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Design of Hexagonal Multi Input Multi Output Antenna for Ultra-Wide Band Applications

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Abstract:

MIMO technology has become very popular in a wireless communication system (i.e.) Multiple antennas at the transmitting end and Multiple antennas at the receiving end. It becomes popular because through MIMO systems, higher data rate and higher reliability and higher bandwidth can be achieved. It uses spatial multiplexing technique diversity techniques. The disadvantage of RF modules is the cost of that systems. In this paper, the antenna selection technique based on required direction is proposed. This minimizes the cost of MIMO systems. A system of size 40 mm × 36 mm with two hexagonal monopole elements with 'L' shaped slots is proposed. Ultra-wide band (UWB) is achieved by a semi-circular shaped Defected Ground Structure (DGS) and the shape of the DGS is optimized to get good return loss. Simulations are done with HFSS simulation software. Simulated results show that the MIMO antenna with DGS has less than 10 dB return loss from 5.6 GHz to 12 GHz. The parameters like return loss, gain, radiation pattern and VSWR (Voltage Standing Wave Ratio) are simulated and analyzed.

I. INTRODUCTION

HEXAGONAL MIMO ANTENNA

UWB is a recent technology for information exchange with large bandwidth providing high data rates and low power consumption. Federal Communication Commission authorized the use of 3.1 to 10.6 GHz for unlicensed. Multiple inputs and multiple output (MIMO) system transmit the same power using multiple antennas at the transmitter and receiver thereby increasing the channel capacity without the need of additional bandwidth or power. MIMO systems are considered as an extension of antenna array to improve channel capacity, spectral efficiency and multipath fading.

Many researchers have been working on various MIMO system with some radiating elements and various methods are employed to improve isolation between elements. Different kinds of Electromagnetic Band Gap structures and defected ground plane structures have been proposed to reduce the mutual coupling. Numerous methods have been proposed to improve the bandwidth. Defected ground structure is one of the methods to improve the bandwidth. It is a purposefully created defect on the ground plane of a printed microstrip board. It is typically created in the form of an etched-out pattern on the ground plane. The disturbance at the shielded current distribution will influence the impedance and the current flow of the antenna.

MIMO Antenna are be classified depending on their physical parameters. Multi-antenna MIMO (or single-user MIMO) technology has been developed and implemented in some Standards. Single User Single Output (SISO)/ Single User Multi Output (SIMO)/ Multi Input Single Output MISO are special cases of MIMO. Multiple-input single-output (MISO) is a special case when the receiver has a single antenna. Single-input multiple-output (SIMO) is a special case when the transmitter has a single antenna Single-input single-output (SISO) is a conventional radio system where neither transmitter nor receiver has multiple antennas.

1.1 Advantages of MIMO Antenna

The MIMO antenna has wide applications and few are listed below:

1. Beam steering – MIMO offers the opportunity to electronically guide the directivity of the RF signal by controlling the signal propagating phase over multiple antennas.
2. Increased data capacity
3. The higher data rate can be achieved with the help of multiple antennas and SM (Spatial Multiplexing) technique. This helps in achieving higher downlink and uplink throughput.
4. There is lower susceptibility of tapping by unauthorized persons due to multiple antennas and algorithms.

5. The wide coverage supported by MIMO system helps in supporting large number of subscribers per cell.
6. The MIMO based system is widely adopted in latest wireless standards viz. WLAN

1.2 DISADVANTAGES OF MIMO ANTENNA

Through MIMO antenna provides variety of applications it lags with few properties and are listed below:

- The resource requirements and hardware complexity are higher compare to single antenna- based system. Each antenna requires individual RF units for radio signal processing. Moreover, advanced DSP chip is needed to run advanced mathematical signal processing algorithms.
- The hardware resources increase power requirements. Battery gets drain faster due to processing of complex and computationally intensive signal processing algorithms. This reduces battery lifetime of MIMO based devices
- MIMO based systems cost higher compare to single antenna-based system due to increased hardware and advanced software requirements.

1.3 APPLICATION

Hexagonal MIMO antenna operating at frequency of 7.5 GHz application for UWB application especially for security purposes. Normally UWB antennas have been used in mobiles so that if someone enters the home or trying to open the lock, the notifications will be popped up in the mobiles. Now with the help of Hexagonal MIMO antenna with defected ground structure there is more speed in transmission of data which is most important characteristics in wireless communication. With the help of this antenna when placed in mobile phones will convert 2D space into grid format such that it is more helpful in specifically spotting the lost item in the room for ex: car keys, chain, rings etc.

