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Gain Enhancement of Uwb Mimo Antennas Using A High Isolation Technique

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Abstract: *Antenna diversity is an important technique for modern wireless communication systems. By employing multiple-antennas, effects such as multi-path, small-scale fading as well as co-channel interference, can be reduced. Furthermore, the system's capacity can be increased significantly by using multiple–antenna However, for compact devices, mutual coupling between antenna elements may become severe due to their small distance. In order to improve the isolation between array elements, several scenarios have been proposed. Two truncated square monopoles orthogonally and symmetrically printed on ground plane to improve the isolation. A slot is placed on the ground plane to reduce the mutual coupling between two radiators. Three stubs are introduced to achieve spatial diversity.In this project, a novel diversity antenna for UWB applications is proposed. Two square shaped monopoles are employed to achieve wideband performance. The 10dB return loss bandwidth of the antenna ranges from3.1GHz to 10.6GHz. In order to improve the isolations between the two radiators, a T stub is employed. The antenna design is accomplished by using EM simulator IE3D. As reported, the isolation between the two ports is higher than 39dB within 3.3GHz to 10.4GHz, stable omnidirectional radiation patterns with gain flatness of about 3dBi over the entire frequency rangearealsoobtained*

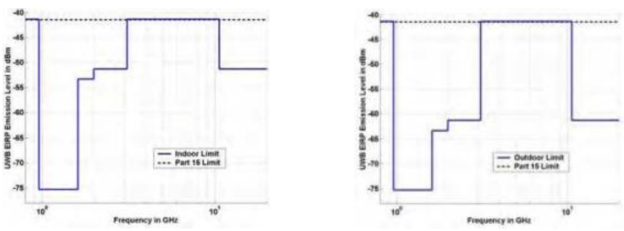
I. Introduction

ULTRA WIDE BAND

In 2002, the Federal Communications Commission (FCC) of the United State officially released the regulation for Ultra-wideband (UWB) technology. In this regulation, the spectrum from 3.1 GHz to 10.6 GHz is allocated for the unlicensed indoor UWB wireless communication system. According to the released regulation, UWB technology which is based on transmitting ultra-short pulses with duration of only a few nanoseconds or less has recently received great attention in various fields for the short-distance wireless communications. Because of the ultra-wideband property,UWB technology has many benefits, which are high data rate, low power consumption, compact, low cost, excellent immunity to multipath interference and reduced hardware complexity. Due to these advantages UWB system gets good attention in the field of wireless communication.[1]

UWB impact in daily life

UWB has the potential to eventually dominate every wireless "area network," from wireless personal area networks (WPANs) to wireless wide area networks (WWANs). In its current restricted state, UWB will most likely be the preferred technology for wireless personal area networks, replacing Bluetooth's 1-2Mbps bandwidth with 400-500Mbps data rate



(a) (b)

Fig.1.1. Spectrum mask of UWB for (a) indoor environments and (b) outdoor environment

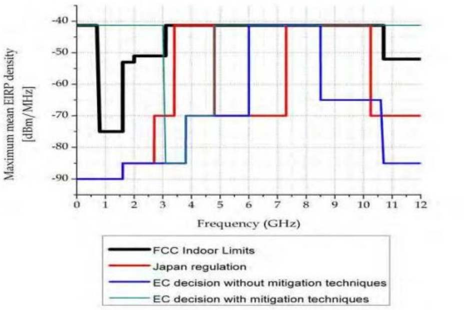


Fig.1.2 The worldwide spectrum masks for

UWB communication device

Applications of UWB
UWB applications are classified three major categories.
- Communications and sensors
- Position location and tracking
- Radar

Multiple-Input Multiple-Output (MIMO)

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 and optimize data speed all wireless products with 802.11n support MIMO, which is part of the technology that allows 802.11n to reach much higher speeds than products without 802.11n.

