cell Phones	Texting (SMS), MMS, Conference Calls, Long Distance Call Tracking	Cheap data transmission, GPS, Web Browsing, SD Video Streaming	HD Video Streaming, Wearable Devices, High Speed Applications	Internet of Things, Cloud Storage, Remote Surgical Robots
Frequency	30 KHz	1.8 GHz	1.6-2 GHz	2-8 GHz	3-30 GHz
Bandwidth	2 kbps	364 kbps	3 Mbps	100 Mbps	10 Gbps
Avg Speeds	2 kbps	40 kbps	300 kbps	25 Mbps	150 Mbps
Range	N/A	50 mi	35 miles	10 miles	1,000 ft

Fig 1.12: Evolution of 5G Network

1.1.5 NEED OF 5G FOR CONNECTIVITY AND DATA

According to the regulator of FCC, we will be using 13 times more data in 2025 than we are today. Today there are 7 billion internet-connected devices worldwide, by 2025, there will be an estimated 21 billion. Many of these new devices will be things that power and monitor our homes, city infrastructure, transport and more; this network iswhat is commonly known as Internet of Things (IoT). It is touted as one of the next big digital revolutions and because of how important it is to maintain connectivity to critical devices controlling our safety and security, improvement will be required in the network response times or latency.

In order to meet this challenge and according to the current demands, a novel ultra-wide band (UWB) 2 × 2 Multiple Input Multiple Output (MIMO) antenna system has been designed. This antenna system will cover the frequency band ranging from 2 GHz to 12 GHz, which covers all the lower 5G frequency bands. Its array is an ideal candidate for 5G enabled, handheld devices including mobile phones and tablets.

1.2 ULTRA WIDE BAND

In 2002, the Federal communication commission (FCC) permitted the utilization of unlicensed frequency bandwidth ranging from 3.1GHz to 10.6GHz in commercial applications. The Ultra-wideband (UWB) is an interesting technology, which permits ultra high-speed communication at low power consumption for short-range applications.

UWB is a radio technology that can be used for transmitting and receiving a large amount of data over an ultra-wide frequency band with very low power and for short distances. It has some advantages like high data rate, low equipment cost, multipath immunity and finally ranging and communication at the same time is possible. In all wireless communication systems, the antenna has an essential role since it is the means by which the signals are converted from electrical to electromagnetic wave form and vice versa.

The design of an UWB antenna is subject to numerous challenges such as achieving a wide impedance bandwidth and keeping high radiation efficiency. Also meeting the equipment physical constraints like size and portability is another challenge. Research results have proven that some of these challenges can be resolved by adopting a MIMO antenna system. The multiple antenna system increases the diversity gain, multiplexing gain or array gain and thus enhances the overall antenna performance.

However, there are some challenges in designing a MIMO antenna for a technology like UWB including reduction of the mutual coupling and the correlations between the elements. The objective in this work is to design a MIMO antenna for UWB communication suitable for many applications in a wireless personal area network (WPAN) that outperforms antenna systems reported in the literature.

UWB systems experience multipath fading problem and this issue can be resolved by the utilization of Multiple-input-Multiple-output (MIMO) techniques in UWB systems. MIMO techniques improve system reliability and channel capacity. The main antenna parameters considered are

1) the bandwidth which is expected to extend over the entire UWB 3.1 to 10.6 GHz with reflection coefficients better than −10 dB
2) the radiation pattern which is to be omni directional
3) the radiation efficiency that is to exceed 70%
4) the gain over the UWB bandwidth that is to be uniform
5) the Total Active Reflection Coefficient which accounts for both coupling and random signal combination and offers a better representation of a MIMO antenna efficiency and varies between 0 and 1 with the latter as the desired value
6) the envelope correlation
7) Diversity Gain

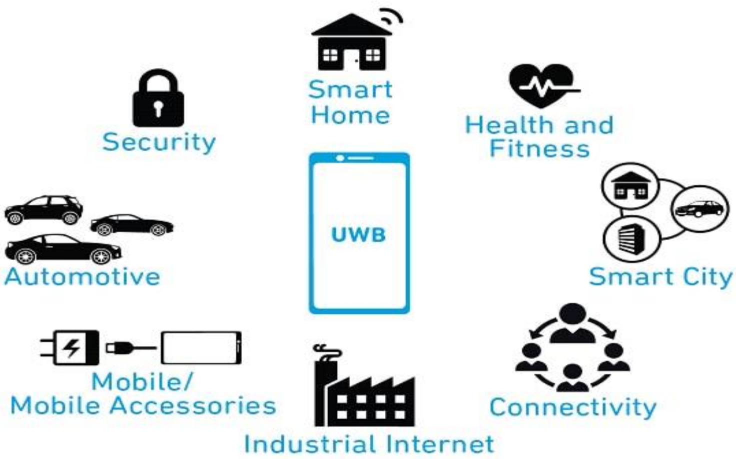


Fig 1.13: UWB Technology Applications

1.2.1 CHARACTERISTICS OF UWB:

Ultra-wideband is a technology for transmitting information across a wide bandwidth (>500 MHz). This allows for the transmission of a large amount of signal energy without interfering with conventional narrowband and carrier wave transmission in the same frequency band. Regulatory limits in many countries allow for this efficient use of radio bandwidth, and enable high-data-rate personal area network (PAN) wireless connectivity, longer-range low-data-rate applications, and radar and imaging systems, coexisting transparently with existing communications systems.

UWB Technology based devices have several merits:

- high data-rates
- increased bandwidth
- being low in cost
- simple design
- High performance in multipath channels

1.3 MICROSTRIP ANTENNAS:

Microstrip antennas became very popular in the 1970s primarily for space borne applications. Today they are used for government and commercial applications. These antennas consist of a metallic patch on a grounded substrate. The metallic patch can take many different configurations. However, the rectangular and circular patches are the most popular because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. The microstrip antennas are low profile, conformable to planar and non-planar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC (Monolithic Microwave Integrated Circuit) designs, and very versatile in terms of resonant frequency, polarization, pattern, and impedance. These antennas can be mounted on the surface of high-performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones.

A microstrip patch antenna (MPA) consists of a conducting patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna for narrow-band microwave wireless links that require semi- hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied and is often used as elements for an array.

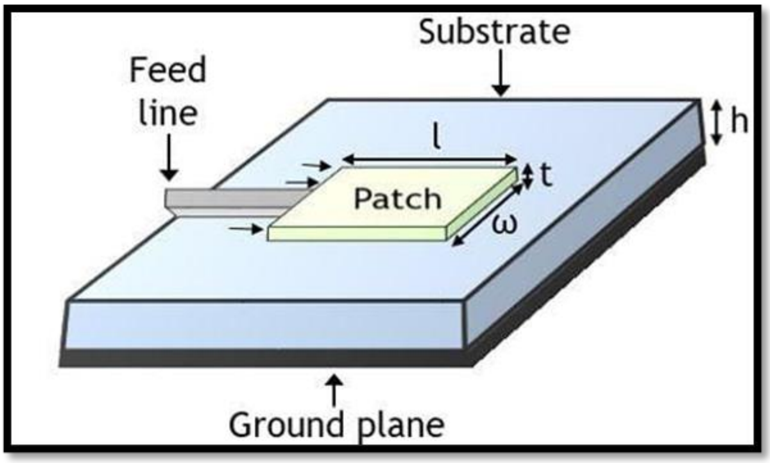


Fig 1.14: Rectangular Microstrip Antenna

1.3.1 BASIC CHARACTERISTICS OF MICROSTRIP ANTENNAS:

Microstrip antennas received considerable attention starting in the 1970s, although the idea of a microstrip antenna can be traced to 1953 and a patent in 1955. Microstrip antennas consist of a very thin (t=thickness) ($t << \lambda_0$, where λ_0 is the free-space wavelength) metallic strip (patch) placed a small fraction of a wavelength ($h << \lambda_0$, usually $0.003\lambda_0 \le h \le 0.05\lambda_0$) above a ground plane. The microstrip patch is designed so its pattern maximum is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. End-fire radiation can also be accomplished by judicious mode selection. For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$. The strip (patch) and the ground plane are separated by a dielectric sheet (referred to as the substrate).

There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of $2.2 \le \varepsilon_r \le 12$. The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of larger element size. Thin substrates with higher dielectric constants are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes. Since microstrip antennas are often integrated with other microwave circuitry, a compromise has to be reached between good antenna performance and circuit design.

Often microstrip antennas are also referred to as patch antennas. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. The radiating patch may besquare, rectangular, thin strip (dipole), circular, elliptical, triangular, or any other configuration. These and others are illustrated in Square, rectangular, dipole (strip), and circular are the most common because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. Microstrip dipoles are attractive because they inherently possess a large bandwidth and occupy less space, which makes them attractive for arrays. Linear and circular polarizations can be achieved with either single elements or arrays of microstrip antennas.

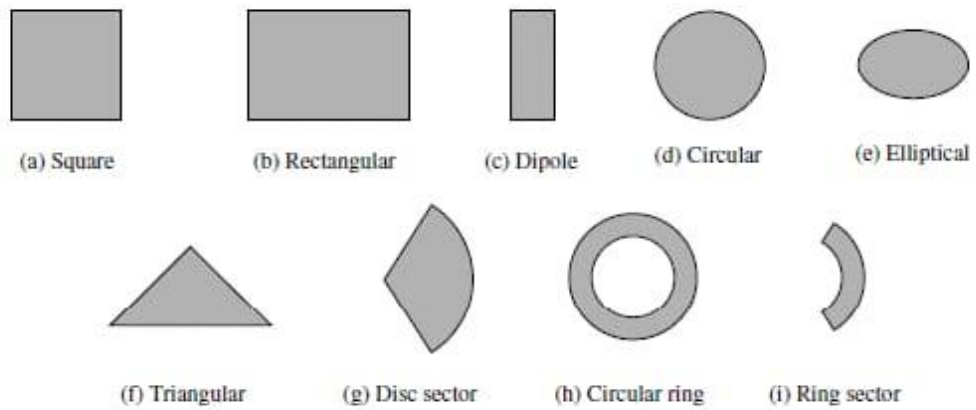


Fig 1.15: Different Shapes of Radiating Patches

1.3.2 DESIGN STEPS:

Step -1: Evaluate width 'W' of the patch using the formula below.

$$\boldsymbol{W} = \frac{\boldsymbol{V_0}}{\boldsymbol{2f_r}}\sqrt{\frac{\boldsymbol{2}}{\epsilon_r + \boldsymbol{1}}}$$

Step - 2: Calculate the effective dielectric constant ϵ_{reff} of the patch using formula below.

$$\epsilon_{reff} = \frac{\epsilon_r + \boldsymbol{1}}{\boldsymbol{2}} + \frac{\epsilon_r - \boldsymbol{1}}{\boldsymbol{2}}\left[\boldsymbol{1} + \boldsymbol{12}\frac{\boldsymbol{h}}{\boldsymbol{W}}\right]^{-1/2}$$

Step – 3: Calculate ΔL using formula below.

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

Step – 4: Calculate length of the patch using formula below. v_0 is speed of light in free space.

$$L = \frac{v_0}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L$$

1.4 MIMO ANTENNA

MIMO (multiple input-multiple output) is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination(receiver).

The antennas at each end of the communications circuit are combined to minimize errors, optimize data speed, and improve the capacity of radio transmissions by enabling data to travel over many signal paths at the same time.

MIMO technology uses a natural radio-wave phenomenon called multipath. With multipath, transmitted information bounces off walls, ceilings, and other objects, reaching the receiving antenna multiple times at different angles and slightly different times. In the past, multipath caused interference and slowed down wireless signals. With multipath, MIMO technology uses multiple, smart transmitters and receivers with an added spatial dimension, increasing performance and range.

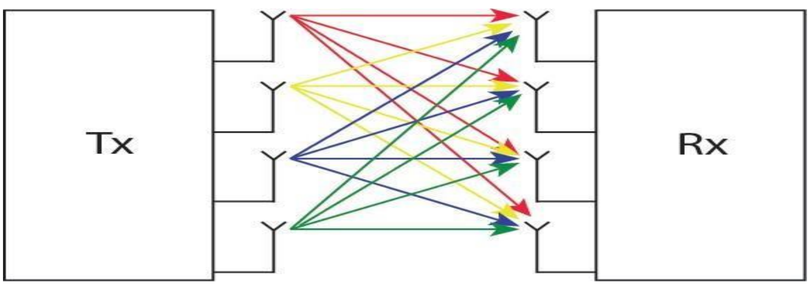


Fig 1.16: Example of 4X4 MIMO System

More antennas usually equate to higher speeds. A wireless adapter with three antennas can have a speed of 600 Mbps. An adapter with two antennas has a speed of 300 Mbps. The router needs multiple antennas and must fully support all features of 802.11n to attain the highest speed possible.

But compact size MIMO antennas experience high mutual coupling, which degrades the performance of an antenna. Reducing mutual coupling in a compact MIMO antenna is always challenging. While techniques like electromagnetic band-gap structures, meta materials, meta surface and sometimes neutralization line are more favorable for minimizing mutual coupling between elements of narrow-band MIMO antennas.

1.5 ADVANTAGES OF MIMO

- A MIMO system provides better signal strength even without clear line-of-site as they utilize the bounced and reflected RF transmissions.
- The higher throughput allows better quality and quantity of video sent over the network.
- Multiple data streams reduce the number of lost data packets, which results in better video or audio quality.

By utilizing multiple data streams, issues such as fading caused lost or dropped data packets can be reduced, resulting in better video or audio quality.

Fig 1.17: Example of SISO System

1.6 SPECIFIC PARAMETERS FOR MIMO ANTENNAS:

There are also some additional parameters other than the fundamental parameters to be considered while designing MIMO antennas.

1.6.1 MUTUAL COUPLING:

In MIMO applications, the signals transmitted by multiple antenna elements are generally supposed to be independent or uncorrelated. But, the current induced on one antenna produces a voltage at the terminals of nearby elements, termed as mutual coupling. It means there is always mutual coupling present between nearby antenna elements. However, for MIMO applications, the mutual coupling should be minimized to as low value as possible. In a contradictory way, it should be noted that it is also studied that mutual coupling can help to reduce the correlation between the different channel coefficients in nearby placed antenna elements scenario, thus escalating the capacity.

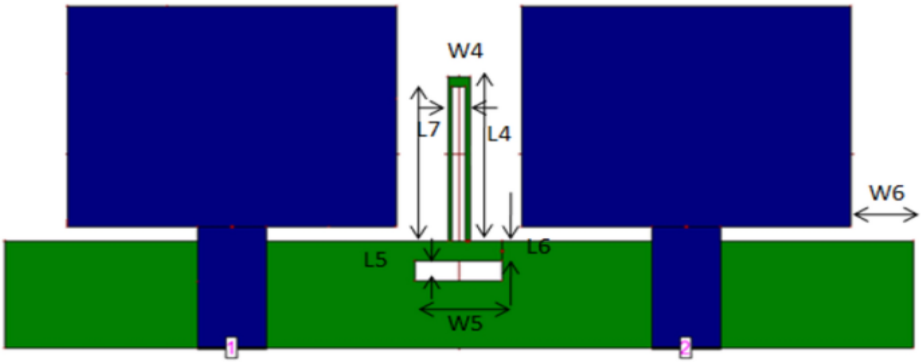


Fig 1.18: Mutual Coupling in MIMO Antenna

EFFECTS OF MUTUAL COUPLING:

- The mutual coupling between antenna elements affects the antenna parameters like terminal impedances, reflection coefficients.
- The antenna array performance in terms of radiation characteristics, output signal-to-interference noise ratio (SNR), and radar cross section (RCS).

1.6.2 ISOLATION:

The port-to-port isolation is defined as the transmission of power between two of the input ports of the multiport antenna under test. It is characterized by $|S21|$ parameter. It must be noted that isolation is a positive quantity and is given as

$$\text{Isolation} = -10\log_{10}|S_{21}|^2$$

Antenna isolation is the technique of separating antennas that coexist so that there are only acceptable levels of interference between systems.

- Multiple antennas are often embedded in a single device. The crowding of antennas in a single unit can overdrive the receiver signal strength or degrade the receiver signal quality.
- The lack of separation between antennas causes different interferences in the form of direct radiation, enclosure resonances, waveguide mode excitation, and noise coupling. Providing sufficient antenna separation can help mitigate the issues like Transmitter noise, Receiver desensitization, Intermodulation issues etc.
- The S-parameters S_{21} and S_{12} describe the effect on port 2 due to port 1 and vice versa. These parameters determine the insertion loss and isolation between antennas.

1.6.3 RETURN LOSS:

It is a parameter which indicates the amount of power that is "lost" to the load and does not return as a reflection. Hence the RL is a parameter to indicate how well the matching between the transmitter and antenna has taken place. Simply put it is the S11 of an antenna. A graph of s11 of an antenna vs frequency is called its return loss curve.