The objective of the paper is to design hexagonal MIMO Flexible antenna and determine the parameters such as (i)Directivity (ii). S- parameter (iii) Gain value at E and H planes (iv) VSWR (v) Radiation pattern (vi). Radiation pattern. MIMO techniques ensure a significant boost in the efficiency of wireless systems. MIMO systems are considered as an extension of antenna array to improve channel capacity, spectral efficiency and multipath fading.

II. LITERATURE SURVEY

Sharawi et al. [1] discussed the design of a novel dual-band 4-shaped printed multiple-input- multiple-output (MIMO) antenna system of two elements. This antenna is designed and fabricated for Long Term Evolution (LTE) wireless handheld and portable terminals. It covers the low frequency band 803-823 MHz, and the high frequency band 2440-2900 MHz. Isolation between the two elements was more than 17 dB in the low band after using a defected ground plane structure (DGS) between the two antenna elements. The overall size of the printed MIMO antenna system was $50\times 100\times 1.56\ mm^3$.

Mc.Hbal et al.[2] proposed a design of a compact MIMO antenna with a small size of $26*37.48*0.8\ mm^3$ is proposed for polarization and spatial diversity applications. The antenna consists of two planar-monopole antenna elements printed on one side of a FR-4 substrate. The antenna elements are placed side by side a distance D from each other for the first configuration and perpendicularly placed for the second configuration with a separated ground plane. Simulation results show that the proposed MIMO antenna configurations have a bandwidth range from 4.3 to 10.6 GHz and 4.4 to 10.4 GHz with a low mutual coupling of less than -10 dB and -25 dB for the first and the second configurations, respectively.

Misra et al.[3] discussed about the design of a simple, low-cost, and compact printed dual-band fork-shaped monopole antenna for Bluetooth and ultra-wideband (UWB) applications is proposed. Dual-band operation covering 2.4-2.484 GHz (Bluetooth) and 3.1-10.6 GHz (UWB) frequency bands are obtained by using a fork-shaped radiating patch and a rectangular ground patch. The proposed antenna is fed by a 50-Ω micro strip line and fabricated on a low-cost FR4 substrate having dimensions $42 \times 24 \times 1.6$ mm. The antenna structure is fabricated and tested. Measured 11is ≤ -10 dB over 2.3-2.5 and 3.1-12 GHz. The antenna shows acceptable gain flatness with nearly omnidirectional radiation patterns over both Bluetooth and UWB bands.

Mandal et al. [4] discussed a new compact defected ground structure (DGS) is proposed for the micro strip line. The structure is compact in micro strip line direction. Here, this DGS is used to design a compact low pass filter (LPF) that is at least 26.3% more compact lengthwise than other reported compact structures and has sharper transition knee. Chouhan et al. [5] presented the isolation improving with coupling structure, placed between two close antennas. The proposed geometry with series of hexagonal cut and ground slot reduces the size of antenna and shift the frequency band.

Proposed antenna worked on dual frequency 2.4 and 5.2 GHz. Enhancement in isolation and return loss found with coupling structure whereas gain and bandwidth are slightly decreased. Coupling element cancels the value of surface current from antenna1 to 2 and vice versa.

III. PROPOSED DESIGN ANALYSIS

The proposed structure is shown in Figure 1. Two hexagonal units and defected ground structures are combined. While simulating an antenna, the radiation boundary should be positioned in such a way, that it is quarter the wavelength away from the surface of radiation. Feeding is given at the bottom of two hexagonal units.

