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Investigation Of Umbrella Shape With T-Slot Mimo Antenna On The Performance Of Defected Ground U-Shape Geometry For Uwb Applications

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Abstract: The application of multiple antennas for wireless communication systems has increased great interest during the last decade both in academia and industry. The idea of this work is to illustrate the competency of using a planar Electromagnetic Band-Gap (EBG) structure based on a truncated Frequency Selective Surface (FSS) grounded piece to this point. Acompressed Ultra-Wide-Band multiple_input multiple_output (UWB MIMO) umbrella shape antenna using T-slot with great isolation constructed on FR4 material is investigated in this paper. The working frequency band measured by this UWB MIMO antenna is 3.16 GHz – 12 GHz, and the isolation is kept above -36.77 dB in the whole analysis of frequency band. A parametric study of the variation has been carried out in the level of mutual coupling with respect to height of the wall has been carried outin both E and H-planes.

Keywords: Umbrella shape MIMO antenna, T-slot, Defected Ground U-shape stub, Mutual coupling, High isolation.

I. Introduction:

Antenna is one of the important elements in the RF system for receiving and transmitting signals from and into the air as medium. Without proper design of the antenna, the signal generated by the RF system will not be transmitted and no signal can be detected at the receiver [1]-[5]. Moreover, the present wireless communication systems may suffer from more challenges due to the increased demand of compact devices [6]-[7]. Therefore, both academiaand researchers put more effort in to developing various types of antennas for wireless communication systems in wide band applications.

Multiple_Input Multiple_Output (MIMO) systems using in the wireless communication with multiple antenna units in both transmitter and receiver shores can take assistance of multipath modules [8]-[10]. Mutual coupling is a fact that depends on the endwise array elements and deeply affects the radiation qualities of wireless communication systems [11]-[12]. To achieve low mutual coupling, high isolation between end-to-end radiating elements and also quashing the surface waves, numerous methods have been investigated [13]-[17].

In order to pick up the isolation of the planar array, various decoupling methods such as Defected_Ground_Slot (DGS) and parasitic elements structures have been introduced [18]- [21]. To meet the requirements of MIMO, the patch and ground dimensions are to be calculated. The FCC in US released the permitof 3.1 - 10.6 GHz electromagnetic spectrum for applications with low power emission in 2002 [22], Recent trend in wireless communication technology demands compressed UWB MIMO compatible antennas with portable devices that can be used to improve the capacity and link quality [23]. Ultrawideband (UWB) system merged with MIMO technology can provide data rates more than 1 Gb/s [24]-[26].

A compact geometrical parameter that effects the novel umbrella shaped proposed design performance with low mutual coupling and great isolation is presented in this paper. The VSWR, reflection coefficient, S-parameters, mutual coupling, peak gain and radiation characteristics have been evaluated using HFSS software.

II. Antenna Geometry Design and Performance analysis:

To design antenna, the 'FR_4 epoxy' is used as a substrate material with a dielectric constant of 4.4, thickness 1.6 mm and dimensions of substrate are 20x30 mm for SISO and 35x40 mm for MIMO. The objective of this work is to improve the Gain and Efficiency on the performance of Umbrella shape with T-slot MIMO antenna compared to Single-Input Single-Output (SISO) antenna for UWB applications in the range 3.16 GHz to 10.6 GHz. And also, to diminish the mutual coupling amongst the two umbrella shape radiating elements with defected ground U-shape slot is inserted in amongst the monopole radiating elements.

2.1. Proposed Design Equations:

$$W_p = \frac{c}{2f_r\sqrt{\frac{\varepsilon_{r+1}}{2}}} \quad (1)$$

W_p − width of patch antenna

f_r − resonant frequency

$c = 3x10^8$ m/s

ε_r − relative permittivity

$$L_p = L_{eff} - 2\Delta L \quad (2)$$

L_p − length of patch antenna

L_{eff} − effective length of patch antenna.

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)+(\frac{W_p}{h}+0.264)}{(\varepsilon_{eff}-0.258)+(\frac{W_p}{h}+0.8)} \quad (3)$$

h − height of patch antenna

$$f_r = \frac{f_h + f_l}{2} \tag{4}$$

f_l − low frequency

f_h − high frequency

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + \frac{12h}{w_p}}} \tag{5}$$

ε_{eff} − effective permittivity of antenna

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} \tag{6}$$

$$W_s = 6h + W_p \tag{7}$$

$$L_s = 6h + L_p \tag{8}$$

Where,

W_s − width of substrate

L_s − length of substrate

h − height of patch antenna

2.2. Single-Input Single-Output (SISO):

In SISO technique only a single antenna sends the data and also only a single antenna is used to receive data at the receiving end. These are very easy to design and also have less cost. Butit is affected more in the presence of signal interference and fading which leads to poor efficiency. The following figure 1 depicts the structure of SISO antenna.