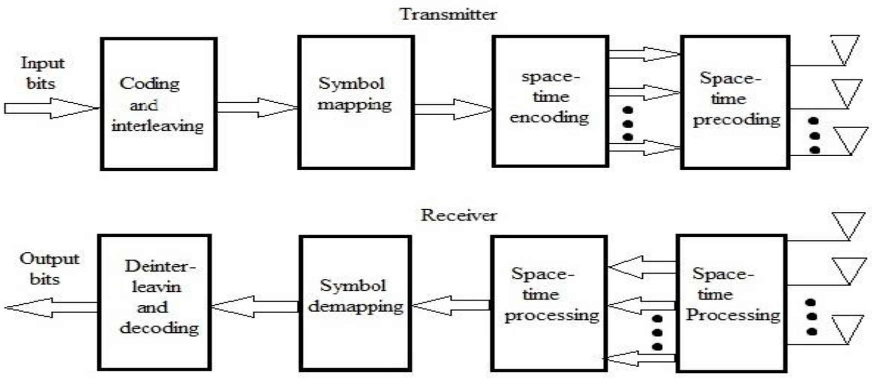


Fig 1.3 A typical MIMO system including the signal processing subsystem

MIMO technology takes advantage of a natural radio-wave phenomenon called multipath. With multipath, transmitted information bounces off walls, ceilings, and other objects, reaching the receiving antenna multiple times via different angles and at slightly different times. Which dramatically increase performance and range. [2]

Conventional Radio System (SISO)

Conventional systems use one transmit and one receive antenna. In

MIMO terminology, this is called Single Input, Single Output (SISO)

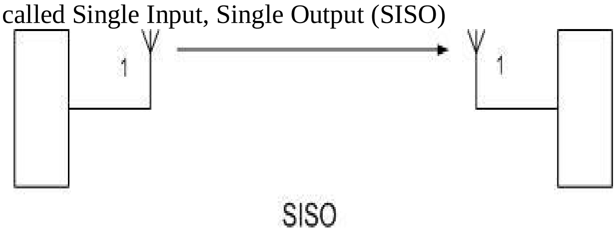


Fig 1.4 SISO antenna configuration

According to Shannon, the capacity C of a radio channel is dependent on bandwidth B and the signal-to-noise ratio S/N. The following applies to a SISO system:

$$C = B \log_2 \left(1 + \frac{S}{N} \right) \quad (1.1)$$

Multiple Antenna Systems

A MIMO system typically consists of m transmit and n receive antenna. By using the same channel, every antenna receives not only the direct components intended for it, but also the indirect components intended for the other antennas. A time-independent, narrowband channel is assumed. The direct connection from antenna 1 to 1 is specified with h_{11}, etc., while the indirect connection from antenna 1 to 2 is identified as cross component h_{21}, etc

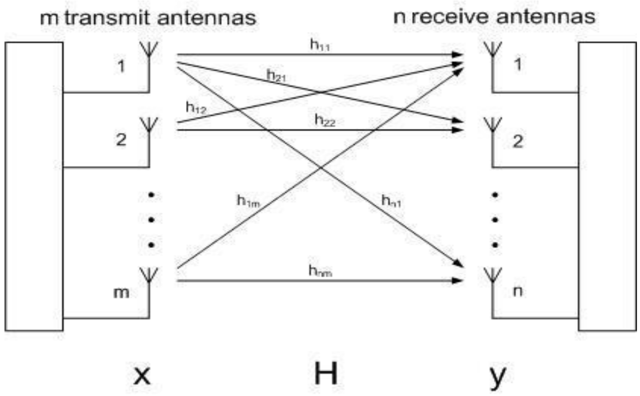


Fig 1.5: General MIMO

The following transmission formula results from receive vector y, transmit vector x, and noise n.

$$y = \mathbf{H}x + n \quad (1.2)$$

Data to be transmitted is divided into independent data streams. The number of streams M is always less than or equal to the number of antennas.
In the case of asymmetrical (m E n) antenna constellations, it is always smaller or equal the minimum number of antennas. For example, a 4x4 system could be used to transmit four or fewer streams, while a 3x2 system could transmit two or fewer streams. Theoretically, the capacity C increases linearly with the number of streams M.