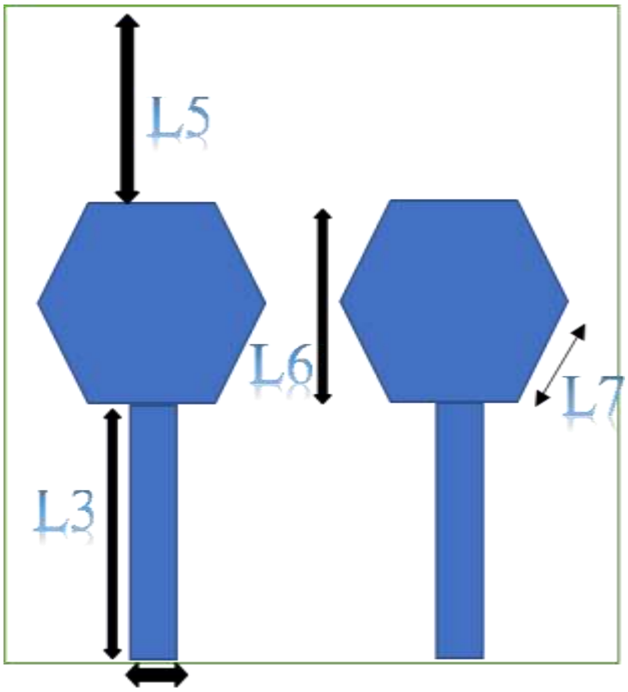


FIGURE 1: Hexagonal MIMO antenna

ANTENNA DESIGN FORMULAS

Individual antenna cells are designed with the following equations. Width of the antenna is calculated by

$$W = \frac{C_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

The effective dielectric constrant used for calculating effective length is determined as follows :

$$\varepsilon_{reff} = \frac{1+\varepsilon_r}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad (2)$$

Extended length ΔL can be calculated from

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad (3)$$

From this extended infinitesimal length, length of the patch can be given as

$$L = \frac{C_0}{\sqrt{\varepsilon_{reff}}2f_r} \qquad (4)$$

Where L- Length of patch; W- Width of patch; h- Height of substrate

LENGTH OF SUBSTRATE(Lg):

$\boldsymbol{Lg}$=6h+L (5)

WIDTH OF SUBSTRATE (Wg):

$\boldsymbol{Wg}$=6h+W (6)

According to this, dimensions of antenna is determined as given in Table 1.

Table 1: Antenna Specification table

Design Parameters	**Dimensions(mm)**
Length of patch(L6)	12.2mm
Width of patch(L7)	6mm
Length of substrate(L1)	40mm

Width of substrate(L2)	36mm
Dielectric thickness	1.6mm
Frequency of operation	7.5GHz
Length of feed(L3)	16.6mm
Width of feed(L5)	3mm

IV. RESULTS AND DISCUSSION

The following parameters are required to design a rectangular microstrip patch antenna. The antenna output is determined by several antenna factors which are also referred to as antenna properties, defined and estimated for the MIMO antenna as follows

Antenna gain

Power gain is defined in terms of ratio of radiated intensity of an antenna in a particular direction at a random distance to the radiated intensity by an isotopic antenna at the same distance. A high gain antenna is normally unidirectional or emits radiation in a specific direction on the other hand the low gain antenna emits radiation equally in all directions. Gain can also be given by,

Gain = Directivity × Efficiency **(7)**

Table 2: Frequency vs Gain

Frequency(GHz_)	PEAK GAIN(dB)
7.5	3.529
8.5	2.981
9	3.17
10	3.308
12	5.18

Directivity

Directivity of an antenna is given by the ratio of the maximum intensity of radiation to the average intensity of radiation. Maximum intensity of radiation means power per unit solid angle and average intensity of radiation means average over a sphere. Directivity is given by

D=4πU/Pradiated **(8)**

Table 3: Frequency vs Directivity

Frequency (GHz_)	DIRECTIVITY (dB)	DIRECTIVITY BW(DEGREES)
7.5	4.275	88.83
8.5	3.803	84.17
9	4.44	76.86
10	4.501	85.35
12	6.47	91.91

Voltage Standing Wave Ratio (VSWR)

Usually, VSWR = $\frac{V_{max}}{V_{min}}$. Different VSWR values are given in Table 4.

Table 4: Frequency vs VSWR

Frequency(GHz_)	VSWR (dB)
7.5	0.2523
8.5	1.3802
9	1.3983
10	1.308
12	1.53

Return loss

Return loss is the power loss in the signal that is reflected or returned in a transmission line or optical fiber by discontinuity. RL (dB) is the return loss in terms of dB

RL (dB)=10 log $\frac{P_{in}}{P_{out}}$ (9)

Pin is the incident power

$Pref$ is the reflected power

Table 5: Frequency vs return loss

Frequency (GHz)	RETURN LOSS (dB)
7.5	-36.77
8.5	-22.061
9	-21.90
10	-22.47
12	-21.11

Bandwidth

The antenna's bandwidth refers to the range of frequencies where the antenna can function efficiently. The bandwidth of the antenna is the amount of Hz at which the antenna experiences an SWR less than 2:1. Bandwidth is proportional to frequency. If bandwidth was expressed in absolute units of frequency, it would be vary depending on the frequency of center. Different antenna types have varying limits on bandwidth. The bandwidth can also be defined in terms of percentage of the center frequency of the band.