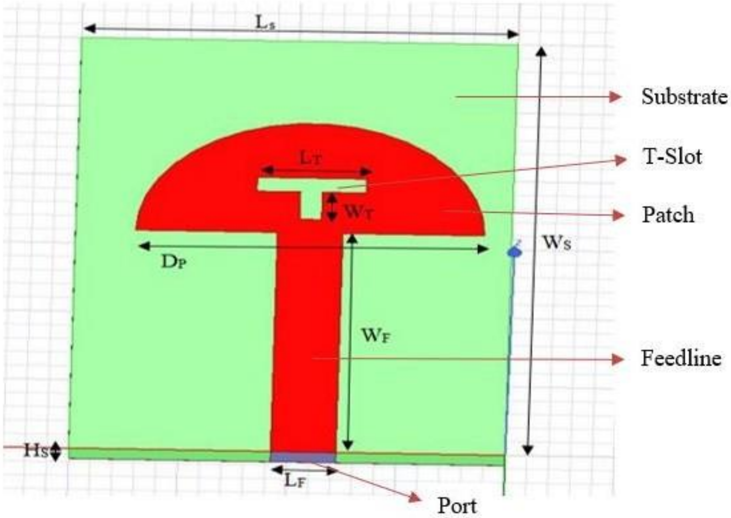

Fig.1: SISO antenna Design with T-Slot

The dimensions of antenna are depicted in the following Table-1.

Table-1: Dimensions of SISO antenna with T-shape slot

S. No.	Parameter	Symbol	Value (mm)
1.	Length of Substrate	L_S	20
2.	Width of Substrate	W_S	30

3.	Height of Substrate	H_S	1.6
4.	Diameter of Patch	D_P	16
5.	Length of Feedline	L_F	16
6.	Width of Feedline	W_F	3
7.	Length of T-Slot	L_T	5
8.	Width of T-Slot	W_T	2

2.3. Proposed MIMO antenna design:

In this, T-slot umbrella shape MIMO antenna is introduced, U-shape single stub is placed in the middle of the radiating elements to diminish the mutual coupling and the array is operated in the Ultra-Wideband (UWB) range of 3.10-10.60 GHz. The figure 2 depicts the Geometry of proposed MIMO array. The isolation between the radiating monopole umbrella shape with T-slot array is increased by changing the grated plane U-shape structure. Asevident from the figure 2 the geometry dimensions are reported in the table-2.

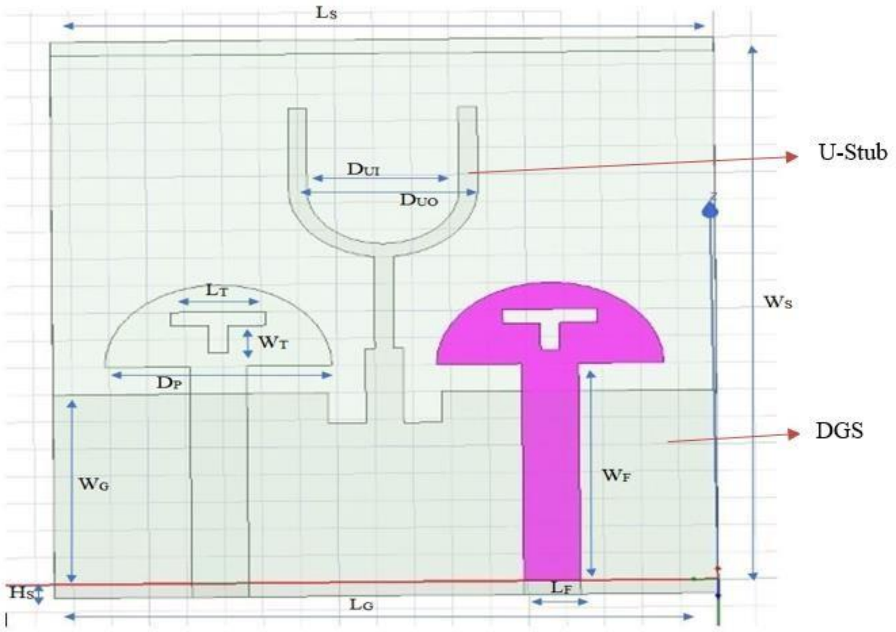

Fig.2: Proposed Umbrella shape with T-slot MIMO array Design using U-shape Stub

Table-2: Dimensions of MIMO antenna

S. No.	Parameter	Symbol	Value (mm)
1.	Substrate_Length	L_S	40
2.	Substrate_Width	W_S	35
3.	Substrate_Height	H_S	1.6
4.	Ground_Length	L_G	15
5.	Ground_Width	W_G	35
6.	Diameter of Patch	D_P	12
7.	Feedline Length	L_F	16