Single User MIMO (SU-MIMO)

$$C = M B \log_2 \left(1 + \frac{S}{N} \right)$$

When the data rate is to be increased for a single UE, this is called

Single User MIMO (SU-MIMO)

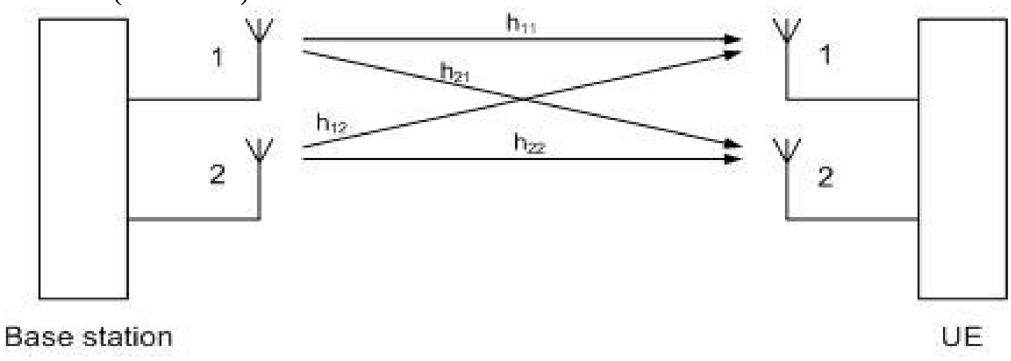


Fig 1.6: SU-MIMO

Multi User MIMO (MU-MIMO)

When the individual streams are assigned to various users, this is called Multi User MIMO (MU - MIMO). This mode is particularly useful in the uplink because the complexity on the UE side can be kept at a minimum by using only one transmit antenna. This is also called 'collaborative MIMO'.

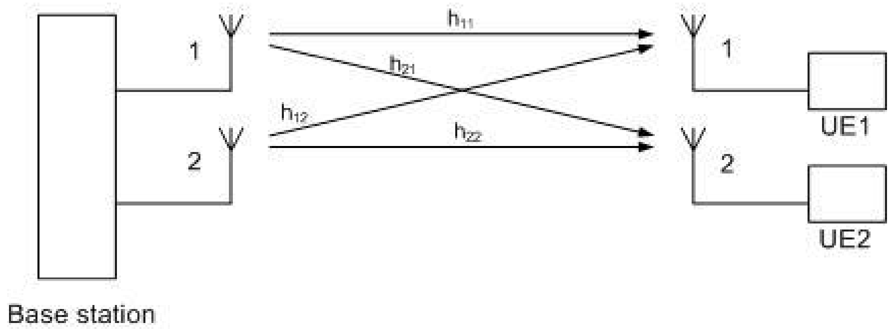


Fig1.7: MU-MIMO

Cyclic delay diversity (CDD)

CDD introduces virtual echoes into OFDM-based systems. This increases the frequency selectivity at the receiver. In the case of CDD, the signals are transmitted by the individual antennas with a time delay. Because CDD introduces additional diversity components, it is particularly useful as an addition to spatial multiplexing.

Spatial Diversity

The purpose of spatial diversity is to make the transmission more robust. There is no increase in the data rate. This mode uses redundant data on different paths.

RX Diversity

RX diversity uses more antennas on the receiver side than on the transmitter side. The simplest scenario consists of two RX and one TX antenna (SIMO, 1x2).