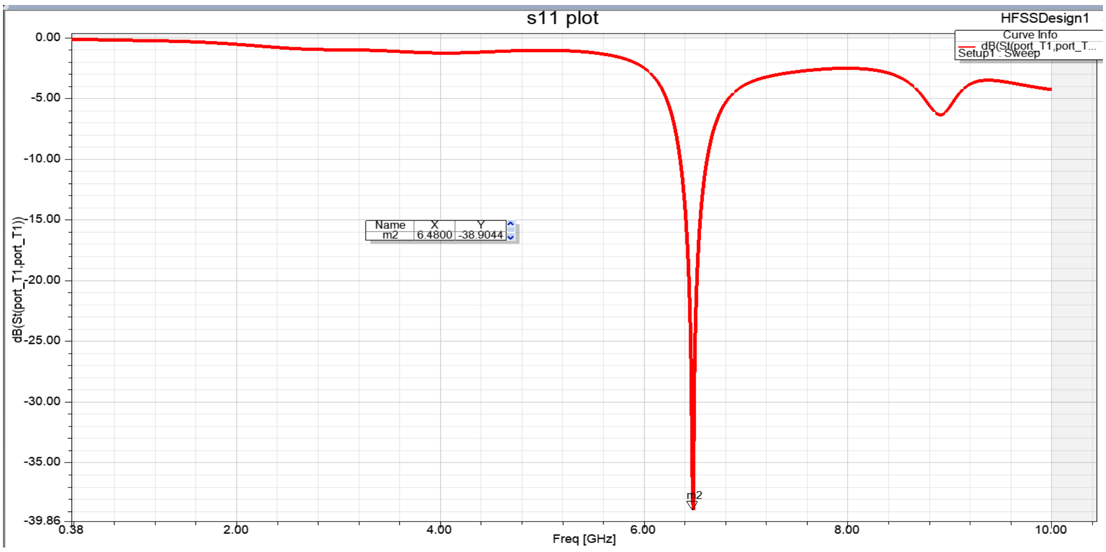


Fig 1.19: Return Loss in Antenna

A measure of the loss of power in the signal reflected by a transmission line to a load, such as an antenna usually expressed in decibels (dB) as the logarithmic ratio of relative magnitudes of input power and reflected power.

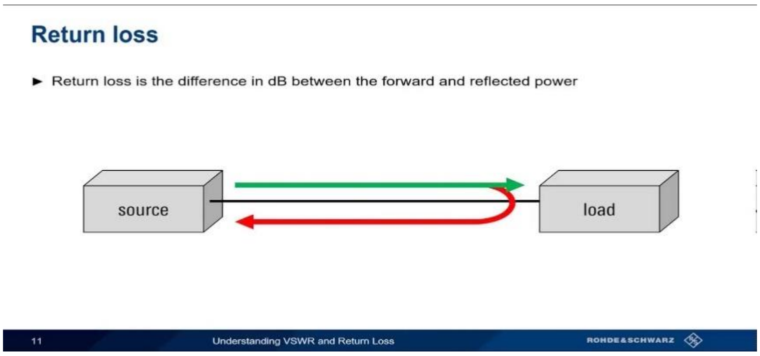


Fig 1.20: Return Loss

Return loss is a power loss of returned or reflected signal by a discontinuity of transmission line. Return loss gives the measure of how well a device is matched. A device is said to be well matched if the return loss is high.

1.6.4 RADIATION PATTERN:

Radiating an equal amount of energy in all the direction is almost impossible for any practical antenna. As the energy radiated from an antenna specifically radiates maximal in one direction and minimum in rest other directions. So, it is measured in terms of field strength. The field strength specifies the achieved radiation at a particular point at a certain distance from the antenna.

Thus, it can be determined by the ratio of voltages between the two points on electric lines of force and the distance of separation between these two points. Thus, its unit is volt per meter.

1.6.5 ANTENNA GAIN:

Gain is a measure of the ability of the antenna to direct the input power into radiation in a particular direction and is measured at the peak radiation intensity. Consider the power density radiated by an isotropic antenna with input power P0 at a distance R which is given by S = P0/4πR2. An isotropic antenna radiates equally in all directions, and its radiated power density S is found by dividing the radiated power by the area of the sphere 4πR2. An isotropic radiator is 100% efficient. The gain of an actual antenna increases the power density in the direction of the peak radiation.

$$\boldsymbol{S = \frac{P_0 G}{4\pi R^2} = \frac{|E|^2}{\eta} \quad or \quad |E| = \frac{1}{R}\sqrt{\frac{P_0 G \eta}{4\pi}} = \sqrt{S\eta}}$$

1.6.6 DIRECTIVITY:

Directivity is a measure of the concentration of radiation in the direction of the maximum.

$$\boldsymbol{Directivity = \frac{maximum\ radiation\ intensity}{average\ radiation\ intensity} = \frac{U_{max}}{U_0}}$$

Directivity and gain differ only by the efficiency, but directivity is easily estimated from patterns. The average radiation intensity can be found from a surface integral over the radiation sphere of the radiation intensity divided by 4π, the area of the sphere in steradians.

1.6.7 ENVELOPE CORRELATION COEFFICIENT:

The envelope correlation coefficient is a parameter of great importance for the systems providing diversity. The signals received in the diversity systems can be correlated to some extent. The correlation coefficient is a mathematical and statistical tool that measures the degree of similarity among the received signals. Its modulus varies from 0 to 1. Ideally, diversity systems require a correlation coefficient of zero or low by default.

$$\text{ECC}, \rho_e = \frac{\left|S_{11}^* S_{12} + S_{21}^* S_{22}\right|^2}{\left(1 - \left(|S_{11}|^2 + |S_{21}|^2\right)\right)\left(1 - \left(|S_{22}|^2 + |S_{12}|^2\right)\right)}$$

$$G_{\text{app}} = 10\sqrt{1 - |\rho|}, \quad |\rho| = \rho_e$$

1.6.8 DIVERSITY GAIN:

Diversity is achieved when the receiver takes multiple versions of the input signal via different propagation channels since multiple antennas are present. If the signals are not correlated to each other, the received signal at the receiver section will offer a better SNR level. As a result, a better signal reception is achieved. The effect of diversity in the communication channel is measured by the diversity gain of the antenna. It is defined as the ratio of the SNR of multiport MIMO antenna system to the SNR of single-port antenna system. The value of diversity gain is calculated with the help of ECC value. The following formula is utilized to obtain the diversity gain of any MIMO antenna system.

$$DG = 10\sqrt{1-(ECC)^2}$$

1.7 MIMO ANTENNA ADVANTAGES

- Coexistence with current narrowband and wideband radio services
- Large channel capacity
- Ability to work with low SNRs
- Low transmit power
- High performance in multipath channels
- Simple transceiver architecture
- High bandwidth can support real-time high-definition video streaming.
- Offers high performance in noisy environments.
- Delivers higher signal strengths in adverse conditions.
- Enables ultra-low power all at a reduced cost.

1.7.1 APPLICATIONS OF MIMO ANTENNA:

- Spatial multiplexing techniques make the receivers very complex, and therefore they are typically combined with orthogonal frequency-division multiplexing or with orthogonal frequency-division multiple access (OFDMA) modulation, where the problems created by a multi-path channel are handled efficiently.

- MIMO is also planned to be used in mobile radio telephone standards such as recent 3GPP and 3GPP2. In 3GPP, High-Speed Packet Access plus (HSPA+) and Long-Term Evolution (LTE) standards take MIMO into account. Moreover, to fully support cellular environments, MIMO research consortia including IST-MASCOT propose to develop advanced MIMO techniques, e.g., multi-user MIMO (MU-MIMO).
- MIMO wireless communications architectures and processing techniques can be applied to sensing problems. This is studied in a sub-discipline called MIMO radar.
- MIMO technology can be used in non-wireless communications systems. One example is the home networking standard ITU-T G.9963, which defines a power line communications system that uses MIMO techniques to transmit multiple signals over multiple AC wires (phase, neutral and ground).

1.8 UWB APPLICATIONS

Real-time location

- UWB is useful for real-time location systems, and its precision capabilities and low power make it well-suited for radio-frequency-sensitive environments, such as hospitals. UWB is also useful for peer-to-peer fine ranging, which allows many applications based on relative distance between two entities.

Radar

- Ultra-wideband gained widespread attention for its implementation in synthetic aperture radar (SAR) technology. Due to its high resolution despite using lower frequencies, UWB SAR was heavily researched for its object-penetration ability. Starting in the early 1990s.

Data transfer

- Ultra-wideband characteristics are well-suited to short-range applications, such as PC peripherals, wireless monitors, camcorders, wireless printing, and file transfers to portable media players. UWB was proposed for use in personal area networks.

CHAPTER-2
EXISTING MODEL

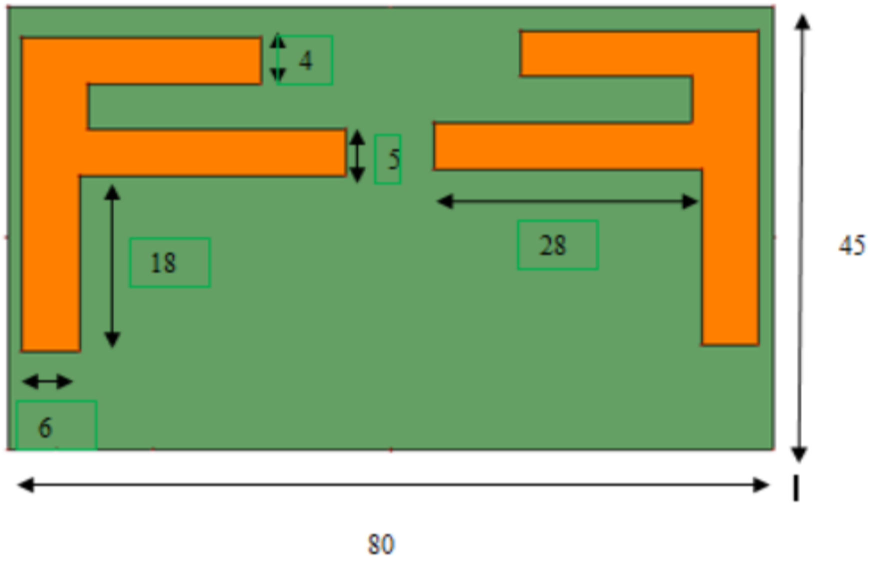


Fig 2.1: Existing Model

In this existing model F shaped MIMO antenna is used for WIMAX applications. WIMAX have become popular due to easy installation and it is now available to provide broad band internet access. WIMAX communication suites best for wireless backhaul technology especially for 4G networks. The proposed antenna not only achieves WiMAX applications, it also satisfies mutual coupling, smaller size, and operating frequency bands.

The existing antenna can function at WIMAX band around 3.5GHz. The two types of F slot are placed opposite to provide polarization diversity for coupling reduction.

The operating frequency of MIMO antenna is 3.5GHz. It can be used for WiMAX applications. The simulated results satisfy the WIMAX applications.

The return loss of existing antenna is -20dB at 3.5GHz,
The gain of existing antenna is 4.5dB at 3.5GHz.
The VSWR of 1.2 is obtained at 3.5GHz.
The radiation pattern in E and H plane are isotropic in direction.

The antenna is circularity polarized; it reduces the signal degradation due to atmospheric conditions. The features of MIMO with circular polarization make the antenna more attractive in WIMAX applications.

The existing antenna can be used for Wi max applications. The length and width of the antenna is 80mm x 45mm with FR4 substrate. It is designed in such a way that an additional F slot is introduced in the radiating element, to reduce the antenna size in lower band. All the simulations are done by mentor graphics IE3D. The antenna dimensions are shown in figure. It consists of two antennas, placed on left and right of the ground plane.

The antenna made on using FR4 substrate with

permittivity	=	4.4
loss tangent	=	0.02
material thickness	=	2.4mm
ground plane thickness	=	0.1mm

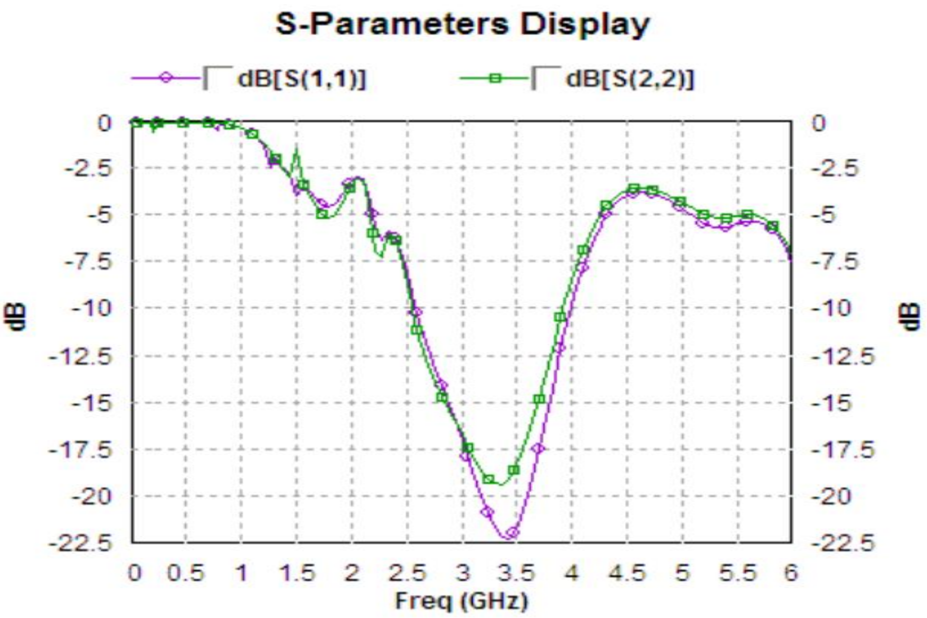


Fig 2.2: Existing Model Results

The proposed antenna can function at WIMAX band around 3.5GHz. The two types of F slot are placed opposite to provide polarization diversity for coupling reduction. The Two F shaped feeding technique is placed on the substrate.

CHAPTER-3
PROPOSED DESIGN

3.1 PROPOSED ANTENNA

A wideband antenna is presented in this proposed model, which is suitable for lower 5G communication, and the operation frequency of the proposed antenna is 2GHz to 12GHz. This antenna gives a reasonable value of gain and return loss. That single element antenna is then used to design a two element MIMO Antenna system, such that the proposed model is shown as ideal candidate for future 5G communication system.

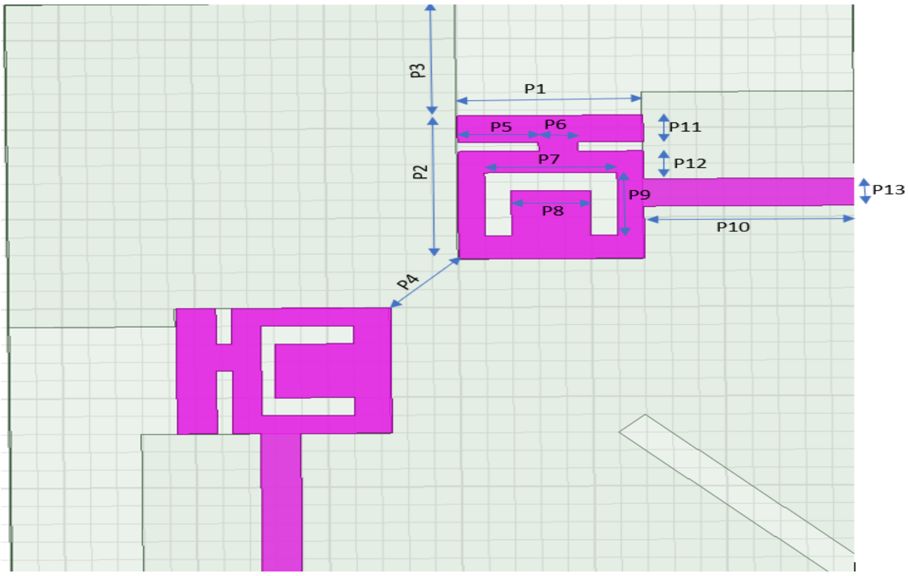


Fig 3.10: Front View of Antenna

Fig 3.11: Back View of Antenna

The proposed design consists of two elements each of them operating at 2GHz to 12GHz with a bandwidth of 7.5GHZ. The gain of antenna element is greater than 3 dB, which shows this proposed MIMO network is an ideal candidate for future communications. The isolation value for the proposed model is 20 db.

3.2 ANTENNA MATERIALS

- The designed antenna is an extremely compact 2 × 2 UWB MIMO antenna system. The antenna consists of two “F” type structures with a very compact fractured ground plane.
- The proposed antenna system has been fabricated on FR4 substrate with
  relative permittivity = 2.2
  dielectric loss tangent = 0.0009
  height = 1.6 mm

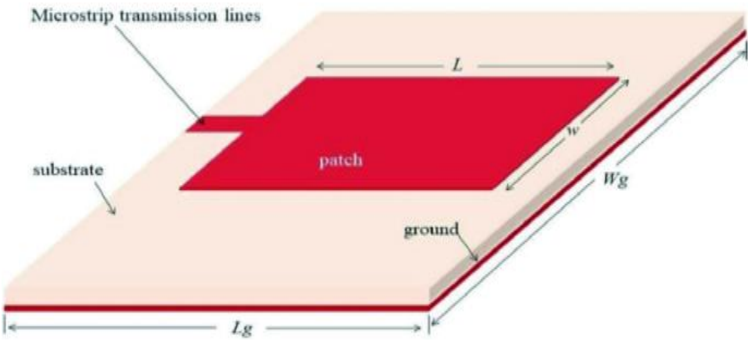


Fig 3.12: Antenna Structure

3.2.1 SUBSTRATE

Lot of work has been done on different substrates. Substrates use in microstrip patch antenna varies from 2.2≤Ɛ≤12. Lower the permittivity of dielectric material larger the size of the antenna but it achieves better efficiency and larger bandwidth. The Ɛr is limited by radio frequency or microwave circuit connected to antennas. When substrate of higher dielectric constants was used than the performance result degrades. The substrate used here is FR4 lossy material of dimensions 32 × 32 × 0.8 mm^3.

3.2.2 GROUND

Defected ground structures are the most popular techniques, especially when it comes to mutual coupling reduction between broadband and ultra-wideband MIMO antenna elements.