8.	Feedline Width	W_F	3
9.	Inside umbrella T-Slot Length	L_T	5
10.	Inside umbrella T-Slot Width	W_T	2
11.	Inner Circle Diameter of U-Stub	D_{UI}	4
12.	Outer Circle Diameter of U-Stub	D_{UO}	5

III. RESULTS AND DISCUSSIONS

In this present work, Ansys High Frequency Structure Simulator (HFSS) has been used significantly towards the performance of antenna simulations. The proposed monopole antennas are characterized by some of the parameters like Return loss, VSWR, radiation pattern, Smith Chart, Gain, Efficiency,3D Polar Plot etc.

S-Parameters

S-parameters describe the input-output relationship between ports (or terminals) in an electrical system. For example, if 2 ports (say Port 1 and Port 2), then S12 represents the powertransferred from Port 2 to Port 1.

3.1. Return Loss (S11):

It is the power of a signal reflected in a transmission line. It is a measure of how welldevices or lines are matched. It should be <= -10dB. Return loss shown in equation 9.

$$\text{Return Loss, RL}=10 \log (P_r/P_i) \tag{9}$$

Where P_r = Reflected power
P_i=Incident power

SISO: Return loss value is -8.0906 dB at operating in a single frequency 7.5 GHz shown infigure 3 which is undesirable for the antenna. Operating bandwidth of SISO antenna is 7.61-8.01 GHz i.e., 0.4 GHz.

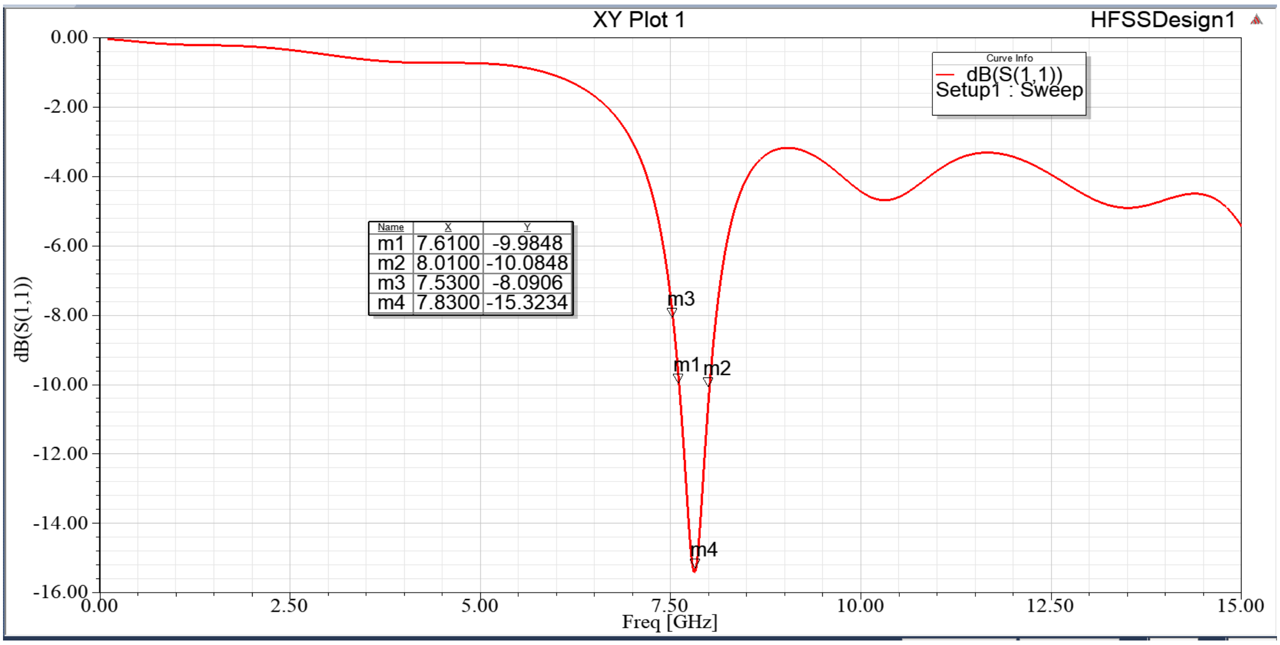

Fig.3: S_{11} Return Loss of SISO antenna

MIMO: The MIMO antenna shown in the figure 4 is operated in the UWB range which is 3.16-10.6 GHz. The values of return loss obtained are -18.3103 dB at 5.53 GHz, -25.1231 dB at 7.84GHz and -11.1990 dB at 10.19 GHz. The return loss value is maximum at 7.84 GHz frequencywhich is more desirable.