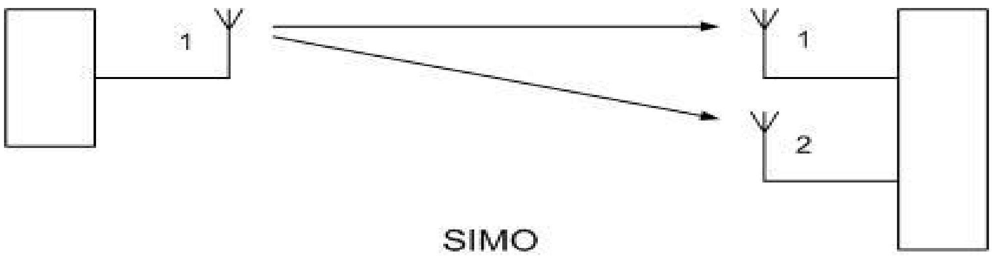


Fig 1.8 SIMO antenna configuration

Because special coding methods are not needed, this scenario is very easy to implement. Only two RF paths are needed for the receiver. Because of the different transmission paths, the receiver sees two differently faded signals. By using the appropriate method in the receiver, the signal-to- noise ratio can now be increased. Switched diversity always uses the stronger signal, while maximum ratio combining uses the sum signal from the two signals.

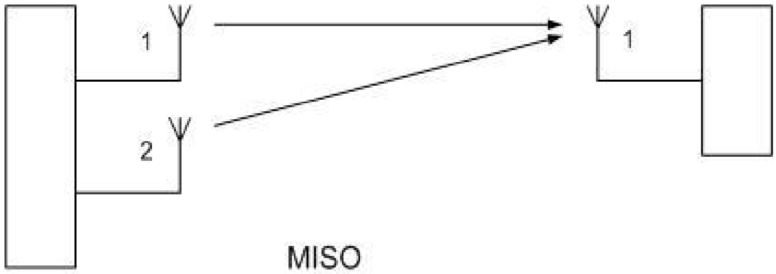


Fig 1.9: MISO antenna configuration

To generate a redundant signal, space-time codes are used. Alamouti developed the first codes for two antennas. Space-time codes additionally improve the performance and make spatial diversity usable. The signal copy is transmitted not only from a different antenna but also at a different time. This delayed transmission is called delayed diversity. Space-time codes combine spatial and temporal signal copies as illustrated in Figure 8. The signals s_1 and s_2 are multiplexed in two data chains. After that, a signal replication is added to create the Alamouti space-time block code.

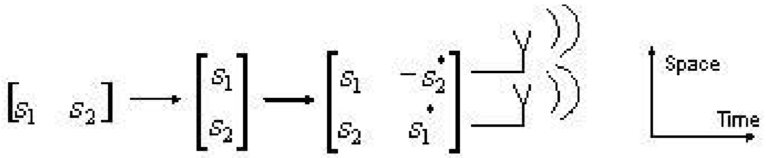


Fig1.10: Alamouti coding

Additional pseudo-Alamouti codes were developed for multiple antennas The coding can also be handled in the frequency domain. This is called Space-frequency coding.

Spatial Multiplexing

Spatial multiplexing is not intended to make the transmission more robust rather it increases the data rate. To do this, data is divided into separate streams the streams are transmitted independently via separate antennas.

Because MIMO transmits via the same channel, transmissions using cross components not equal to 0 will mutually influence one another. If transmission matrix H is known, the cross components can be calculated on the receiver. In the open-loop method, the transmission includes special sections that are also known to the receiver. The receiver can perform channel estimation. In the closed- loop method, the receiver reports the channel status to the transmitter via a special feedback channel. This makes it possible to respond to changing circumstances.