BW=$((FH - FL)/FC) \times 100$ **(10)**

Where ,

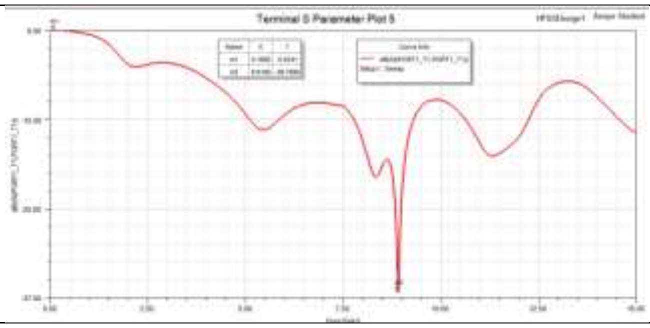
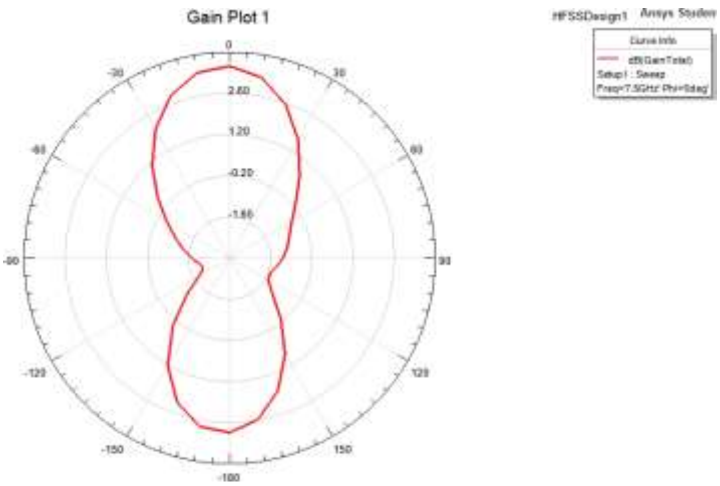
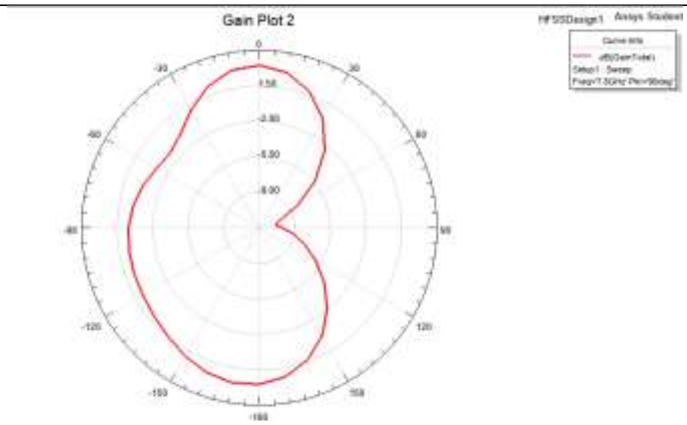
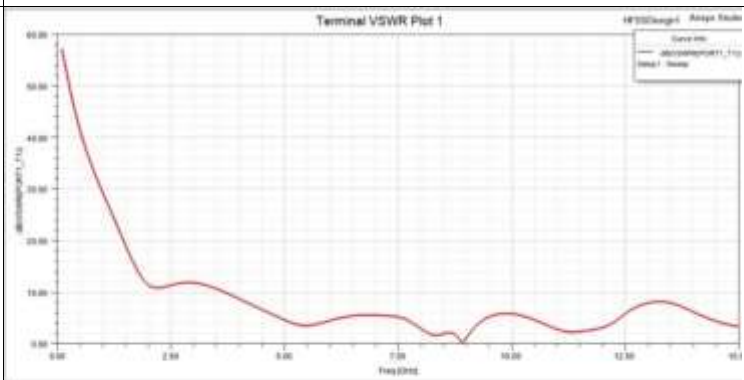
FH is the upper frequency in the band,