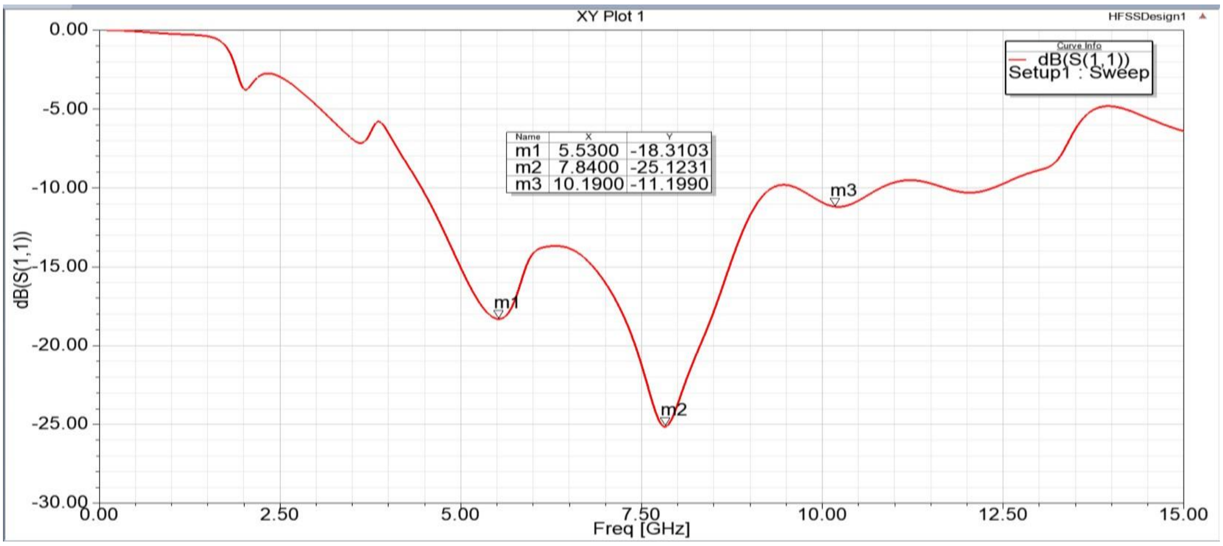

Fig.4: Return Loss of MIMO antenna

3.2. Isolation (S12):

SISO: In SISO only a single antenna is present so there is no scope for S12 plot only S11 exists.

MIMO: The isolation values are obtained at -32.7079 dB for 3.94 GHz, -23.2562 dB at 5.74

GHz, -31.744 dB at 6.77 GHz and -36.7792 dB at 9.57 GHz. Isolation is occurred maximum at 9.57 GHz frequency. It operated in the range of Ultra-wide band at 3.10-10.60 GHz frequency whichis shown in the figure 5.