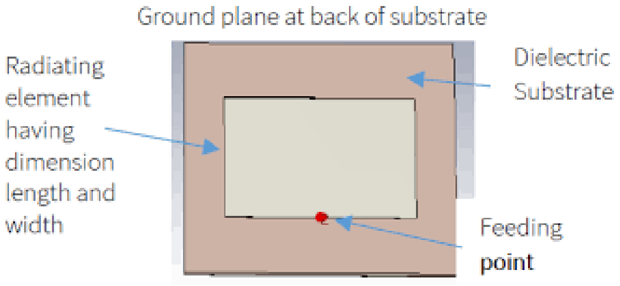


Fig 3.13: Ground Plane

DGS is a defect in ground plane, which intensely disturbs the surface current distribution. As a result, the impedance of the transmission line will change. It acts as a band stop filter and suppresses the coupled fields between the adjacent antenna elements of the MIMO antenna by decreasing the current on the ground plane.

3.2.3 PATCH

A patch antenna is a type of antenna with a low profile, which can be mounted on a surface. It consists of a planar rectangular, circular, triangular, or any geometrical sheet or "patch" of metal, mounted over a larger sheet of FR4 lossy called a substrate.

A patch antenna is a type of antenna with a low profile, which can be mounted on a surface. It consists of a planar rectangular, circular, triangular, or any geometrical sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane.

Generally, patch antennas are considered as low-profile antennas and are used for microwave frequency applications having frequency greater than 100 MHz

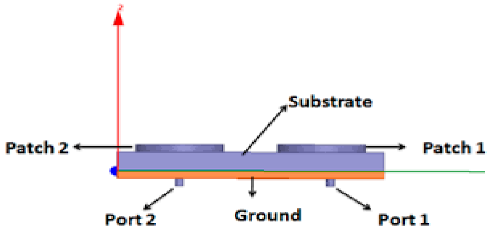


Fig 3.14: Patch of Antenna

3.2.4 FR4 MATERIAL

"FR" stands for "flame retardant", FR-4 glass epoxy is a popular and versatile high-pressure thermoset plastic laminate grade with good strength to weight ratios. With near zero water absorption, FR-4 is most used as an electrical insulator possessing considerable mechanical strength. The material is known to retain its high mechanical values and electrical insulating qualities in both dry and humid conditions.

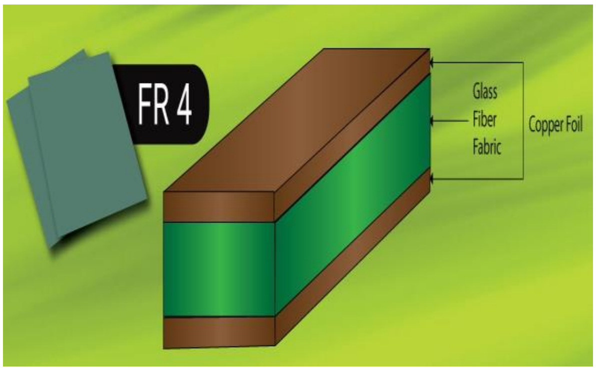


Fig 3.15: FR4 Material

3.2.5 FEED LINE

A feedline is used to excite to radiate by direct or indirect contact. There are many different methods of feeding and four most popular methods are microstrip line feed, coaxial probe, aperture coupling and proximity coupling.

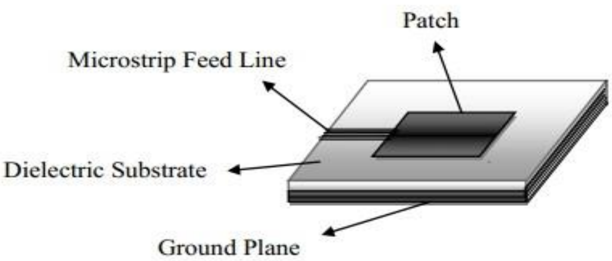


Fig 3.16: Feed Line

Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However, the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.

3.3 SOFTWARE USED

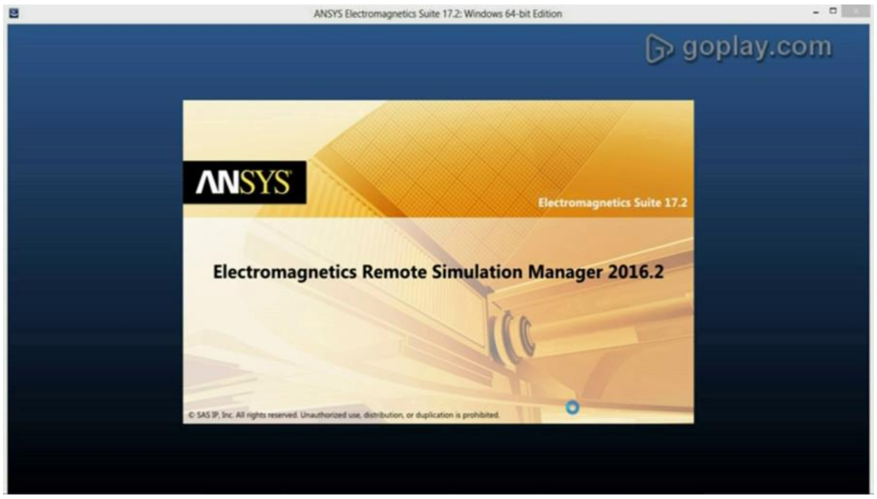


Fig 3.17: HFSS Software 17.2 Version

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards.

- It is an integrated design environment that contains tools for wide range of frequencies. Due to its compatibility, HFSS can solve any high-frequency field problem.

- It is considered as one of the best software for the efficient and fast analysis of the design of filters, antennas, transmission lines, connectors, circuit boards, etc.
- Its dependable automated adaptive mesh refinement allows engineers to concentrate on the design, rather than spending hours figuring out the correct model mesh.

- In addition, Ansys HFSS stands out from all other EM simulators due to its automation and guaranteed accuracy.

- In comparison, competing EM simulators require manual user control, and numerous solutions to ensure that the generated mesh is suitable and accurate.

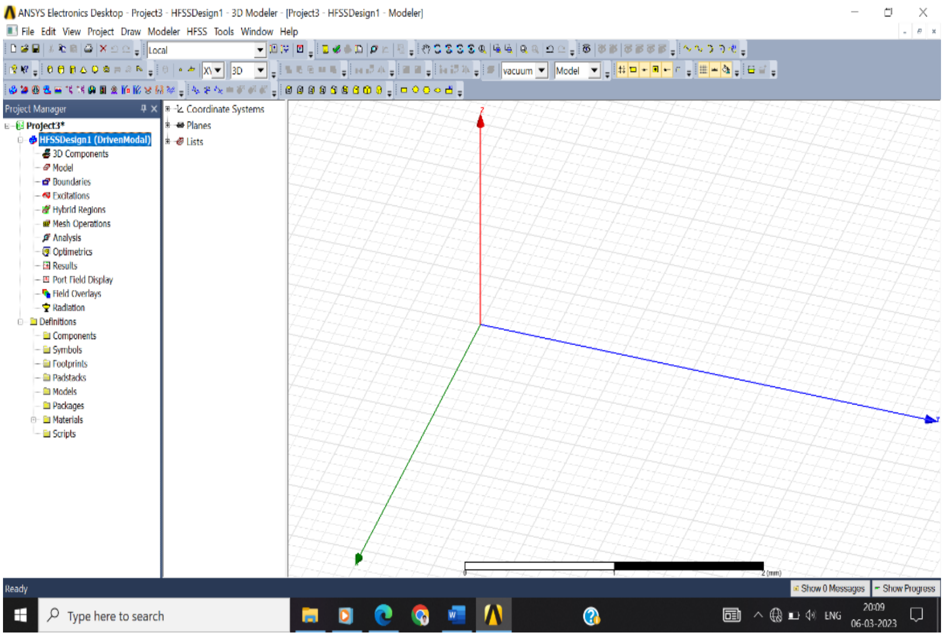


Fig 3.18: Opening Page of the HFSS Software

3.3.1 GENERAL FEATURES OF ANSYS HFSS

- Ansys HFSS Best-In-Class 3D High Frequency Structure Simulation Software
- Component-to-System EM Workflow.
- Coupled EM System Solver.
- Encrypted 3D Design Share.
- Automatic Adaptive Meshing.
- Encrypted 3D Design Share.

Key Features:

HFSS is the premier EM tool for R&D and virtual design prototyping. It reduces design cycle time and boosts your product's reliability and performance.

• EMI/EMC analysis

• Radio Frequency Interference (RFI) in complex environments

• Installed antenna and RF cosite analysis

• RF systems and circuits analysis

• Signal and Power Integrity analysis

3.3.2 MAIN FEATURES OF ANSYS HFSS ANTENNA DESIGN AND MODELING SOFTWARE

Understanding the factors affecting antenna performance when installed on real-world platforms is crucial to a sustainable design process.

Antennas are virtually everywhere. From commercial applications such as smartphones, RFID tags, and wireless printers, to defense applications such as phased array antennas for aircraft radar systems or autonomous vehicles, to integrated ground-based communication systems.

Electromagnetic simulation of antenna design and its interaction with the entire system allows designers to evaluate "what if" real life scenarios

3.4 ANTENNA DESIGN METHODOLOGY

In Antenna design Methodology, the microstrip patch antennas are designed on top of the substrate material. The shape of the patch materials is designed according to our requirement. Most of the microstrip antennas uses PEC material as patch element due to high conductivity and low in cost.

The Ground structure design is done bottom side of the substrate, in the proposed antenna, a Defective Ground Structure (GSD) is considered to reduce the transmission losses and to improve gain. Here also the Ground element is designed with PEC material considered.

Design of Single Antenna using HFSS Software step by step Process:

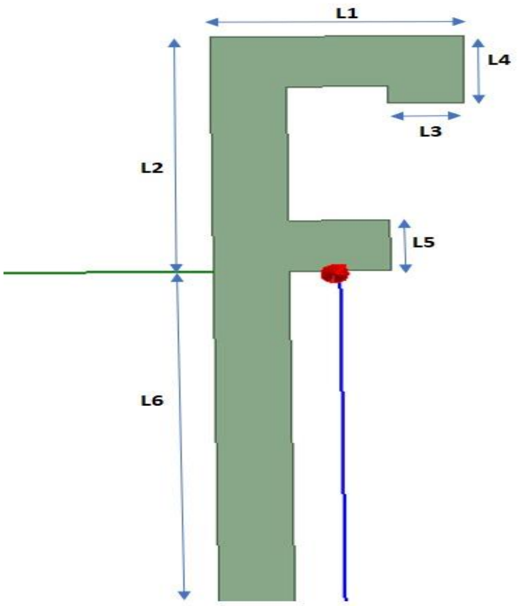


Fig 3.19: Single Antenna

Component	Material	Parameter	Value[mm]
Substrate	FR4	L	40
		W	28
		H	1.6
Ground Plane	PEC	Lg	32
		Wg	28
Feed line	PEC	Wf	3
		L6	20
Patch	PEC	L1	10
		L2	14
		L3	3

Table 3.1: Dimensions of Single antenna

GROUND PLANE

A rectangular ground plane with a rectangular slot is designed at the back side of the substrate. The antenna elements share a common ground plane. The upper edge of the common ground is stepped and incorporated with the slotted stubs to improve isolation between the antenna elements. The stubs act as a band stop filter for the desired frequency range. It produces transmission zeros within the radiating elements that in turn disturb the flow of current, surface waves, and near fields.

A Ground plane is a flat or nearly flat horizontal conducting surface that serves as part of antenna, to reflect the radio waves from other antenna elements. Ground will eliminate static electricity, as well as protest energy to the mast if the antenna meets live electrical wires.

Ground plane significantly affects the impedance and radiation performance of the antenna. As a result, the performance of the slotted ground plane antenna has the advantage of the suppressed ground plane effects over the conventional designs without choke-slot.

Step 1: Take Rectangle and plot Ground plane

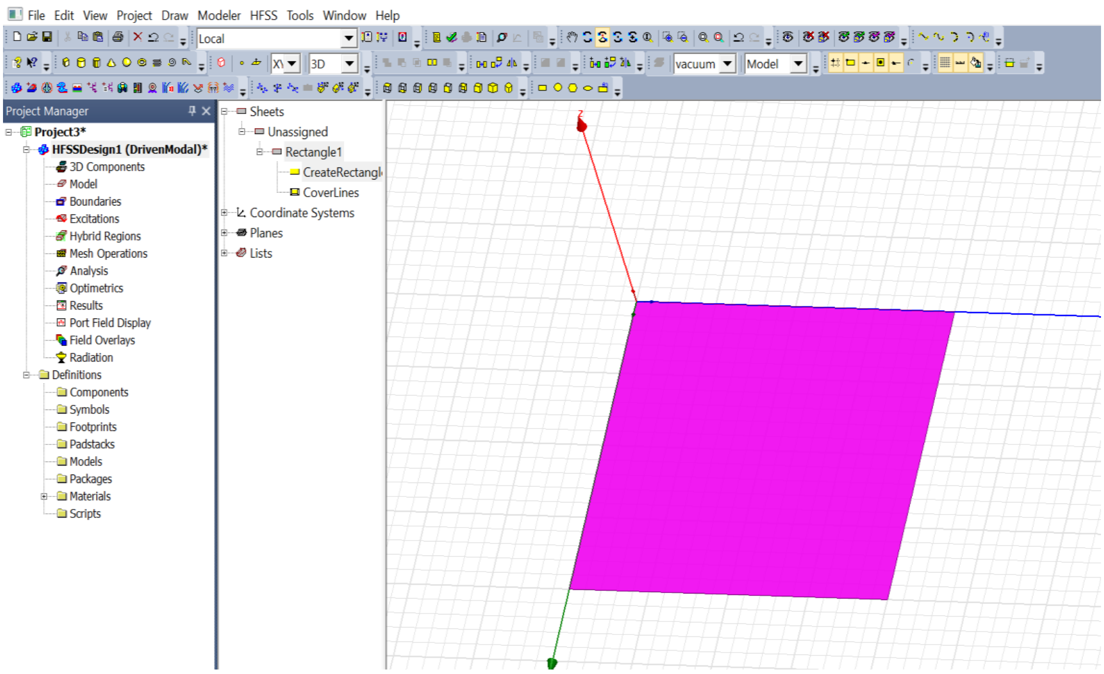


Fig 3.20: Creating Rectangle Plane

Step 2: Enter Coordinates and size values of Ground plan by clicking create Rectangle.

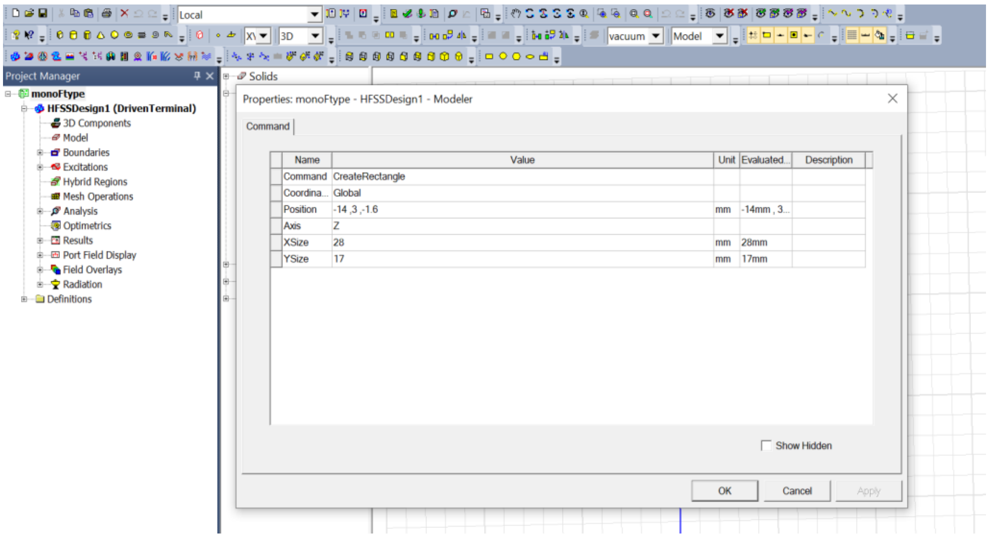


Fig 3.21: Assigning Dimensions

SUBSTRATE MATERIAL:

Lot of work has been done on different substrates. Substrates use in microstrip patch antenna varies from 2.2 ≤ Ɛ ≤ 12. Lower the permittivity of dielectric material larger the size of the antenna but it achieves better efficiency and larger bandwidth. The Ɛr is limited by radio frequency or microwave circuit connected to antennas. The dielectric constant of the substrate is assumed to be 2.2. The substrate used here is FR4 Lossy with a thickness of 1.6 mm and of dimensions 33 x 32 mm^2.

Step 3: Create Substrate by clicking cube in HFSS Tools and take material as FR4 in Box.

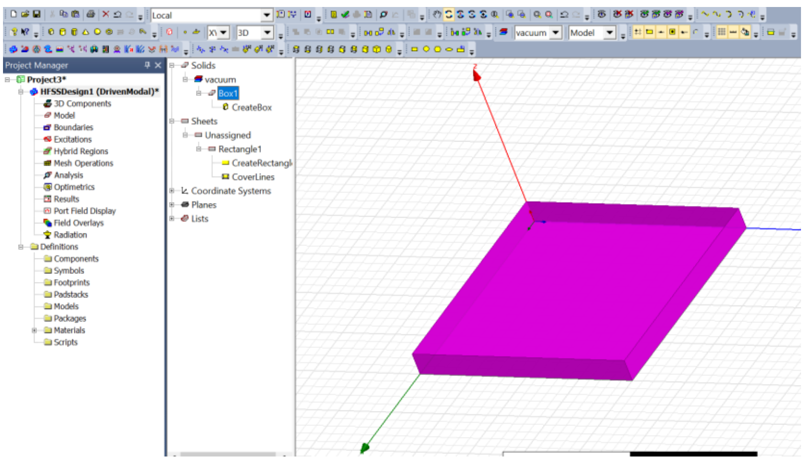


Fig 3.22: Creation of Substrate Material

Step 4: Give position and X, Y co-ordinates dimensions in Box modeler.