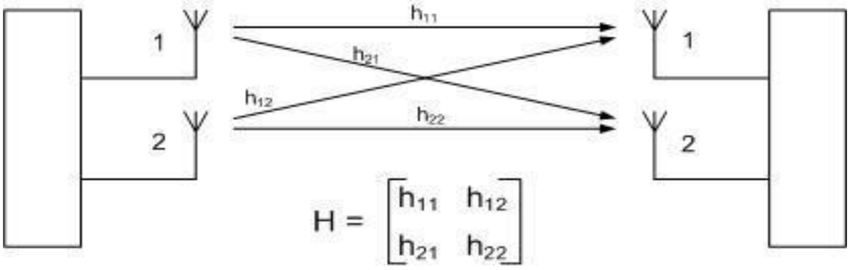


Fig1.11:MIMO2x2antennaconfiguration

3.7 COMPARISON BETWEEN THE HIGH ISOLATION TECHNIQUES

TECHNIQUE	ISOLATION (in dB)	RADIATION PATTERN (wrt H-plane)	BANDWIDTH (in GHz)	GAIN VARI-ATION (in dBi)	SIZE (in mm^2)
Inverted-Y shaped stub	15	Omnidirectional	3.1-10.6	< 2.5	40×68
Fork Shaped Structure	17	Omnidirectional	4.4-10.7	< 2.5	40×68
Cantor set Fractal UWB antennas	20	Omnidirectional	4.5-10.6	< 2.5	40×68
Stepped Impedance Resonators	23	Omnidirectional	3.1-10	< 2	35×40
Closely-packed UWB MIMO diversity antenna	26	Omnidirectional	3.1-5.15	< 2	48×25
T-shape slot	44	Omnidirectional	2.4-2.48	< 2.5	40×68
Multiple Ground slits	12	Omnidirectional	0.7	< 2.5	60×100
Tree like structure	20	Omnidirectional	3.1-10.6	< 3.1	35×40

Table 3.1 comparison between the high isolation techniques

Proposed method

DESIGN ENVIRONMENT

HFSS is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modeling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modeling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are quickly and accurately obtained.

Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, andbrilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to calculate parameters such as SParameters, Resonant Frequency, and Fields.

Typical uses include:

Package Modeling - BGA, QFP, Flip-Chip

PCB.Board.Modeling -Power/Ground planes, Mesh Grid

Grounds, Backplanes Silicon/GaAs - Spiral Inductors, Transformers EMC/EMI - Shield Enclosures, Coupling,
Near- or Far Field Radiation

Connectors - Coax, SFP/XFP, Backplane, Transitions
Waveguide - Filters, Resonators, Transitions, Couplers Filters - Cavity Filters,
Microstrip, Dielectric Antennas/Mobile -Patches, Dipoles, Horns, Conformal Cell
Communications Phone Antennas, Quadrifilar Helix,

Specific Absorption Rate (SAR), Infinite Arrays, Radar Cross Section (RCS), Frequency Selective Surfaces (FSS)
HFSS is an interactive simulation system whose basic mesh element is a tetrahedron. This allows you to solve any arbitrary 3D geometry, especially those with complex curves and shapes, in a fraction of the time it would take using other techniques.

The name HFSS stands for High Frequency Structure Simulator. Ansoft pioneered the use of the Finite Element Method (FEM) for EM simulation by developing/implementing technologies such as tangential vector finite elements, adaptive meshing, and Adaptive Lanczos-Pade Sweep(ALPS). Today, HFSS continues to lead the industry with innovations such as Modes-to-Nodes and Full- Wave Spice.

Ansoft HFSS has evolved over a period of years with input from many users and industries. In industry, Ansoft HFSS is the tool of choice for high-productivity research, development, and virtual prototyping

ANTENNA DESIGN

Objectives and Challenges

Taking a little overview of UWB and MIMO, it makes easier to understand the idea of implementing MIMO technique in UWB communications systems. As per FCC rules, extremely low power is being allowed to be transmitted i.e. –41.3 dBm/MHz and it impedes the development of UWB communication systems with higher data rates or covering longer distances.

To overcome this bottleneck, MIMO technique has been considered to be one of the solutions that Will improve the reliability and the capacity of UWB systems. However, a number of challenges arise to shape this solution physically. In this project, will take the challenges into account related to antennas as their properties play a key role in determining MIMO system performance.

In context of UWB where the whole band approved by FCC is required to be covered in one shot, the design of antenna becomes challenging enough. The characteristics of the antennas are required to be stable for the wide frequency band. Moreover, time domain measurements like dispersion and group delay become significant in addition to conventional frequency domain characteristics. Furthermore, the development of future UWB-MIMO communication systems brings more challenges for the antenna design. MIMO antennas are required to be characterized for mutual coupling, correlation and diversity gain.