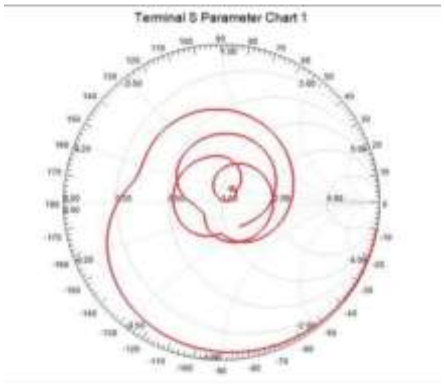
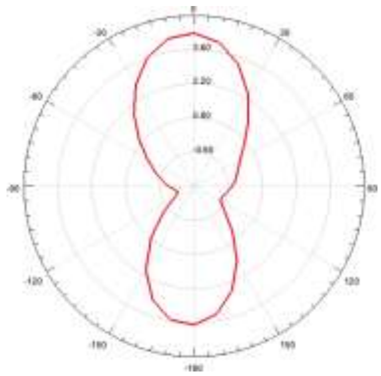
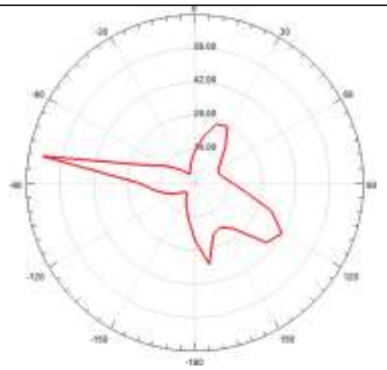
FL is the lower frequency in the band,

Fc is the center frequency in the band.

RESULT ANALYSIS FOR FREQUENCY OF 7.5GHz

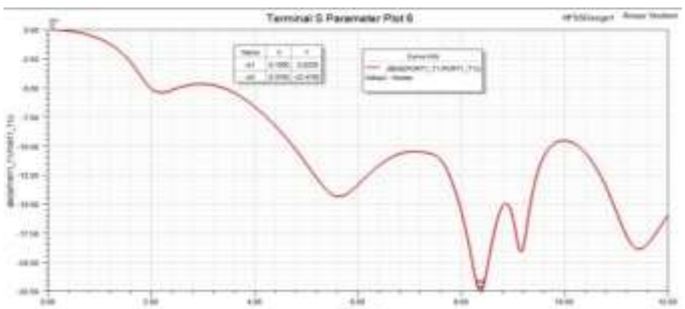
Table 6: Analysis at frequency of 7.5 GHz

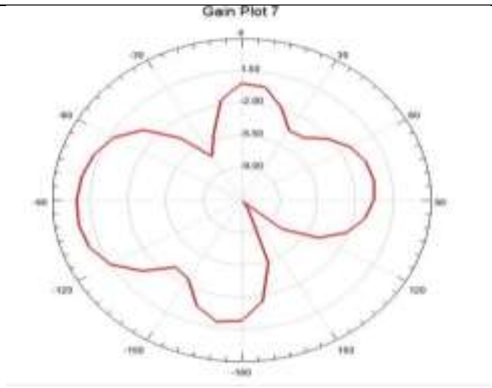
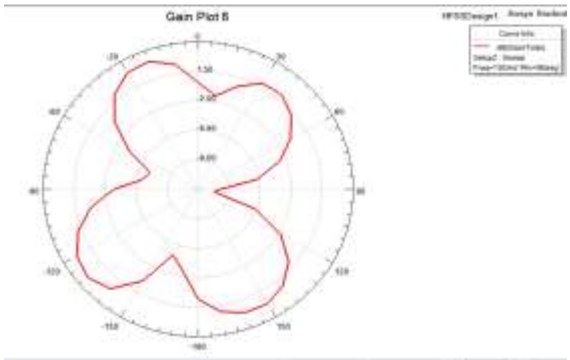
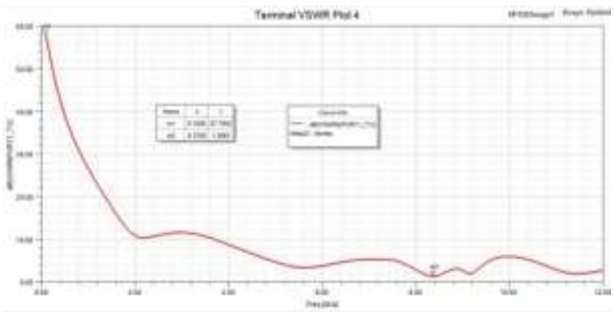
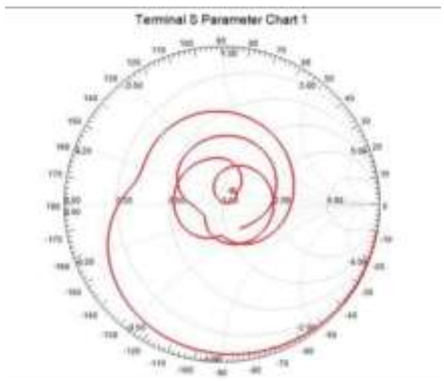
S-PARAMETER OR RETURN LOSS PLOT:	
RADIATION E PATTEN:	
RADIATION H PATTEN:	
VSWR	