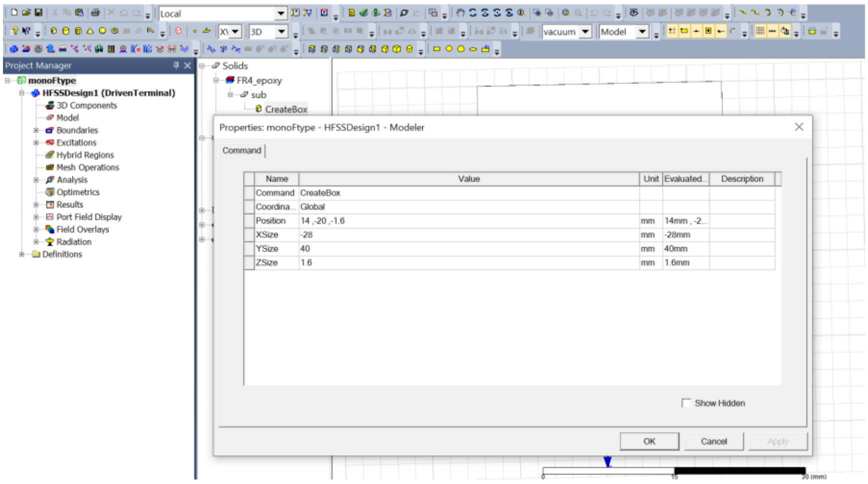


Fig 3.23: Assigning Dimensions

PATCH MATERIAL

A patch antenna is a type of antenna with a low profile, which can be mounted on a surface. It consists of a planar rectangular, circular, triangular, or any geometrical sheet or "patch" of metal, mounted over a larger sheet of FR4 lossy called a substrate.

Step 5: Create Patch Material by Clicking Rectangle block and give coordinates and X, Y sizes in Modeler.

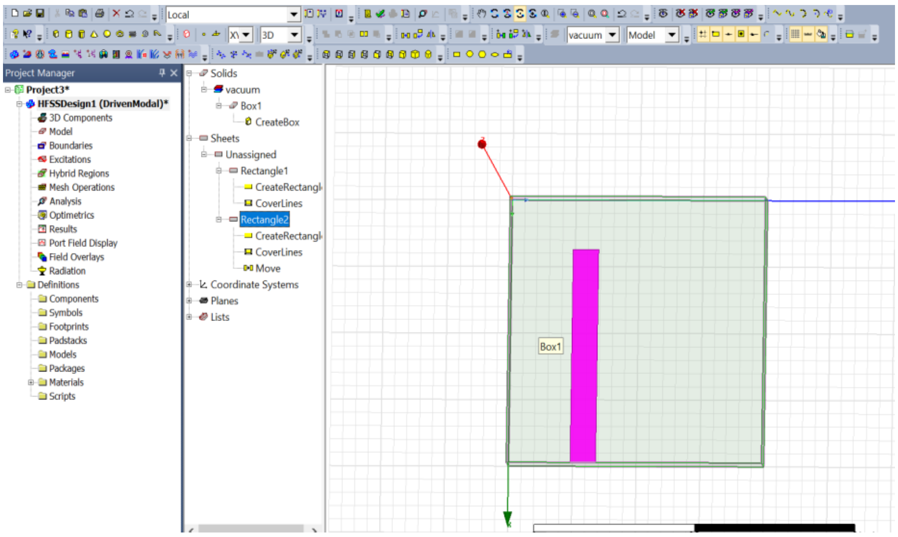


Fig 3.24: Creating Patch Element

Step 6: Place the Rectangle blocks in the position, add X, Y size values

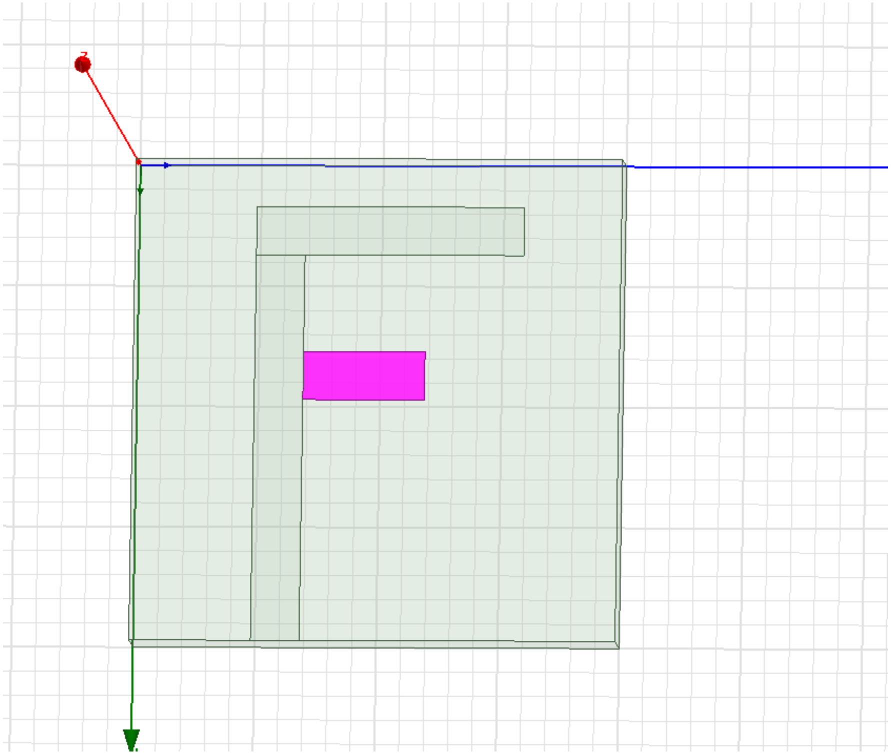


Fig 3.25: F Shaped Patch Element

Step 7: Combine all the patches by selecting rectangle blocks and click the add icon in tools.

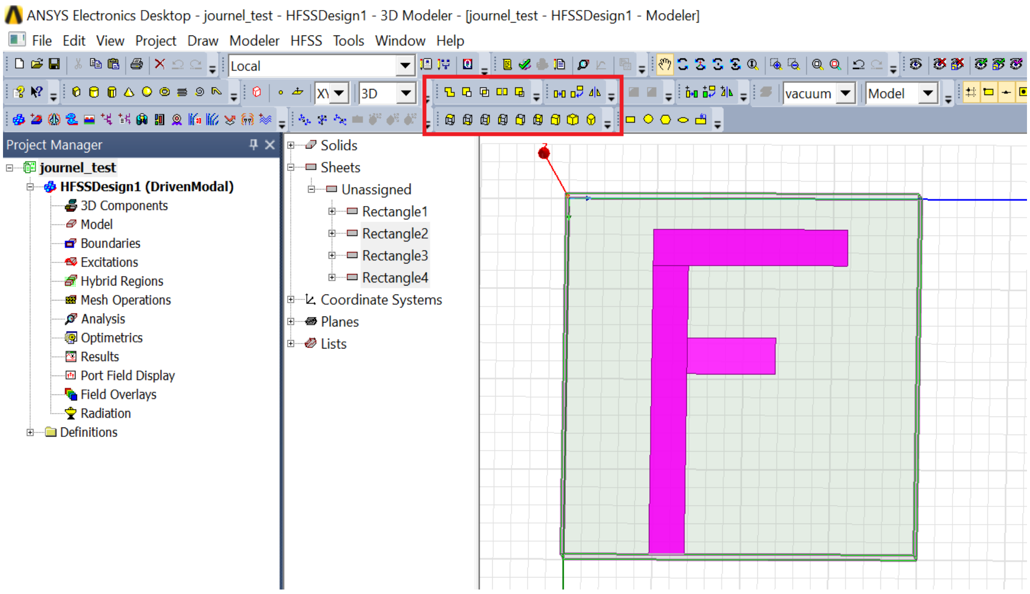


Fig 3.26: Combining Patch Elements

Step 8: Create a Port between Patch and Ground material with same measurement of Feedline of Patch.

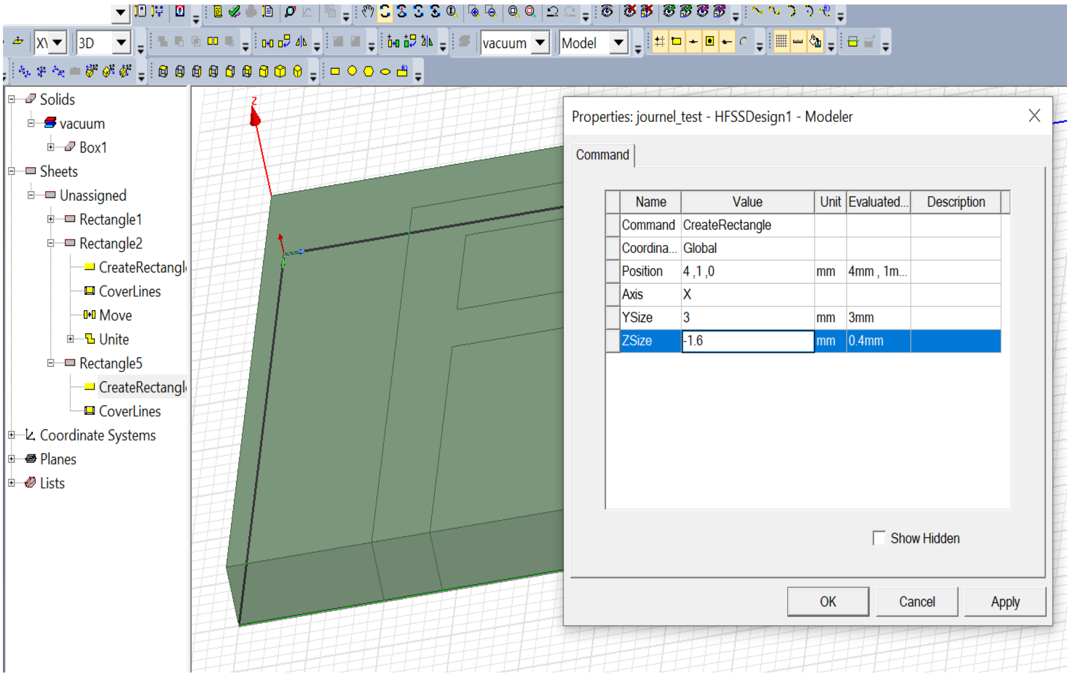


Fig 3.27: Creation of Port

Step 9: Give names to patch and Ground materials. Now Assign the Boundaries to them.

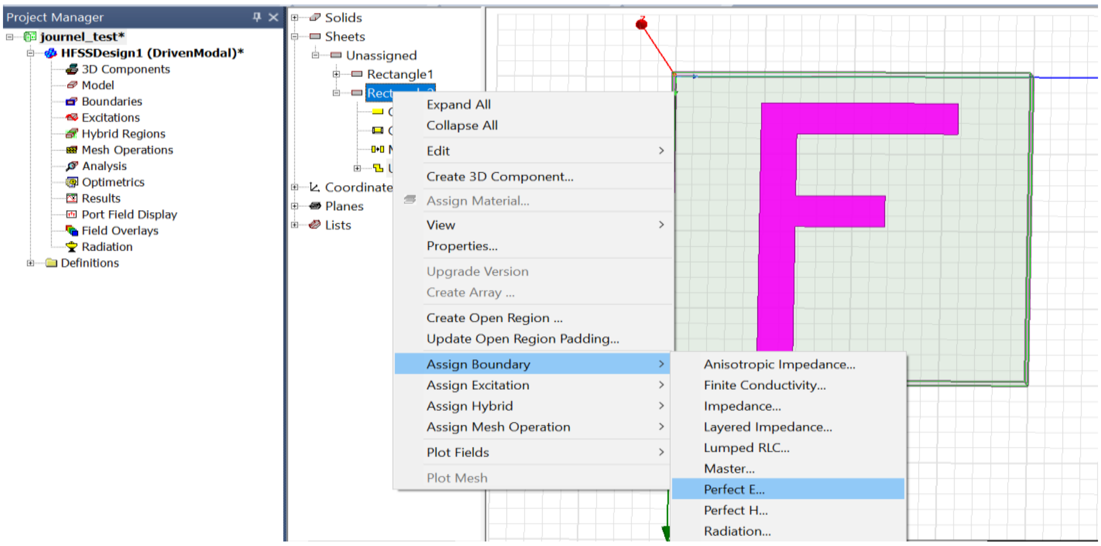


Fig 3.28: Assigning of Perfect E Boundary

Step 10: Assign Excitation to the Port and select Lumped Port and then click OK.

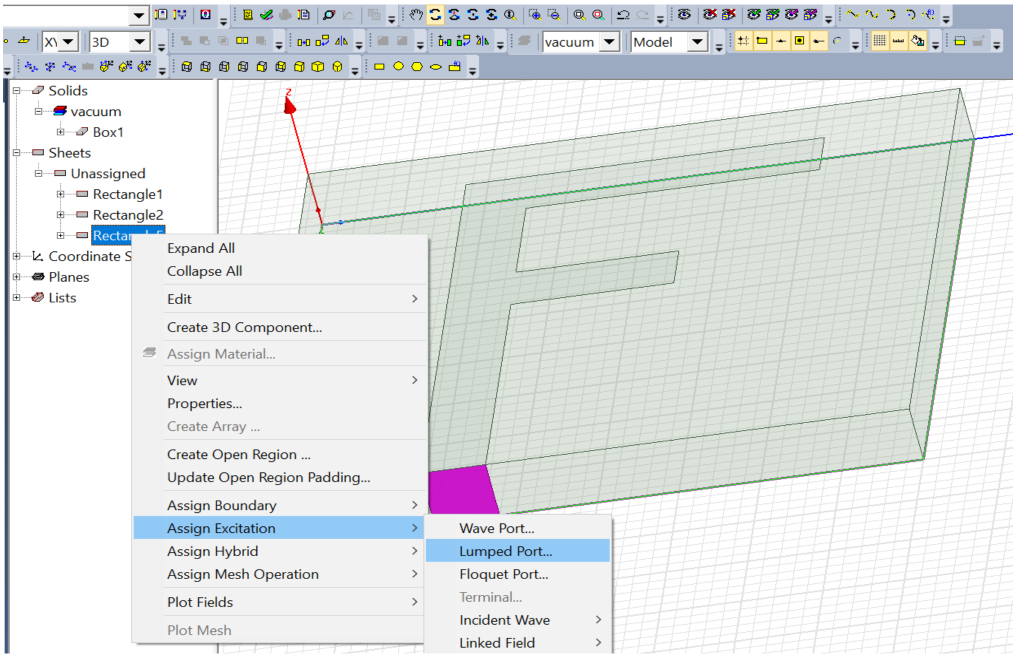


Fig 3.29: Assigning Port to Excitation

Step 11: Go to Analysis click Solution setup and add Solution frequency, add number of passes to 20.

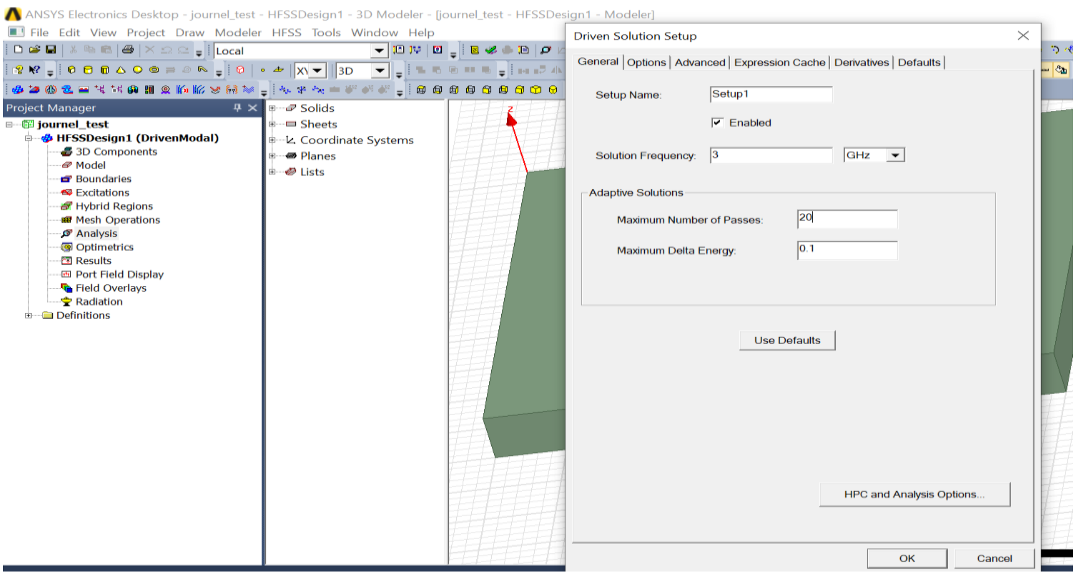


Fig 3.30: Setting Solution Frequency

Step 12: Give the frequency range values, Type and step size in Set Up.