However, a detailed study on characterization of MIMO antennas for UWB is among the current hot topics of research. Also, the design of UWB- MIMO antenna system is always confronted with the same constraints like cost, size, ease of fabrication and integration with other circuits as in the case of single antenna design.

Existing Antenna Parameters

A compact diversity antenna for Ultra-wideband applications which is composed of two square monopoles and to reduce the mutual coupling between the two elements, A T shape stub is introduced. The antenna is designed on a dielectric substrate with relative permittivity of 2.65, loss tan of 0.001 and thickness h=1mm. The antenna consists of two square radiators and a T stub is placed between them on the ground. The characteristic impedance of the microstrip feed line is designed as 50Ohm. The size of the antenna is 62mm×45mm. The monopoles edge l=13mm, the distance between them is 36mm. The T stub is with parameters of h1= 9mm, w=3mm, s=10mm. The ground plane is 62mm×24mm.

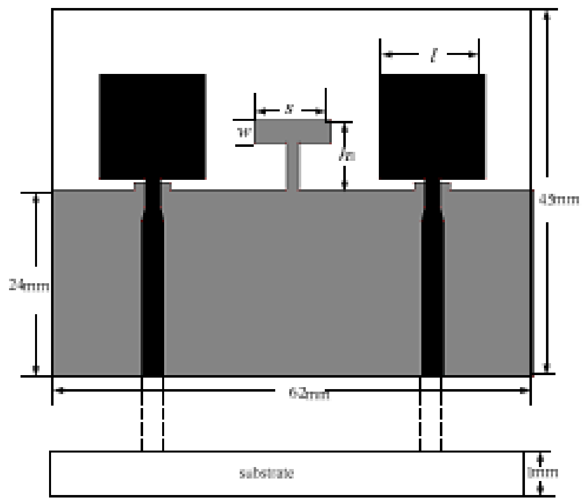


FIG 5.1: Schematic Diagram of the Existing Antenna

5.3 Antenna Design Procedure Using HFSS

- Substrate is created and Taconic TLX(tm) material is assigned.
- To achieve UWB bandwidth generally the ground plane is designed to be partial rather than full ground plane. Hence, Partial Ground plane is made.
- Boundary has to be assigned to the ground plane in order to define it as a perfectly matched conductor. So the ground plane is assigned Perfect E boundary.
- Two radiator monopole antennas of above dimensions are created and assigned Perfect E boundary.
- To reduce the mutual interference between the radiator elements some stubs has to be placed in between them. In this existing antenna a T- shape Stub is used and it is placed between the antennas.
- Two feeds are placed between the ground plane and 2 monopole antennas and assigned its excitations as wave port.
- The centre frequency has to be defined and also the range of frequency for which the design has to be performed. Solution setup and Adaptive sweep is defined in the analytical step.
- In order to validate whether the given excitations and boundaries does not overlap validation check is done.
- Analysis all is performed if no overlap exists after the validation check.
- The results are analysed by plotting various graphs.
- Result includes rectangular plot, radiation pattern, 3D polar plot, 3D rectangular plot