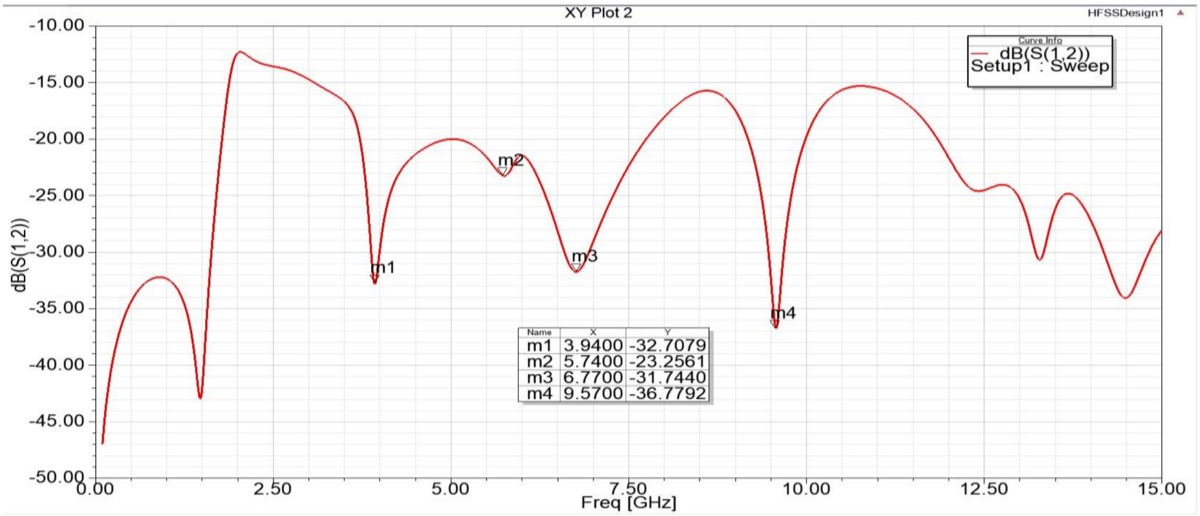

Fig.5: Isolation of MIMO antenna

3.3. VSWR:

SISO: The VSWR value at 7.5 GHz is 2.5079. VSWR should be 1 to 2 for perfect impedancematching. So, in SISO perfect impedance matching does not occur hence less power is produced to the antenna which is obtained in the figure 6.

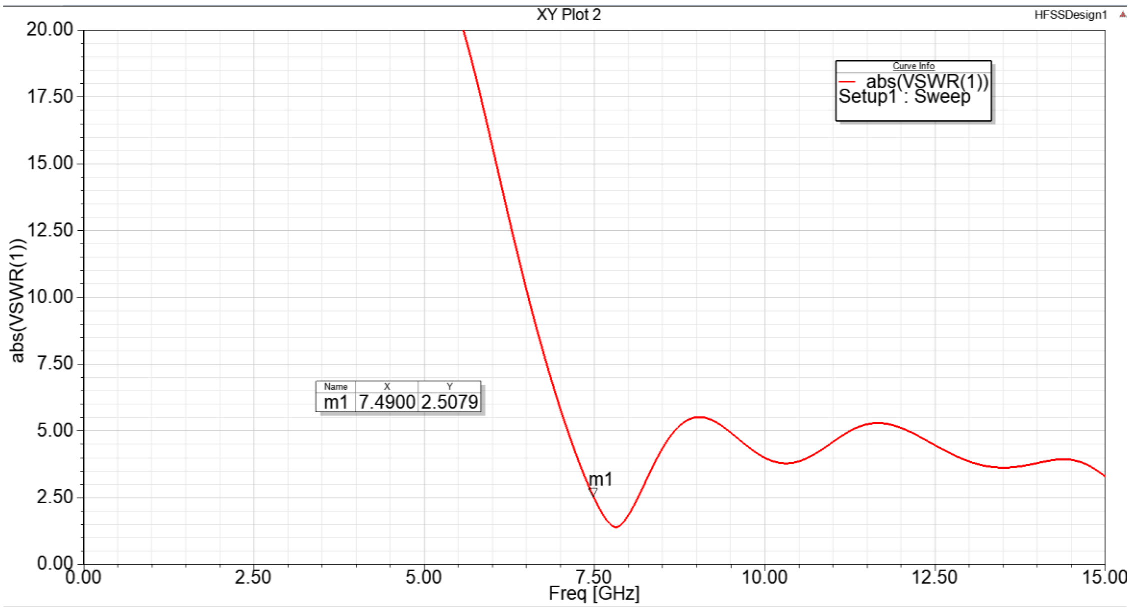

Fig.6: VSWR of SISO antenna

MIMO: The VSWR curve is depicted in figure 7 and the values are 1.1898 at 7.5 GHz and 1.8838 at 10.7 GHz. The MIMO antenna is perfectly matched hence more power is distributed to the antenna.