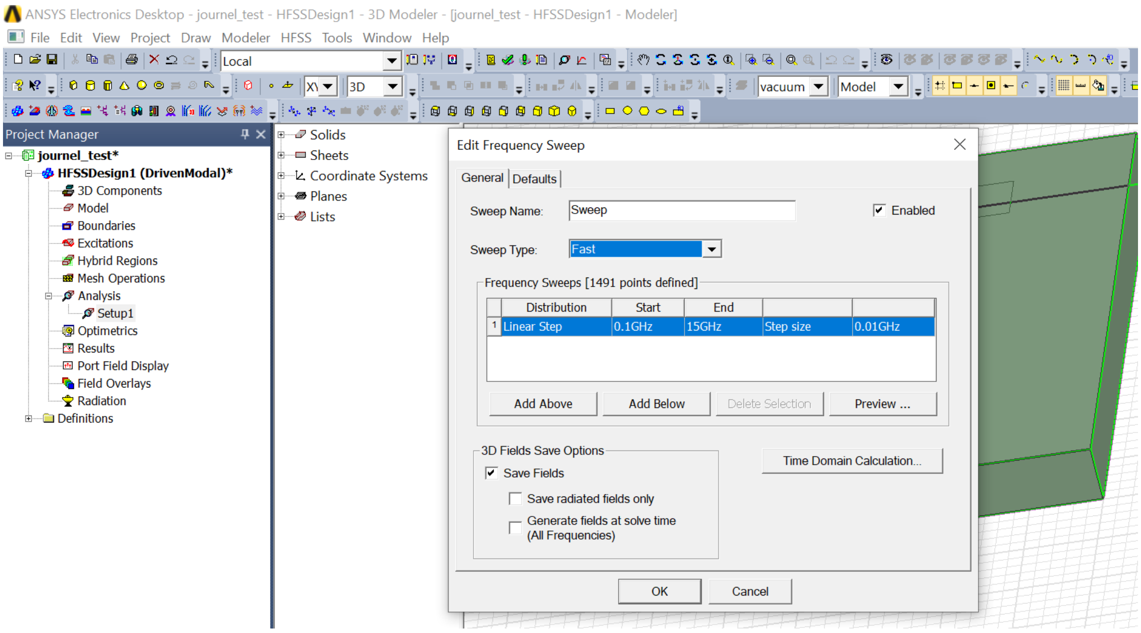


Fig 3.31: Assigning Operation Frequency Range

Step 13: Create Radiation Box with Cube component and assign the values and give the Vacuum as Material Type and Assign Perfect E boundary.

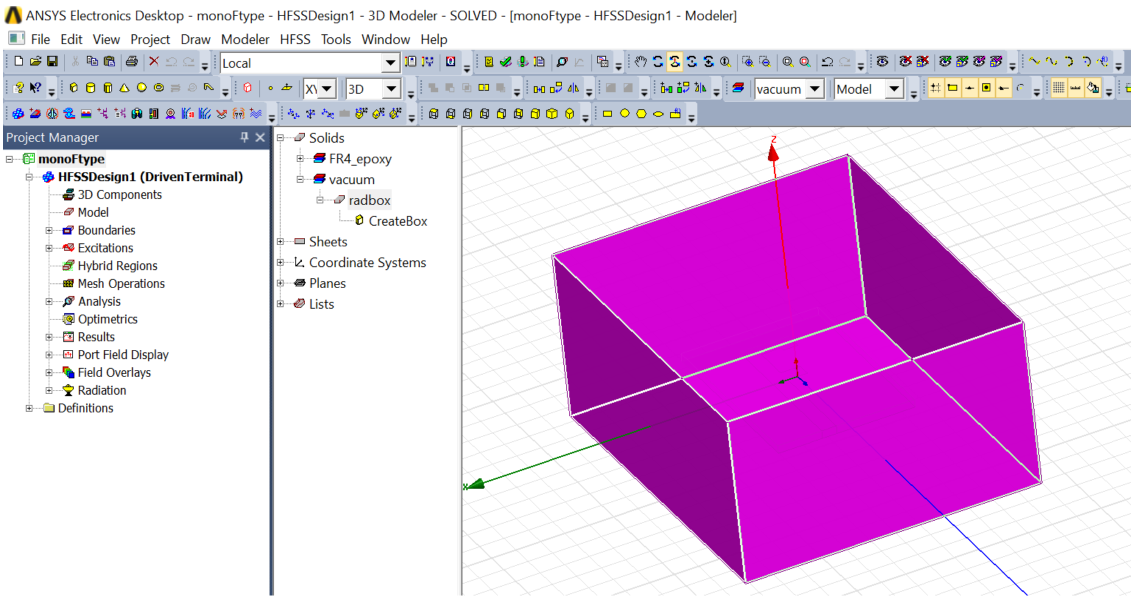


Fig 3.32: Creating Radiating Box

Step 14: Save the file and click On Validation check if there is no errors found click on Analyze All.

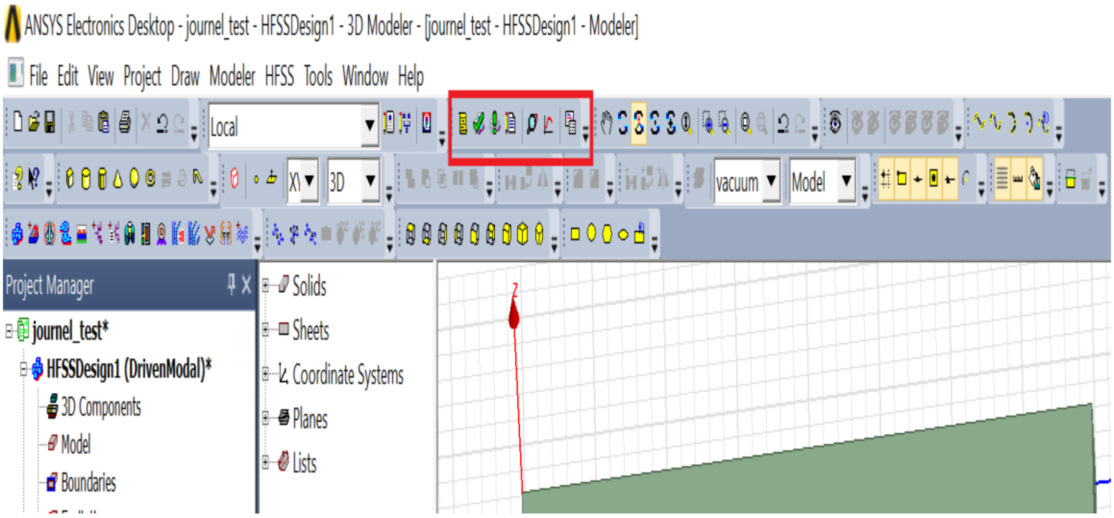


Fig 3.33: Validation Check and Analyze all

Step 15: To View the results go to Results and click on Create field report and Rectangle plot.

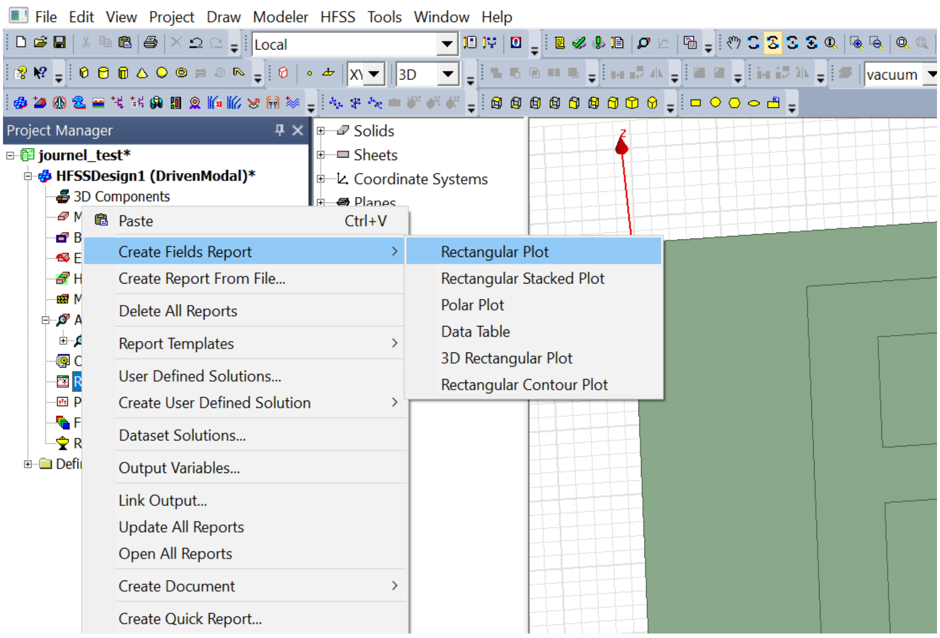


Fig 3.34: Checking the Results

Step 16: Select the desired output from the Category and set them in dB and finally click on New Report.

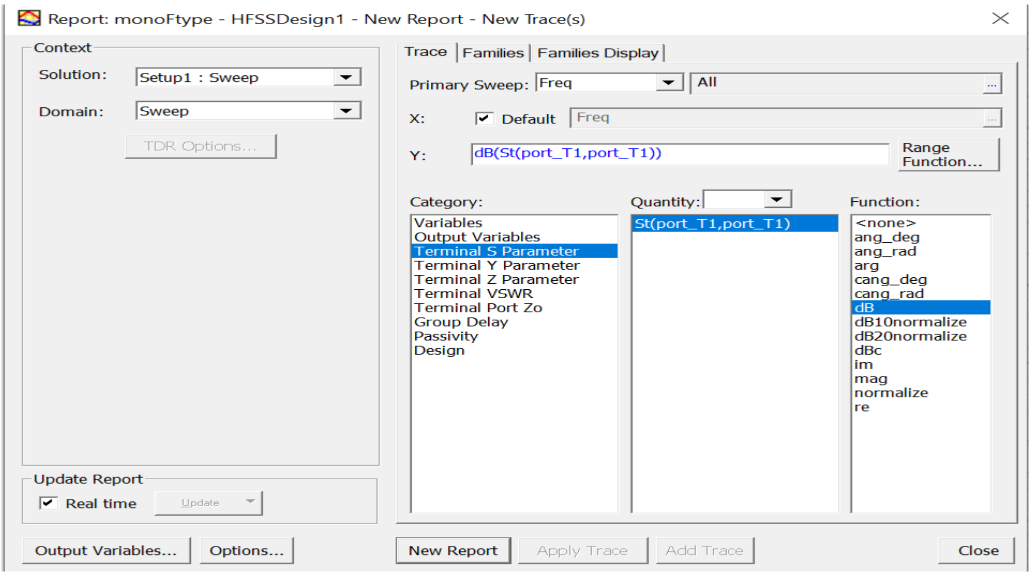


Fig 3.35: Selection of Required parameter

3.5 PROPOSED ANTENNA DESIGN:

In order to obtain Ultra-Wide Band frequency range, some modifications are done in the patch and Ground structures. The F structured patches are designed with considerable dimensions. These Patch materials are placed orthogonally with a diagonal distance of 2.8 mm. And the patch is internally removed with shape of F as per our requirement. Design the second patch material with same dimensions and place it with 2.8 mm distance to avoid Mutual coupling.

After completion of Patch Antenna, design the Ground by Defective Ground Structure (DGS) architecture. Add Stubs to the ground to avoid Mutual coupling between antennas and reduce the return loss of the signal.

Component	Material	Parameter	Value[mm]
Substrate	FR4	L	32
		W	32
		H	0.8
Ground Plane	PEC	G1	7
		G2	14.3
		G3	9.3
		G4	8
		G5	1
Patch	PEC	P1	7
		P2	8
		P3	6.3
		P4	2.7
		P5	3.05
		P6	1.5
		P7	5
		P8	3
		P9	3.5
		P10	8
		P11	1.5
		P12	1.2
		P13	1.53

Table 3.2: Proposed Antenna Dimensions

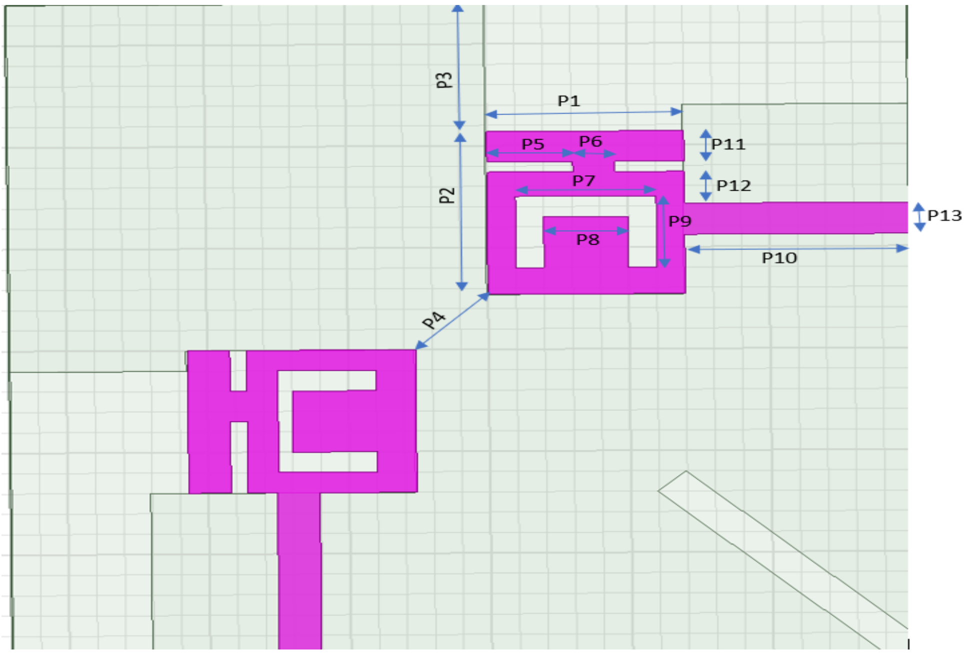


Fig 3.36: Front View of UWB Antenna

Fig 3.37: Back View - Ground Structure

Defected ground structures are the most popular techniques, especially when it comes to mutual coupling reduction between broadband and ultra-wideband MIMO antenna elements. Fig 3.37: Ground Plane DGS is a defect in ground plane, which intensely disturbs the surface current distribution. As a result, the impedance of the transmission line will change. It acts as a band stop filter and suppresses the coupled fields between the adjacent antenna elements of the MIMO antenna by decreasing the current on the ground plane.

CHAPTER 4

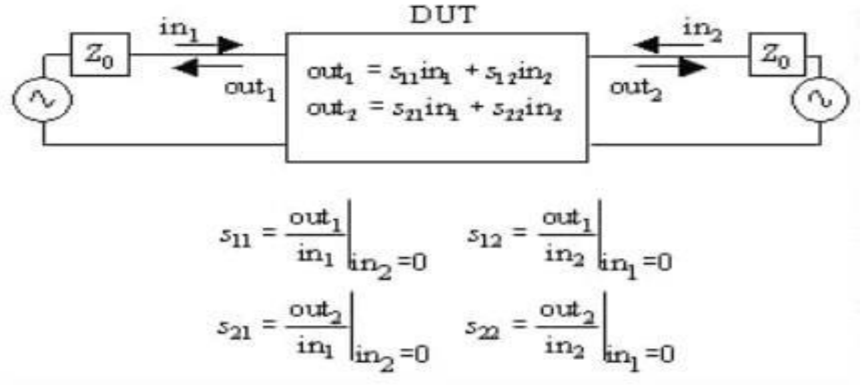
SIMULATION RESULTS

4.1 SINGLE ANTENNA RESULTS

4.1.1 S-PARAMETERS:

Scattering parameters describes the input-output relationships between ports in an electrical system. Specifically at high frequency it becomes essential to describe a given networkin terms of waves rather than voltage or current. Thus, in S-parameters we use power waves.

For a two-port network, s-parameters can be defined as



S11: REFLECTION COEFFICIENT

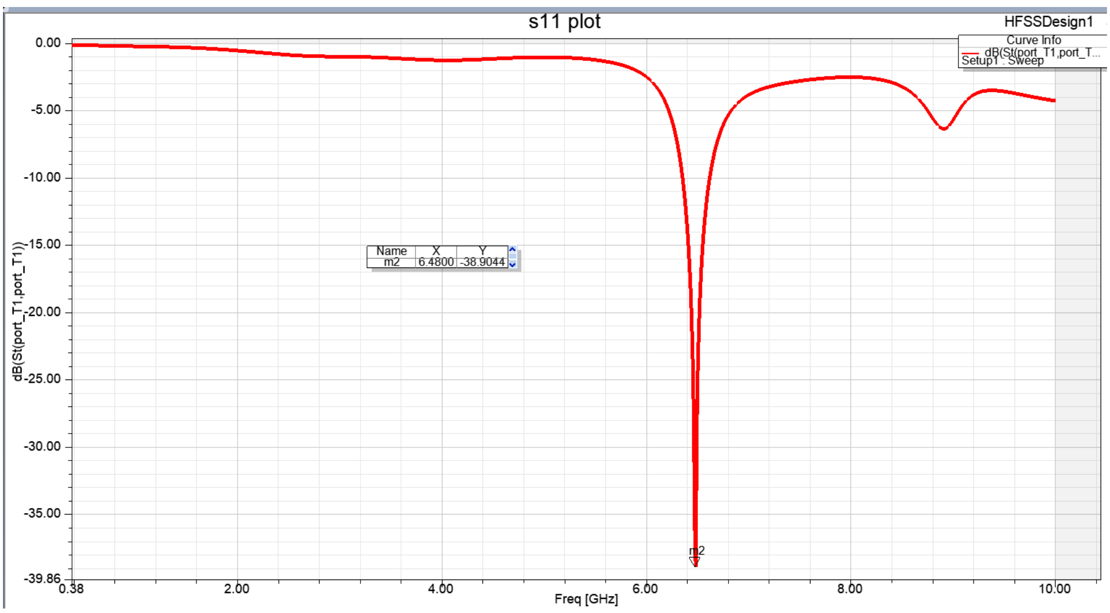


Fig 4.10: S11 at 6.48GHz with -39dB

It determines how much amount of power reflected from antenna due to standing wave. Above figure represents the s-parameter plot (simulated) of a single element. From the plot, it is evident antenna is resonating at 39.9 GHz at 6.48GHz, which covers the desired bandwidth recommended by the federal communication commission (FCC).