HFSS view of the existing antenna

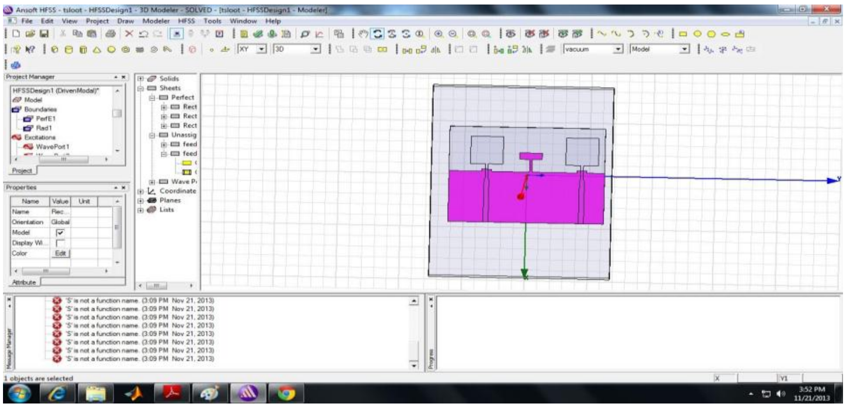


FIG 5.2: Existing Antenna Designed in HFSS

II. Simulated Results

Based on the above design the simulation is performed and various plots are plotted using the various parameters like S-parameter, total gain, phi values. The various plots are 2D rectangular plot, radiation pattern, polar plot, 3D rectangular plot. The characteristics of these plots are studied and analysed.

2D Rectangular Plot

The effects of the stub to the mutual coupling between the two ports is significant because it is observed that the isolation characteristic may be improved significantly by inserting a T stub above the ground plane. The isolations between the two ports are sensitive to the stub the h1, the height of the stub. The optimized h1 is 9 mm. The 2D rectangular plot is shown in FIG
5.3. The rectangular plot gives an idea about the isolations between the two port. To plot this graph the S-parameter is used. S_12 parameter against the different frequencies is plotted. The UWB bandwidth ranges from 3.3-10.4
GHz. This designed antenna operates well in the UWB band and throughout this bandwidth the isolation obtained is over 35 dB. This isolation shows that the mutual interference between the radiator antennas will not affect each other. There are two peaks obtained, one at 36.2 dB and another at 37.4 dB. So the highest isolation obtained is 37.4 dB.

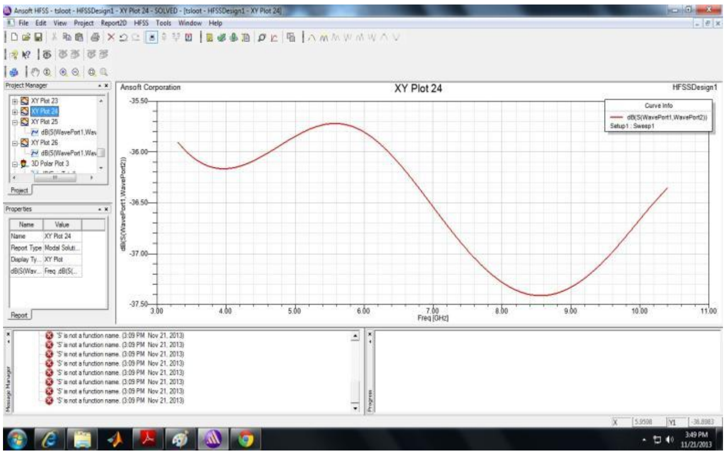


FIG 6.1: 2D Rectangular Plot showing the isolation between the antenna elements

Radiation Pattern

The radiation pattern of this existing antenna is plotted. The radiation pattern is a three dimensional plot of its radiation at far field. The radiation pattern gives the directional dependence of radio waves strength. To obtain the radiation pattern total gain in dB and the various values of phi is plotted. The phi value varies from 0 to 360 degree. FIG 5.4 shows the radiation pattern for various phi values. From the plot it is clear that omnidirectional pattern is obtained.

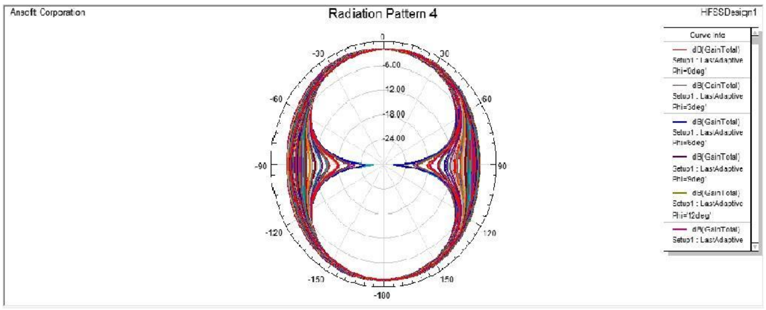


FIG 6.2: Radiation pattern for various phi value

Polar Plot

The polar plots are most popular because they provide a better visualization of the radiation distribution in space. The part of the linear graph that is used to construct the polar plot is determined by the radius of the circle and the relative position of its center along the abscissa. The usable part of the linear graph is referred to as the visible region and the remaining part as the invisible region. Only the visible region of the linear graph is related to the physically observable angle θ.