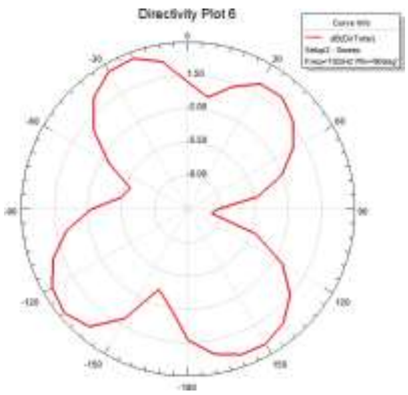
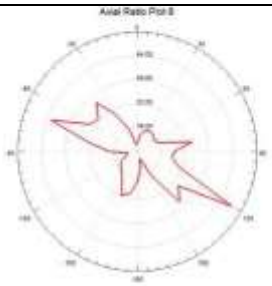
Smith chart	
Directivity	
Axial ratio	

RESULT ANALYSIS FOR FREQUENCY OF 10GHz

Table 7: Analysis at frequency of 7.5 GHz

S-PARAMETER OR RETURN LOSS PLOT:	

RADIATION E PATTEN:	
RADIATION H PATTEN:	
VSWR	
Smith chart	

Directivity	
Axial ratio	

From the above table, H-pattern BW is 42.71 degree. radiation E-pattern BW is 85.35 degree; The gain obtained is 3.308 dB. The VSWR obtained by our proposed antenna at the frequency 10 GHz is 1.308 dB. The directivity is 85.35 dB at 10GHz. All the parameters analysis for different frequencies are given in Table 8.

Table 8: COMPARISON TABLE OF ANTENNA PARAMETER FOR DIFFERENT FREQUENCIES:

FREQUENCY (GHz)	**RETURN LOSS (dB)**	**VSWR (dB)**	**RAD- E PATTERN BW(DEG)**	**PEAK GAIN (dB)**	**RAD-H PATTERRN BW(DEG)**	**RP (dB)**	**DR (dB)**	**DRBW (DEG)**
7.5GHz	-36.77	0.2523	88.834	3.529	60.027	-21.14	4.275	88.83
8.5GHz	-22.061	1.3802	84.17	2.981	64.19	-20.93	3.803	84.17
9GHz	-21.90	1.3983	76.86	3.17	64.39	-21.72	4.44	76.86
10GHz	-22.47	1.308	85.35	3.308	42.71	-22.04	4.501	85.35
12GHz	-21.11	1.53	91.92	5.18	164.5	-21.75	6.47	91.92

- RETURN LOSS OBTAINED FROM S-PARMETER MODEL
- RAD-E PATTEREN-RADITION E PATTERN OBTAINED BY PLOTTING GAIN AT DEGREE 0
- RAD-H PATTEREN-RADITION E PATTERN OBTAINED BY PLOTTING GAIN AT DEGREE 90
- RAD-E PATTEREN BW- RADITION E PATTERN BANDWIDTH
- RAD-H PATTEREN BW- RADITION H PATTERN BANDWIDTH
- RP-RADIATED POWER

- DR-DIRECTIVITY
- DRBW-DIRECTIVITY BANDWIDTH
- DEG-DEGREE

5. CONCLUSION:

This paper presents the techniques to enhance the capacity of channel in MIMO systems. A system of size 40 mm × 36 mm (l*w) with two hexagonal monopole elements with L shaped slots is proposed. The UWB operation is achieved by a semicircular shaped Defected Ground Structure (DGS) and the shape of the DGS is optimized to get good return loss. Simulations are done with HFSS software. Simulated results show that the MIMO antenna with DGS has less than 10 dB return loss from 5.6 GHz to 12 GHz. The parameters like return loss, gain, radiation pattern and VSWR are been analyzed and simulated using ANSYS HFSS software.

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