4.1.2 VSWR:

VSWR stands for Voltage Standing Wave Ratio, and is also referred to as Standing WaveRatio (SWR). VSWR is a function of the reflection coefficient, which describes the power reflected from the antenna. If the reflection coefficient is given by s11 or reflection coefficient or return loss, then the VSWR is defined by the following formula.

$$\boldsymbol{VSWR = \frac{1 + |S_{11}|}{1 - |S_{11}|}}$$

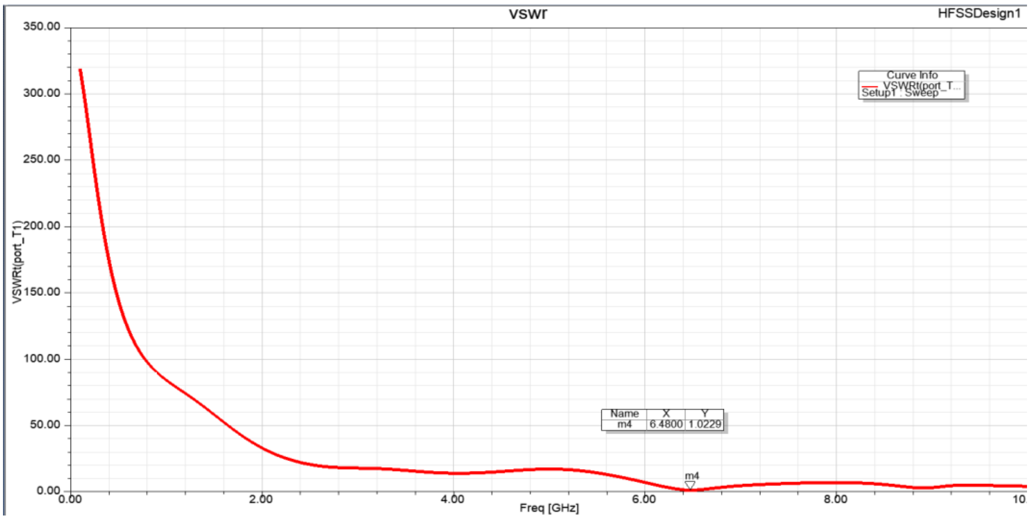


Fig 4.11: VSWR =1.02 at 6.48GHz

The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal.

4.1.3 GAIN:

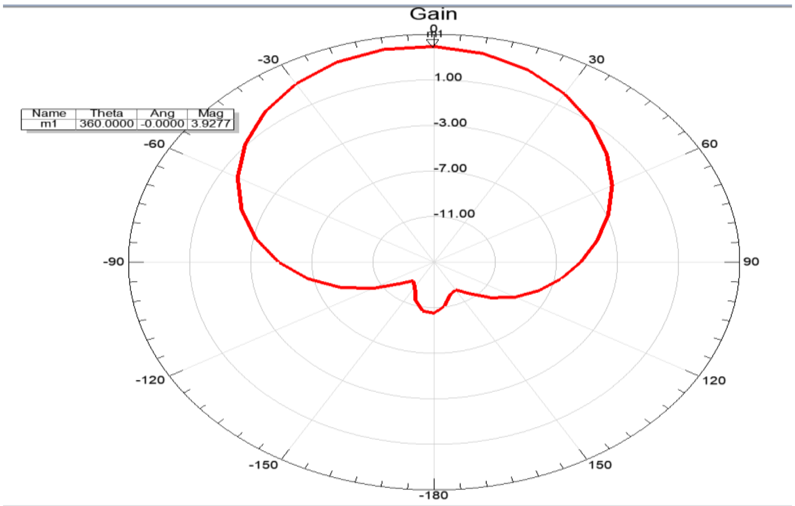


***Fig 4.12: Gain = 3.92dB at* 6.48GHz**

The realized gain of the single antenna is found to be 3.9 dB, at the resonance frequency of 6.48GHz. The maximum gain of 3.9 dB observed at Angle 0 deg.

4.1.4 3D POLAR PLOT:

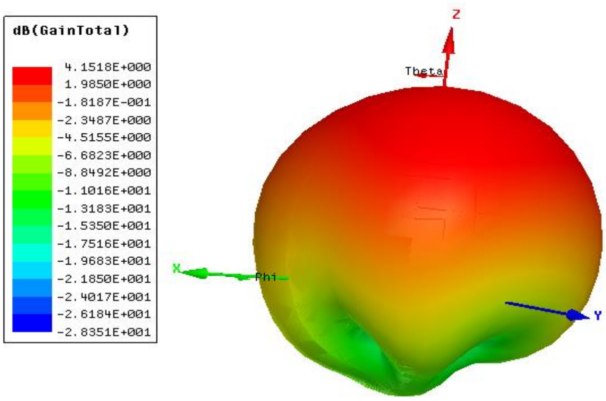


Fig 4.13: 3D Polar Plot at 6.48GHz

The gain of single antenna is represented in the form of 3D polar plot. The red color in that plot represents high radiation in that direction. And the Blue color indicates low radiation. Mostly the minor lobes indicate in blue color.

4.1.5 DIRECTIVITY:

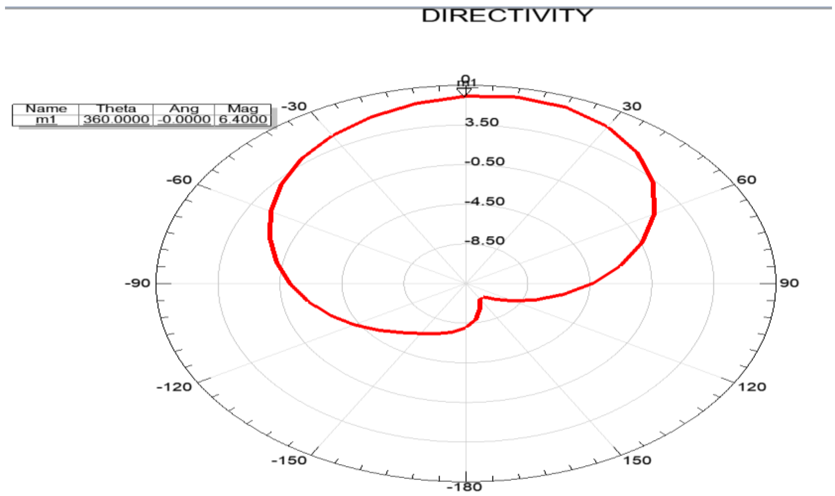


Fig 4.14: Directivity =6.4dB at 6.48GHz

The Directivity of the single antenna is found to be 6.4 dB at the resonance frequency of 6.48GHz.

4.2 SIMULATION RESULTS OF PROPOSED ANTENNA

The simulation results of proposed antenna are shown in given figures. The proposed antenna is a MIMO antenna, so it consists of two or more antennas on same substrate. So, the results of two antennas having S Parameters (S11, S21, S12, S22), gain and VSWR.

4.2.1 S-PARAMETERS

S11 – Reflection Coefficient

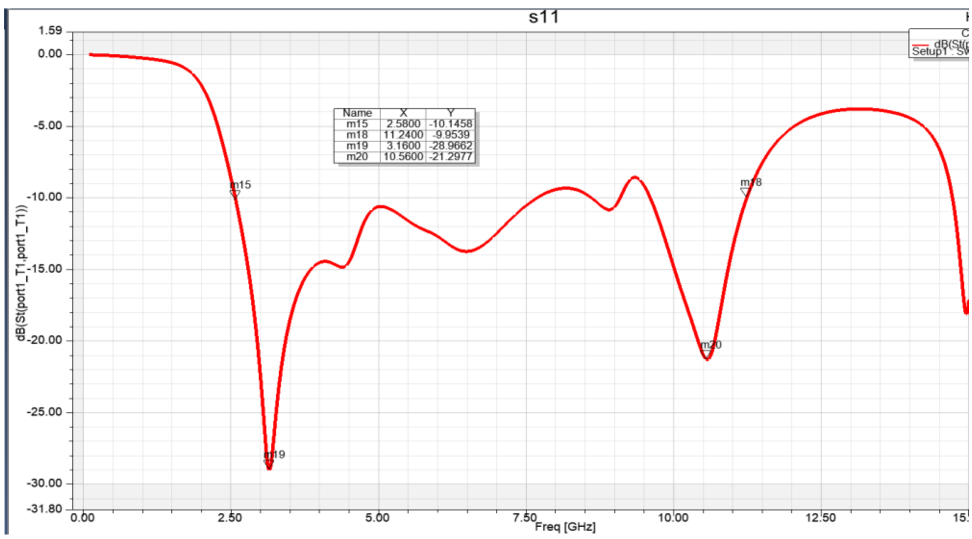


Fig 4.15: S11 Parameter

The S-parameter matrix can be used to determine reflection coefficients and transmission gains from both sides of a two-port network. This concept can further be used to determine s- parameters of a multi-port network.

S12- TRANSMISSION COEFFICIENTS

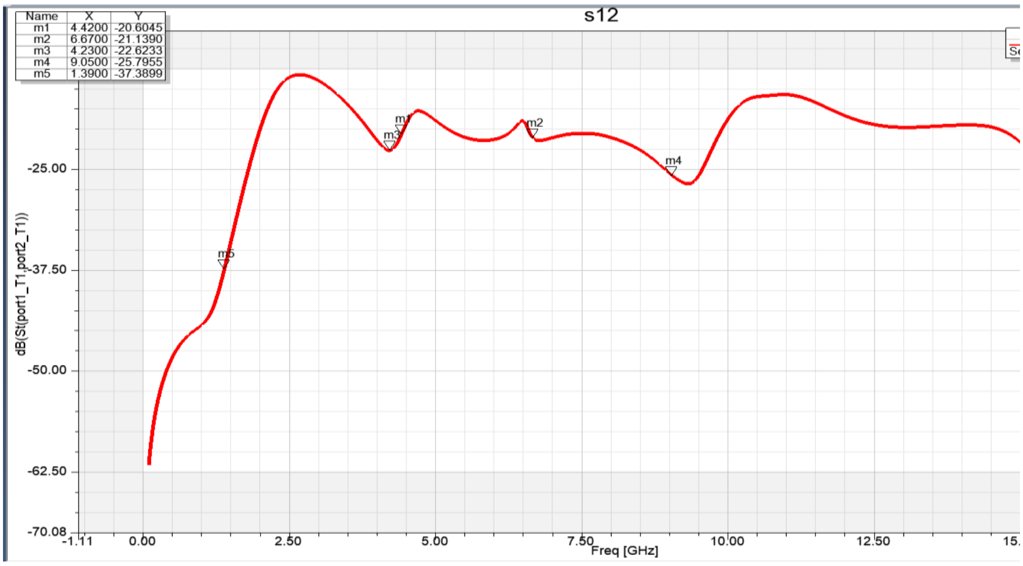


Fig 4.16: S12 Parameter

For instance, if we have 2 ports (intelligently called Port 1 and Port 2), then S12 represents the power transferred from Port 2 to Port 1. S21 represents the power transferred from Port 1 to Port 2. S11/S22 and S21/S12 are the reflection and transmission coefficient of the antenna.

S22- Reflection Coefficient

It determines how much amount of power reflected from antenna due to standing wave. Above figure represents the s-parameter plot (simulated) of a MIMO element. From the plot, it is evident antenna is resonating at 3.1GHz to 10.6GHz less than 10dB, which covers the desired bandwidth recommended by the federal communication commission (FCC).

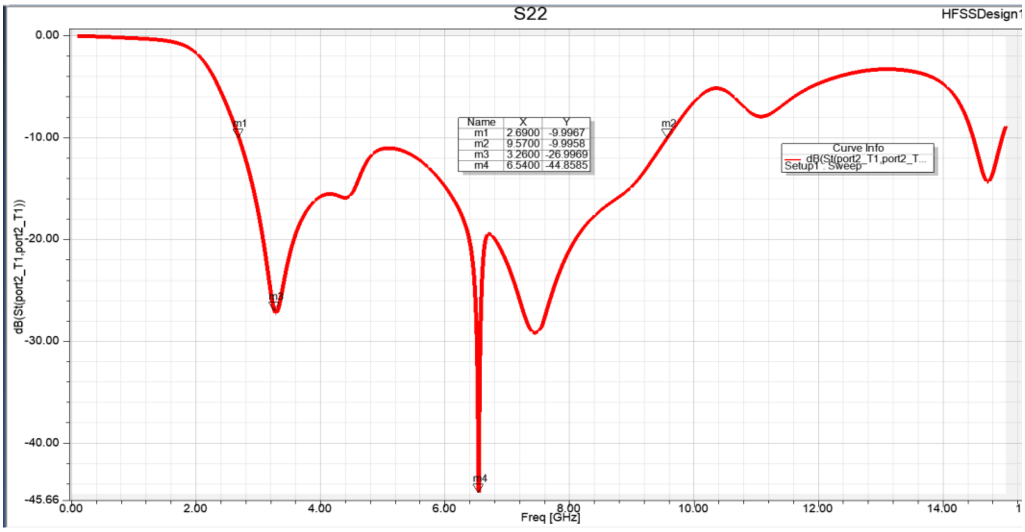


Fig 4.17: S22 Parameter

4.2.2 3D POLAR PLOT:

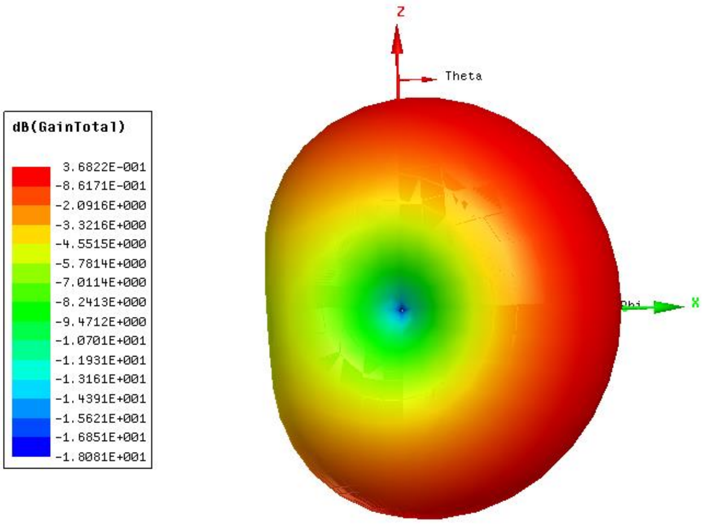


Fig 4.18: 3D Polar Plot at 3.1GHz

The gain of single antenna is represented in the form of 3D polar plot. The red color in that plot represents high radiation in that direction. And the Blue color indicates low radiation. Mostly the minor lobes indicate in blue color.

4.2.3 RADIATION PATTERN:

The field, which is far from the antenna, is called as far-field. It is also called as radiation field, as the radiation effect is high in this area. Many of the antenna parameters along with the antenna directivity and the radiation pattern of the antenna are considered in this region only.

The field distribution can be quantifying in terms of field intensity is referred to as fieldpattern. That means, the radiated power from the antenna when plotted, is expressed in terms ofelectric field, E (v/m). Hence, it is known as field pattern. If it is quantified in terms of power (W), then it is known as power pattern.

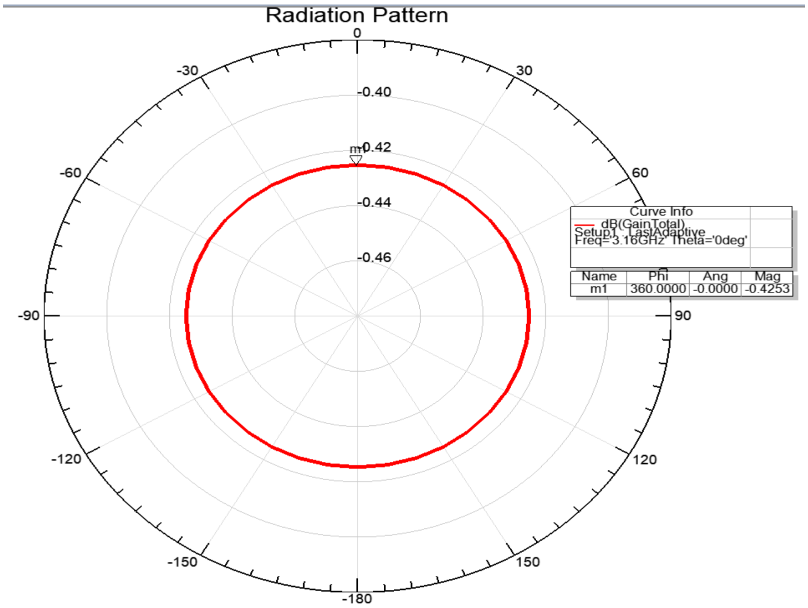


Fig 4.19: Radiation Pattern

The graphical distribution of radiated field or power will be as a function of

- spatial angles (θ, Ø) for far-field.
- spatial angles (θ, Ø) and radial distance(r) for near-field.