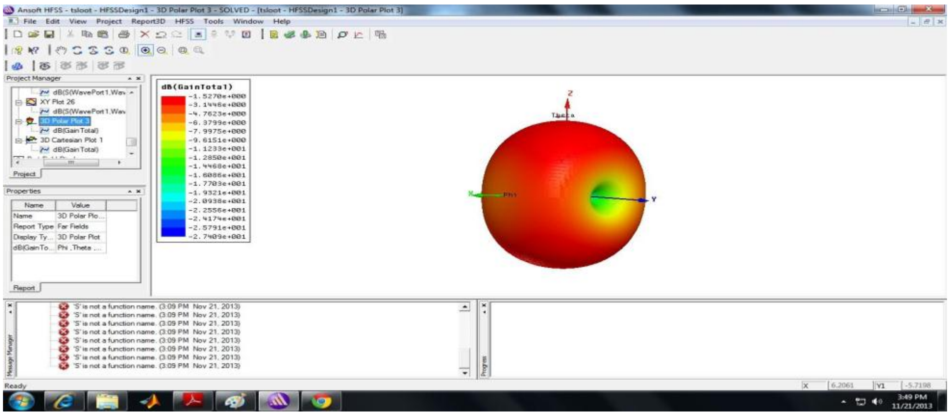


FIG 6.3: Polar Plot

3D Rectangular Plot

To understand about the current distributions between the radiator antenna elements generally 3D Rectangular Plots are used. It also gives an idea about the total gain as we have found out in polar plot. The current distributions near the radiator2 are much smaller than those in the antenna without the stub. As is shown, the current on the stub is strong. This arrangement reduces the mutual coupling and increases isolation between the two monopoles. FIG 5.6 shows the 3D Rectangular Plot.

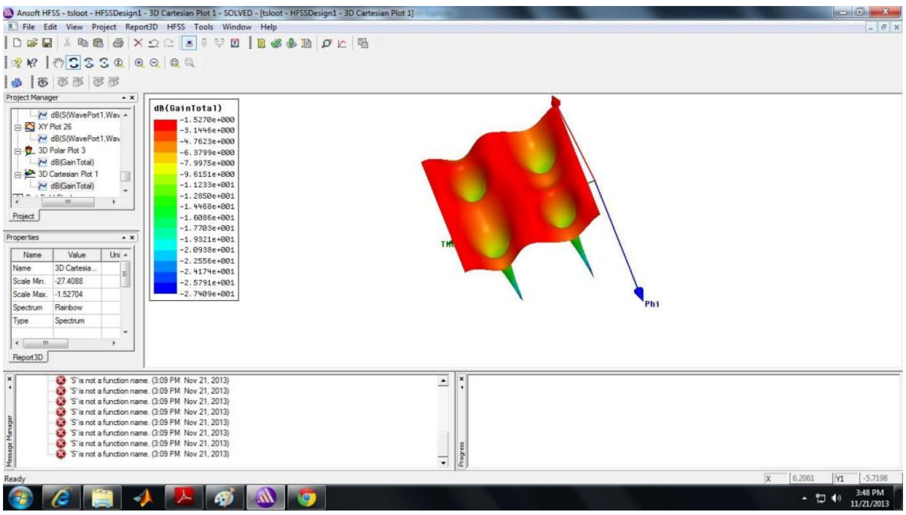


FIG 6.4: 3D Rectangular Plot

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