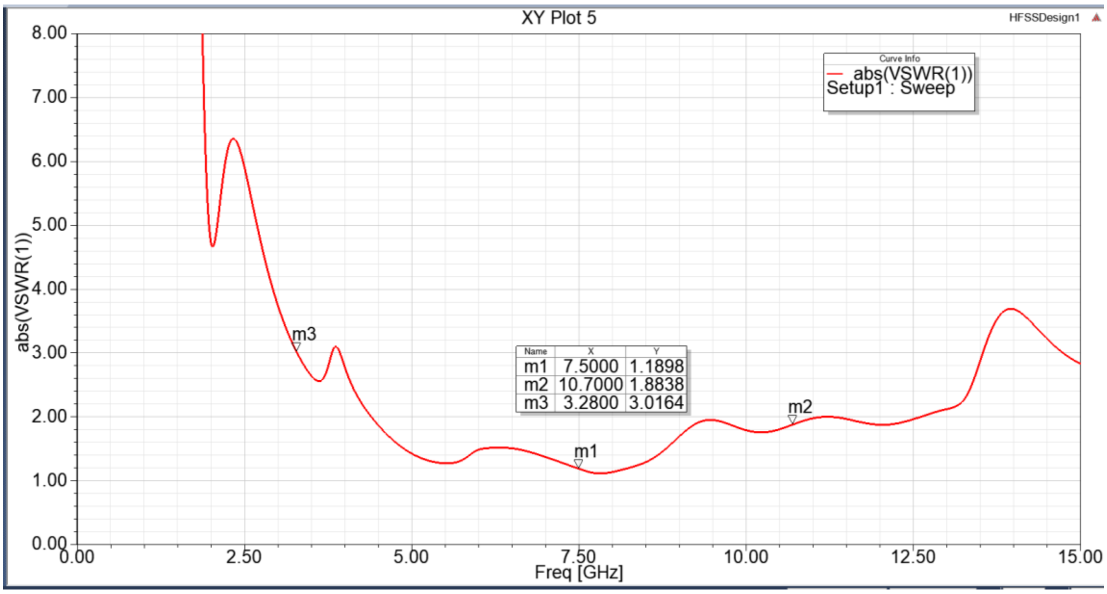

Fig.7: VSWR of MIMO antenna

3.4. Radiation Pattern:

SISO: The graph is plot between Gain vs Theta. The maximum Gain SISO antenna is 2.6711 dB which is very low, shown in the figure 8.

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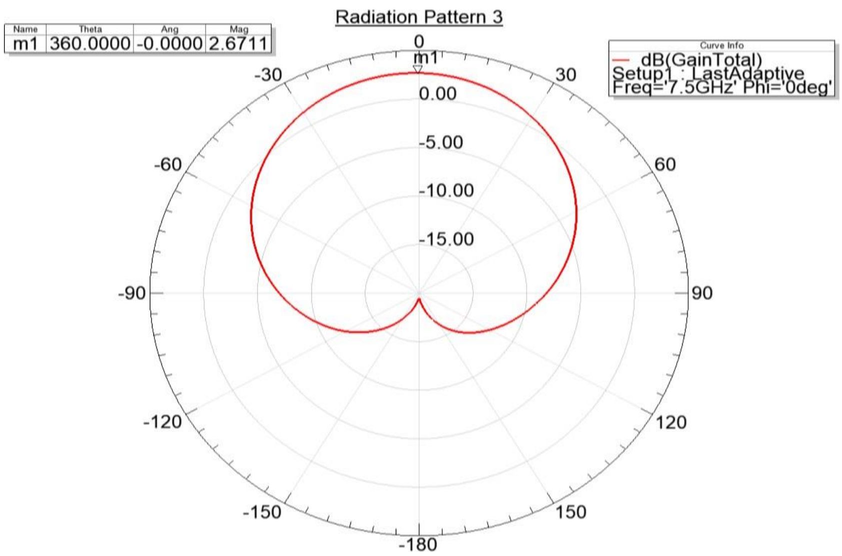

Fig.8: Radiation pattern of SISO antenna

MIMO: The maximum Gain of MIMO antenna obtained is 4.339 dB which is a desirable Gainfor an antenna is shown in the figure 9.

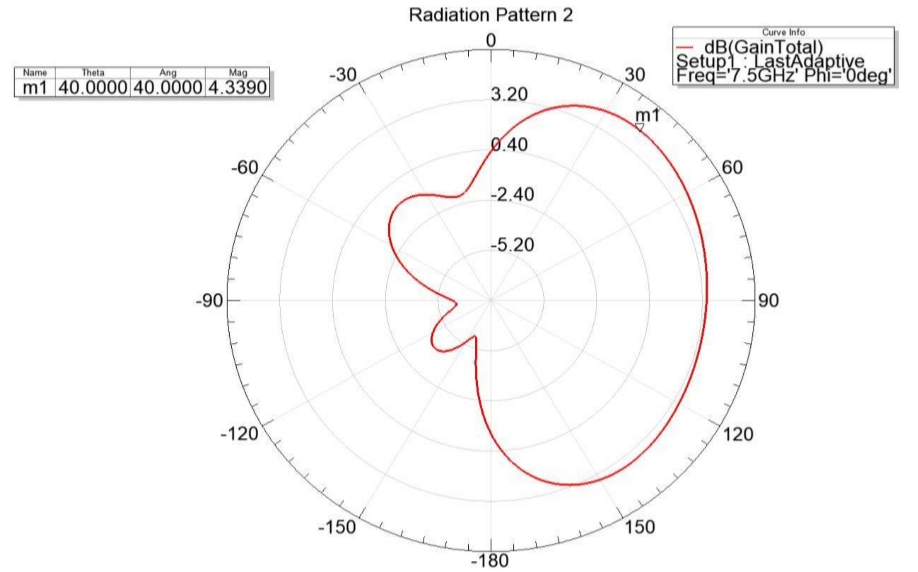

Fig.9: Radiation pattern of MIMO antenna

3.5. 3D Polar Plot:

SISO: The figure 10 shows a 3-Dimensional Gain plot at different azimuthal and elevation angles at 7.5GHz of frequency.