4.2.4 GAIN:

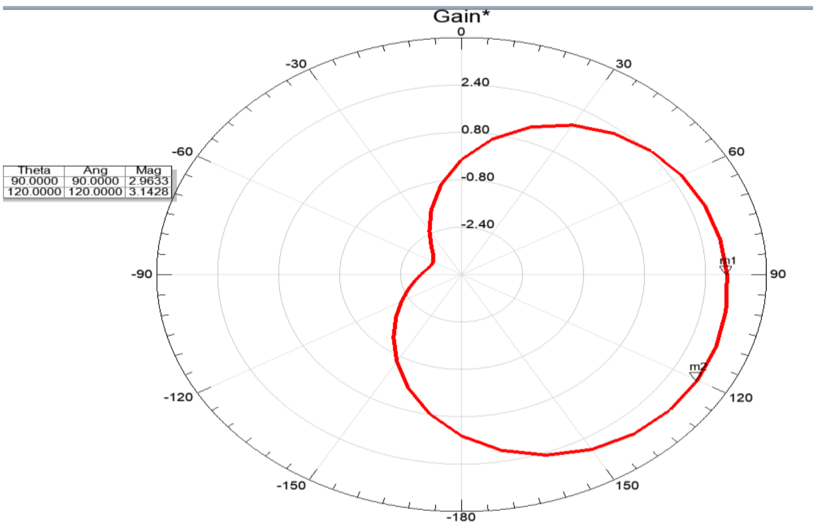


Fig 4.20: Gain of Proposed Antenna

Gain is a measure of the ability of the antenna to direct the input power into radiation in aparticular direction and is measured at the peak radiation intensity. An isotropic radiator is 100% efficient. The gain of an actual antenna increases the power density in thedirection of the peak radiation.

4.2.5 ENVELOPE CORRELATION COEFFICIENT:

Envelope Correlation Coefficient tells us how independent two antennas' radiation patterns are. So, if one antenna was completely horizontally polarized, and the other was completely vertically polarized, the two antennas would have a correlation of zero. Similarly, if one antenna only radiated energy towards the sky, and the other only radiated energy towards the ground, these antennas would also have an ECC of 0. Hence, Envelope Correlation Coefficient considers the antennas' radiation pattern shape, polarization, and even the relative phase of the fields between the two antennas.

$$\mathrm{ECC}, \rho_e = \frac{|S_{11}^* S_{12} + S_{21}^* S_{22}|^2}{\left(1 - \left(|S_{11}|^2 + |S_{21}|^2\right)\right)\left(1 - \left(|S_{22}|^2 + |S_{12}|^2\right)\right)}$$

$$G_{\mathrm{app}} = 10\sqrt{1 - |\rho|}, \quad |\rho| = \rho_e$$

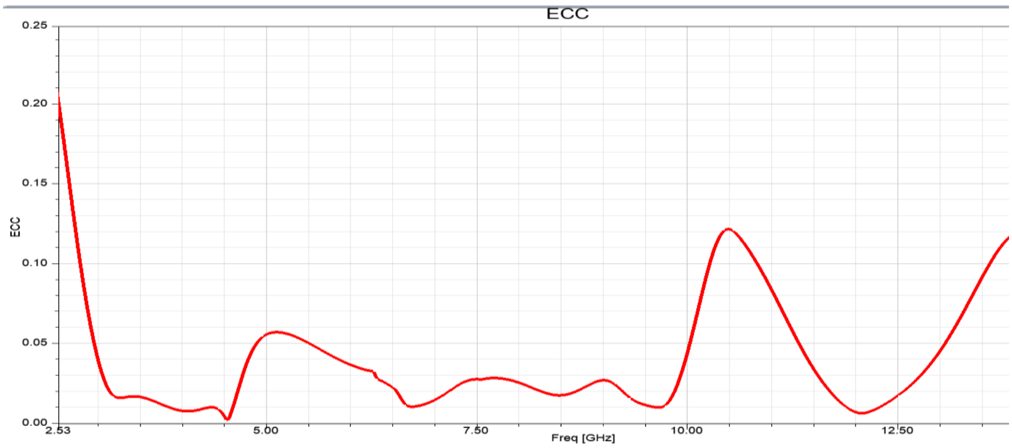


Fig 4.21: ECC

4.2.6 GAIN DIVERSITY:

Diversity gain is the increase in signal-to-interference ratio due to some diversity scheme, or how much the transmission power can be reduced when a diversity scheme is introduced, without a performance loss. Diversity gain is usually expressed in decibels, and sometimes as a power ratio. An example is soft handoff gain. For selection combining N signals are received, and the strongest signal is selected. When the N signals are independent and Rayleigh distributed, the expected diversity gain has been shown to be $\sum_{k=1}^{N} \frac{1}{k}$, as a power ratio.

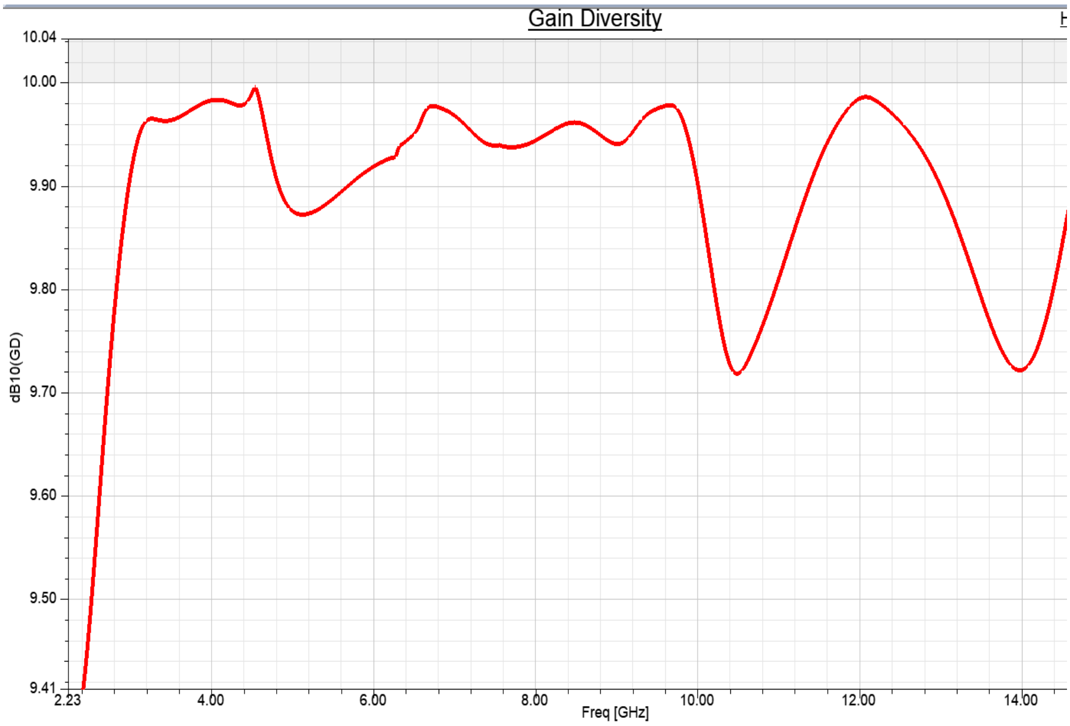


Fig 4.22: Gain Diversity

$$DG = 10\sqrt{1-(ECC)^2}$$

In MIMO antenna system Gain Diversity plays major role. It is calculated using Envelope Correlation Coefficient (ECC). Using S Parameters, the measurement of Gain Diversity is done. In this design the gain diversity is almost 9.9, according to MIMO antennas it must be nearly equal to 10. So, the satisfied results are obtained. But some fluctuations are observed in between the 2GHz to 12GHz frequency range, it is due to some internal reflections in the antenna components.

CHAPTER-5

CONCLUSION AND FUTURE SCOPE

CONCLUSION

A proposed F-structured 2x2 UWB MIMO antenna is designed for lower 5G applications. The main applications of lower 5G bands are Internet of Things (IoT) and Wi-Fi based devices. So, for this requirement UWB technology-based antenna is designed for both UWB and lower 5G applications.

Coming to design of proposed antenna, it is a compact UWB MIMO antenna with size of 32 x 32 x 0.8mm^3 designed and simulated using HFSS software. Here the FR4 material taken as substrate. Because it is mostly available in market and low in cost. The ground structure is designed based on Defective Ground structure model. The patch elements are designed with PEC material, the internal patch is shaped into F structure. Two patch materials are placed on a substrate orthogonally with 2.8mm to avoid mutual coupling and to improve isolation.

The proposed antenna results satisfy the UWB applications with return loss of -29dB at 3.16GHz and -21.29dB at 10.56GHz. And the maximum Gain at 3.16GHz is 3.12dB. In MIMO antennas Gain Diversity is most important parameter, so for this design the gain diversity is nearly 10 and radiation pattern of this antenna is isotropic. The designed prototype of the MIMO antenna system and its simulated model findings have been found to be in good agreement.

FUTURE SCOPE

There are many ways 5G technology will be used in the future, utilizing its fast speed data transfers. Due to a reduced waiting time and ease of access, and with every remote action made smother and way more precise thanks to the 5G technology, video games and the video consoles that we know of today will disappear, potentiallychanging the whole economic structure of the industry.

UWB is a fundamentally different communication method compared with mainstream methods like Wi-Fi and Bluetooth. The use of radio pulses over a wide spectrum allows UWB to work simultaneously with other technologies, while the use of a wide spectrum allows for advanced features such as accurate tracking.

Outside of the public domain, the possibility for 5G technology is endless. From autonomous cars to smart cities, remote medicine, and surgeries of industry 4.0, all industries could see huge changes as 5G technology is introduced.

5th generation technology is designed to provide incredible and remarkable data capabilities, unhindered call volumes, and immeasurable data broadcast within the latest mobile operating system. Hence, it is more intelligent technology, which will interconnect the entire world without limits. Likewise, our world would have universal and uninterrupted access to information, communication, and entertainment that will open a new dimension to our lives and will change our life style meaningfully.

Moreover, governments and regulators can use this technology as an opportunity for the good governance and can create healthier environments, which will encourage continuing investment in 5G, the next generation technology.

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F STRUCTURED UWB MIMO ANTENNA FOR LOWER 5G BANDS

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ABSTRACT

A F structured compact 2 × 2 Ultra Wide Band MIMO antenna system is presented in this paper. This antenna system is designed for lower 5G bands ranging from 2 GHz to 12 GHz. This antenna system is designed and simulated using HFSS Software. The design structure size of 32 × 32 ×1.6 mm³ on FR4 material. The simulated return loss values for designed antenna are less than −10 dB over the frequency band and the S11 values of −28.9 dB and −21.29 dB can be observed at 3.16 GHz and 10.56 GHz, independently. The transmission coefficient between both antenna elements is less than −20 dB over the 2GHz to 12GHz frequency range. The VSWR of 0.68 can be observed at 3.16 GHz frequency. The maximum gain is measured as 3.14dB. The radiation patterns shows nearly isotropic far fields in E and H planes at lower return loss frequency . The result of gain diversity of this design is achieved by considering multipath propagation environment.

Keywords: UWB, Return Loss, Mutual Coupling, Gain, Gain Diversity.

I. INTRODUCTION

In this study, We are introduced to a system that uses MIMO technology to increase reliability, channel capacity, and transmission speed. This F-shaped MIMO antenna is used for applications in the lower 5G applications. The amount of mobile data traffic worldwide is expected to rise by 55% between 2019 and 2022. Mobile video streaming and the adoption of the Internet of Things(IoT) are the key causes of this enormous surge. The availability of frequency spectrum is the primary barrier to the implementation and deployment of 5G networks before 2019, hence both the higher and lower frequency bands are required for 5G. An ultra-wide band (UWB) 2x2 Multiple Input Multiple Output (MIMO) antenna system has been built and modelled in order to fulfil this challenge and present expectations. The frequency range covered by this antenna system, which includes all the lower 5G frequency bands, is 2 GHz to 12 GHz. Additionally, the IEEE 802.11 requirements for Wi-Fi functioning in mobile devices are covered by the designed antenna. Moreover, this frequency complies with the Federal Communication Commission's UWB operation standards (FCC). The proposed antenna not only meets mutual coupling, smaller size, and operating frequency requirements, but also achieves IoT and lower 5G band applications.

Also, the UWB technology based devices have several other advantages like high bit-rate, larger bandwidth, and low cost. In the UWB communication devices, the patch element plays a very important role. Now a days, the UWB and MIMO antennas are installed in wireless systems for enhanced performance in terms of high data-rates. MIMO mobile system with numerous sections with in limited inter element as the coupling is strong between different elements it is difficult to produce space. The main challenge in designing of MIMO antenna systems are to reduce the mutual coupling between the patch elements. So, these two F shaped patches are placed orthogonally to provide polarization diversity for coupling reduction.

II. METHODOLOGY

This proposed antenna is a compact 2 × 2 UWB MIMO antenna system and it consists of two F type structures with a compact defective ground structure. The overall antenna size is 32 × 32 × 1.6 mm³ .

The proposed antenna system is designed on FR4 lossy Material with values

Relative permittivity = 2.2,

dielectric loss tangent = 0.0009

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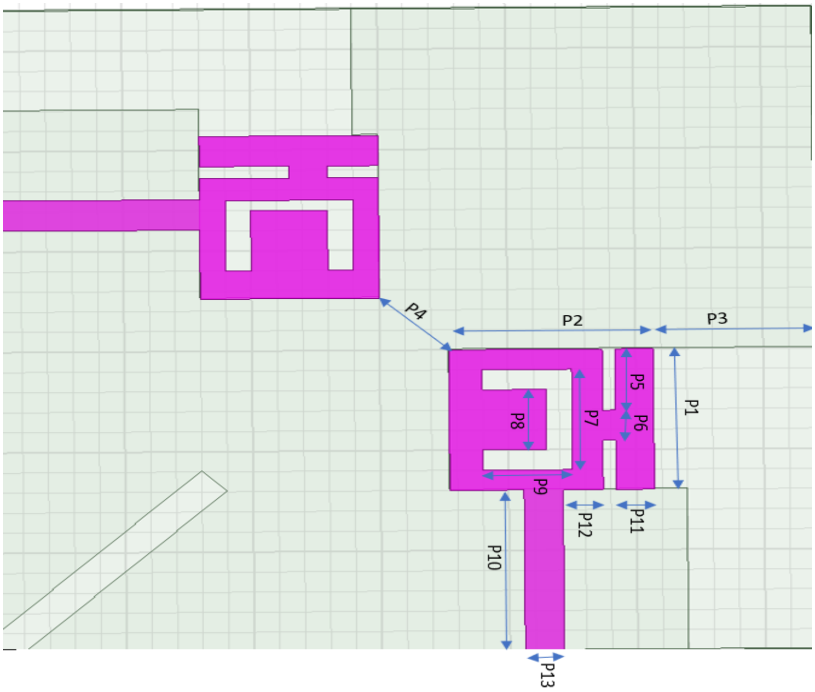
height = 1.6 mm

This antenna design is done using HFSS software. In order to incorporate a 2 × 2 MIMO antenna , a second F shaped patch has been orthogonally placed on the same plane. Before making the design of Patch element, take the substrate material with the given values shown in Table1. For better results and the availability of market take the FR4 lossy material as substrate. Now design the Patch element top of the substrate. Place the Patch elements with distance of 2.7 mm and orthogonal to avoid the Mutual coupling. After design of Patch element design the Ground structure. In this antenna design a Defective Ground Structure is taken for stable S-parameter results. Place the Ground Material bottom side of substrate material. After completion of both Ground and Patch elements, construct the Port between the Ground and patch for both antennas with the length of Feed line of antenna.

III. MODELING AND ANALYSIS

After completion of design set the setup frequency as per requirement and assign the boundaries to the Ground and patch material and Excitation to the port in HFSS software. Then start simulation by clicking analyze all icon.

The dimensions of patch and Ground materials are shown in Table1 and Table 2. These dimension values are measured in mm.