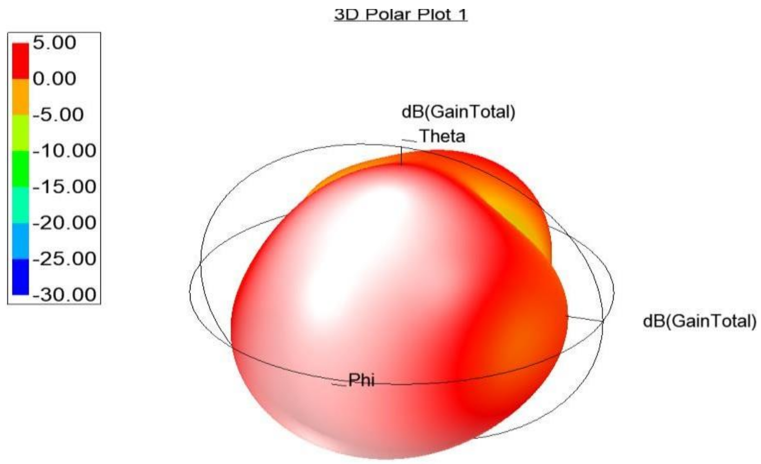

Fig.10: 3D Polar plot of SISO antenna

MIMO: the gain plot is depicted in the figure 11 at the frequency 7.5 GHz.

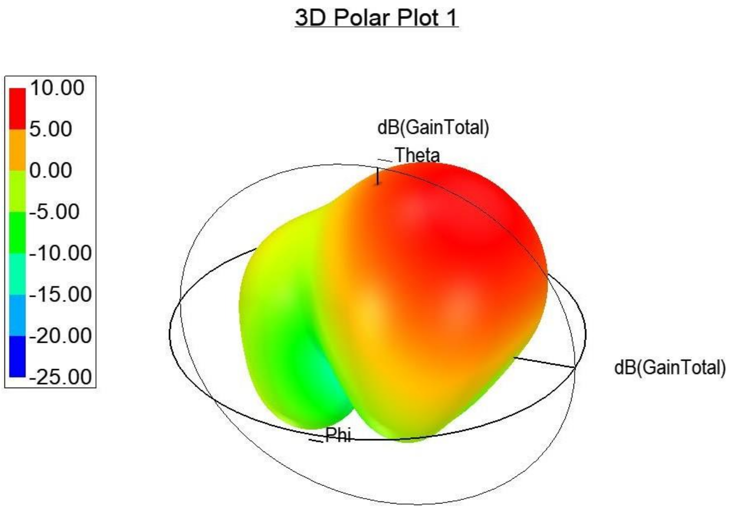

Fig.11: 3D Polar plot of MIMO antenna

3.6. E-Field and H-Field Distribution:

E-Field: The figure 12 reported the Electric field distribution and is obtained by solving Maxwell's equations under the given boundary conditions. It represents the position and magnitude of the maximum Electric field strength on the radiating Patch.

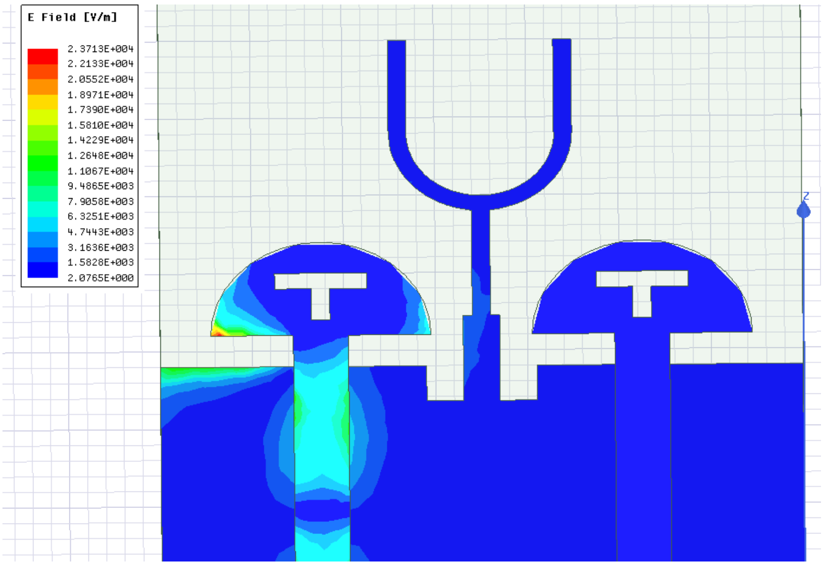

Fig.12: E-field Distribution of MIMO antenna

H-Field: It represents the strength of the maximum Magnetic field at different positionson the Radiating Surface and reported in the figure 13.