(a)Front View of Patch Antenna

Table 1: Patch Element Dimensions

Variables	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
Dimensions	7	8	6.3	2.7	3.05	1.5	5	3	3.5	8	1.5	1.2	1.53

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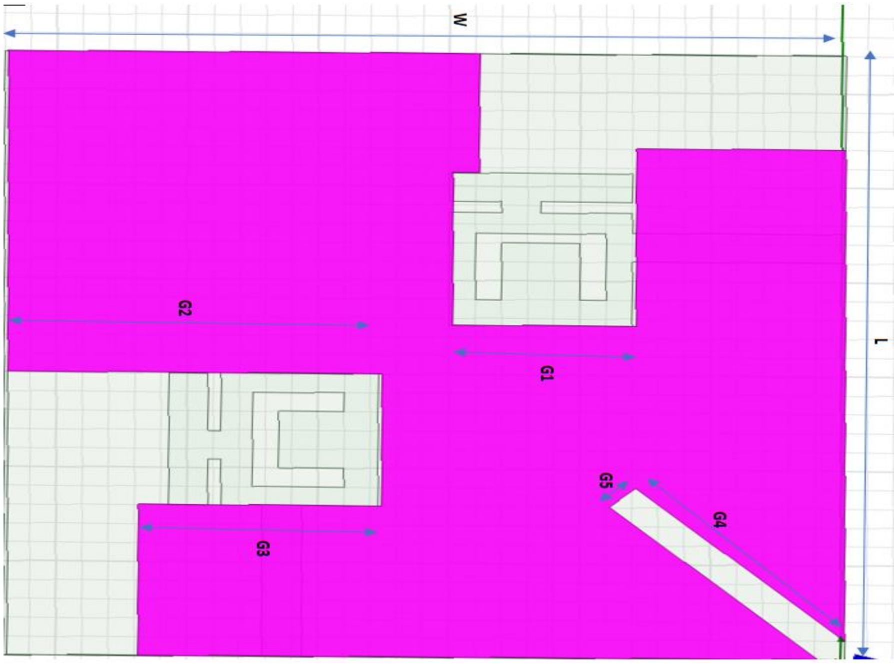


(b) Back View -Ground structure

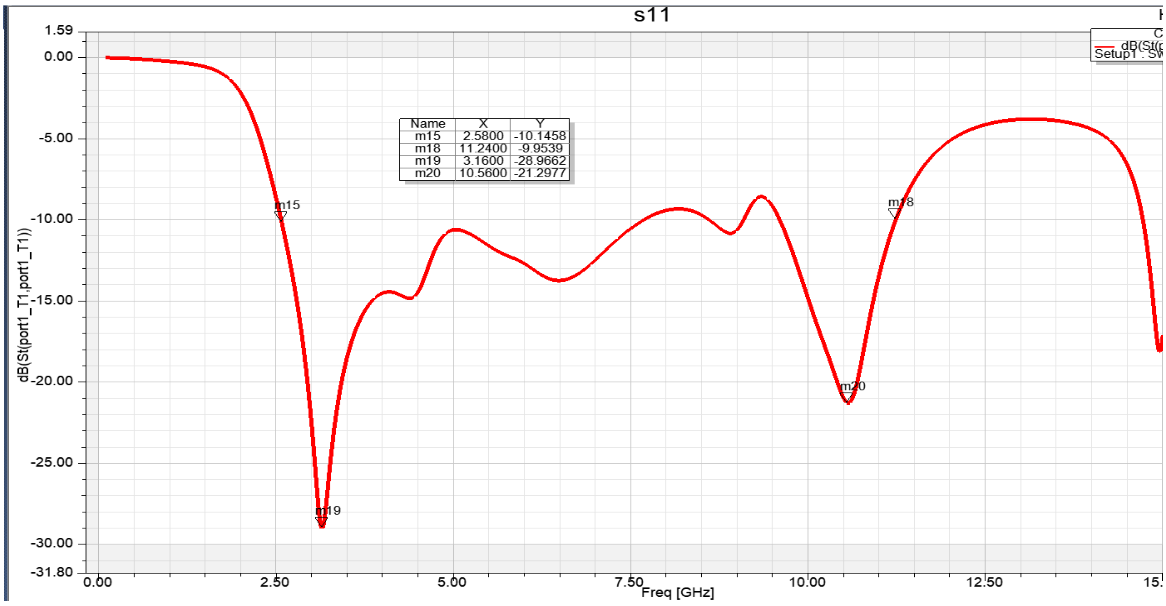
Figure 1: Proposed Antenna Structure

Table 2: Ground structure Dimensions

Variables	G1	G2	G3	G4	G5	L	W
Dimensions(in mm)	7	14.3	9.3	8	1	32	32

IV. RESULTS AND DISCUSSION

The results of Reflection Coefficients S11 and S22 are shown in Figure 2. Here the bandwidth of both S11 and S22 are similar with some variation in decibels. The return loss of signal is resonated at 2.58GHz by crossing -10dB and the lowest values of s11 are measured at 3.16GHz, 10.56GHz with -29 dB and 21.29dB respectively. Coming to the transmission coefficient(s12), the values has been observed below -20dB over the transmission bandwidth. The VSWR value for this antenna design is 0.63 which is less than 2 according to antenna design standards.



(a) S11 Parameter

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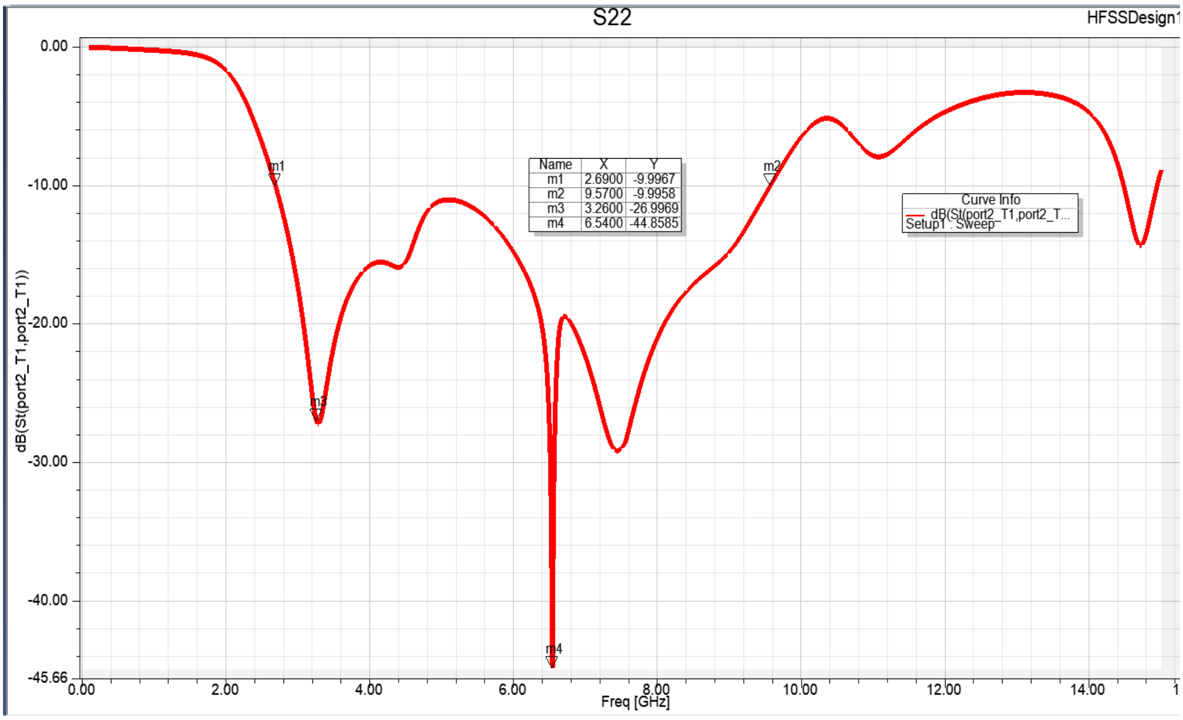

(b) *S*22 Parameter

Figure 2: Reflection Coefficient

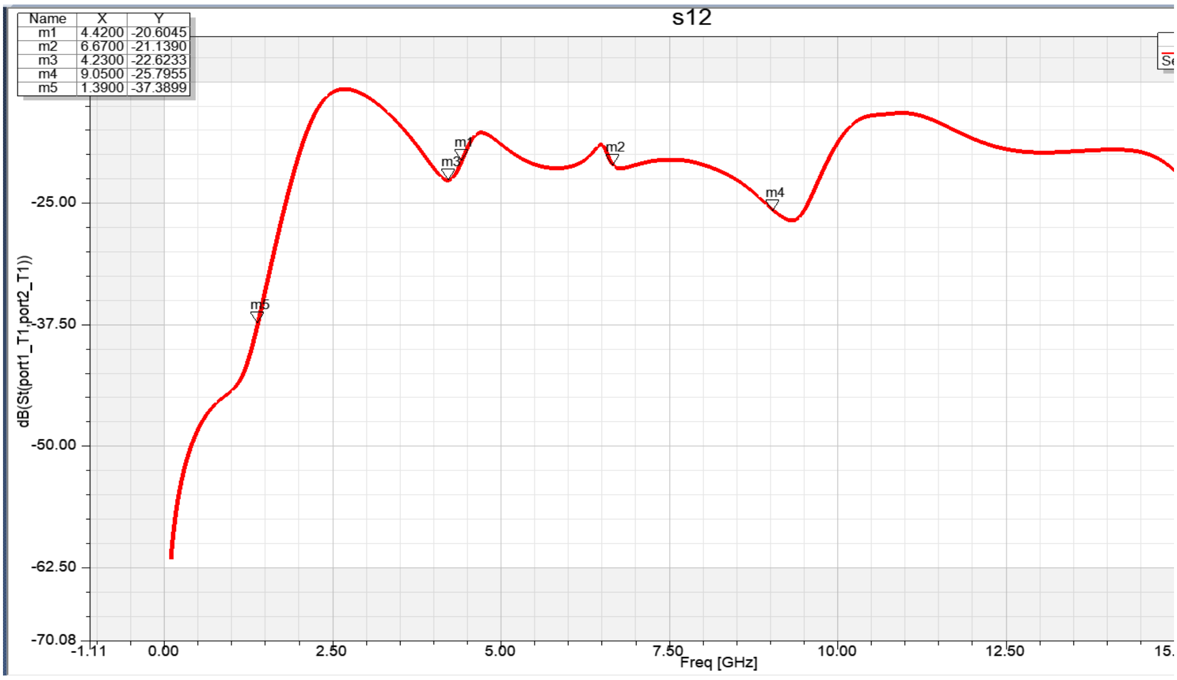

Figure 3: Transmission Coefficient

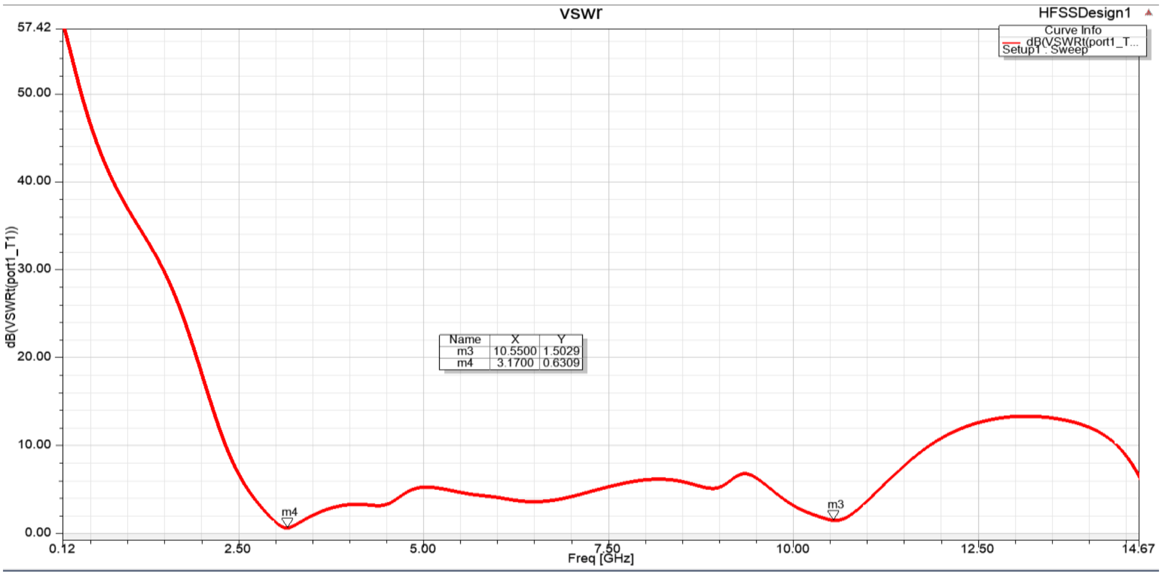

Figure 4: VSWR

The simulated graphs of radiation patterns are shown in Figure 5,6. This measurement of radiation patterns are done by choosing the lowest value of return loss frequency for the better E and H plan patterns. Here the angle theta is taken consideration to view the radiation pattern over the frequency range. Here the Radiation patterns are in isotropic in nature and omnidirectional in pattern. The maximum gain of designed antenna is observed as 3.14dB.

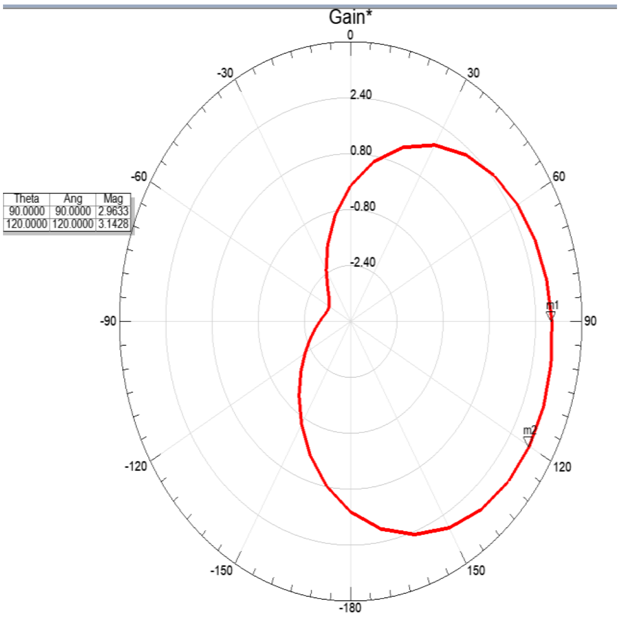

Figure 5: Gain

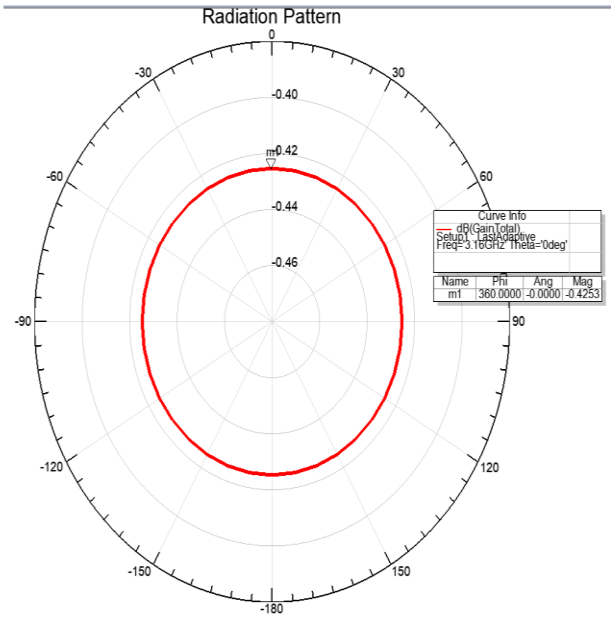

Figure 6: Radiation Pattern

In MIMO antenna system Gain Diversity plays major role. It is calculated using Envelope Correlation Coefficient(ECC). Using S parameters the measurement of Gain Diversity is done. In this design the gain diversity is almost 9.9, according to MIMO antennas it must be nearly equal to 10. So the satisfied results are obtained. But some fluctuations are observed in between the 2GHz to 12GHz frequency range, it is due to some internal reflections in the antenna components.

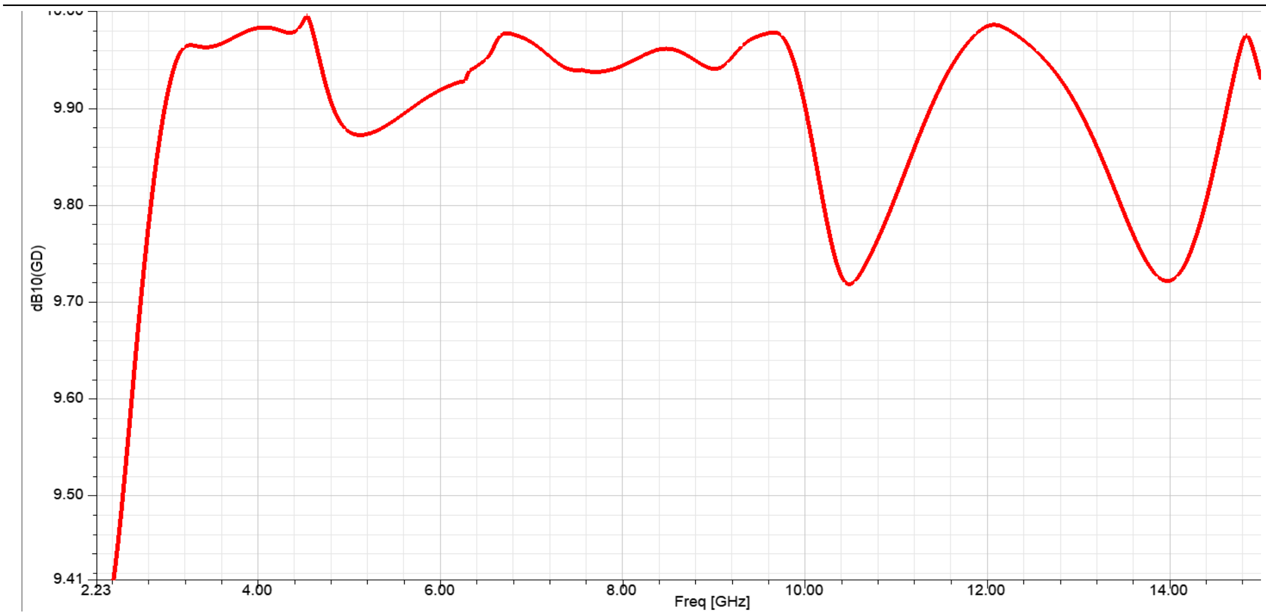

Figure 7: Gain Diversity

V. CONCLUSION

A proposed F-structured 2x2 UWB MIMO antenna is designed for lower 5G applications. The main applications of lower 5G bands are Internet of Things(IoT) and also Wi-Fi based devices. So for this requirement UWB technology based antenna is designed for both UWB and lower 5G applications. The proposed antenna results satisfies the UWB applications with return loss of -29dB at 3.16GHz and -21.29dB at 10.56GHz. And the maximum Gain at 3.16GHz is 3.12dB. In MIMO antennas Gain Diversity is most important parameter, so for this design the gain diversity is nearly 10 and radiation pattern of this antenna is isotropic. The designed prototype of the MIMO antenna system and its simulated model's findings have been found to be in good agreement.

VI. REFERENCES

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