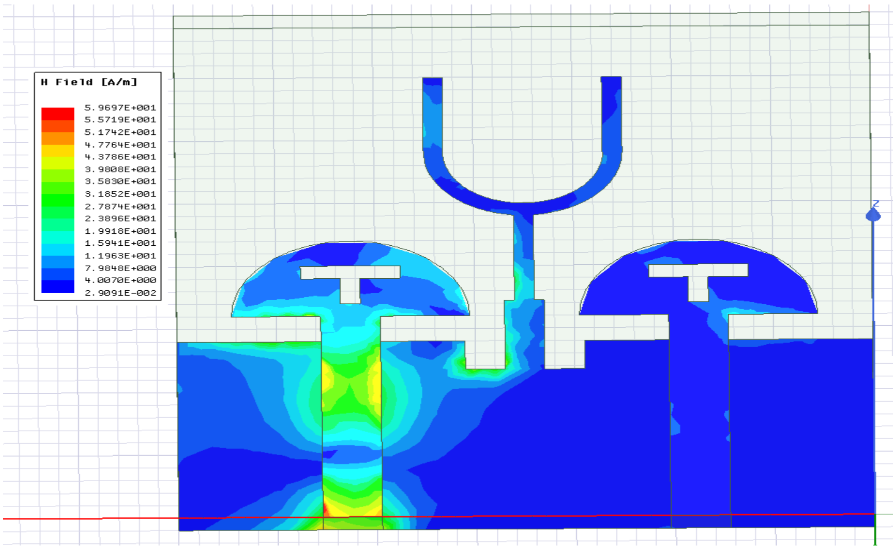

Fig.13: H-field Distribution of MIMO antenna

3.7. J-Surf Current Distribution:

If the entire rectangle is taken as Ground, then current will be distributed into the whole rectangle so there must be some power wasted. Here DGS is used, the current is distributed inthat region so power will be saved very less and low loss occurs, efficiency increases.

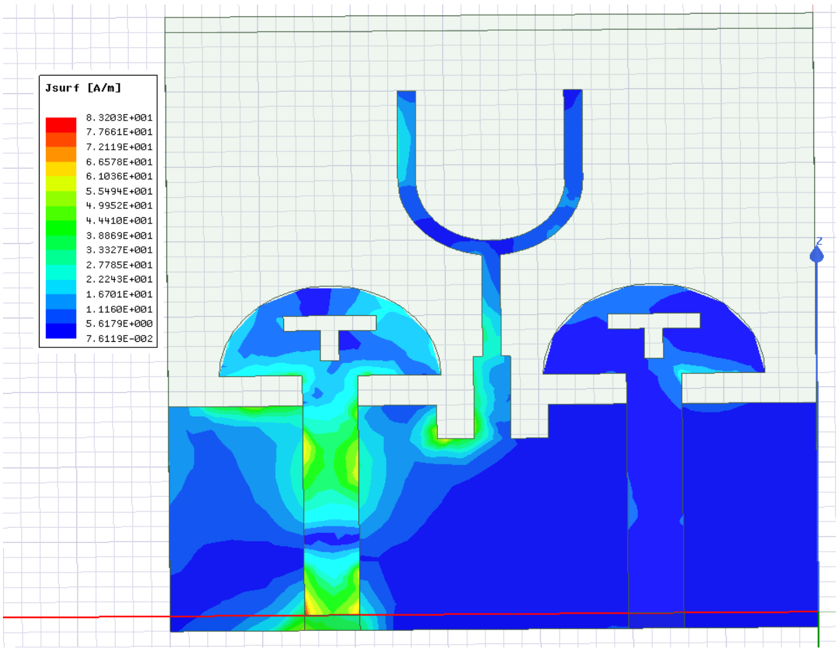

Fig.14: J-Surf Current Distribution of MIMO antenna

3.8. Smith Charts:

Smith charts are shown in the figures 15, 16 and 17 for analysing the impedance of a transmission line as a function of frequency and they are very helpful for impedance matching.Reflection coefficient is used to characterize the load.

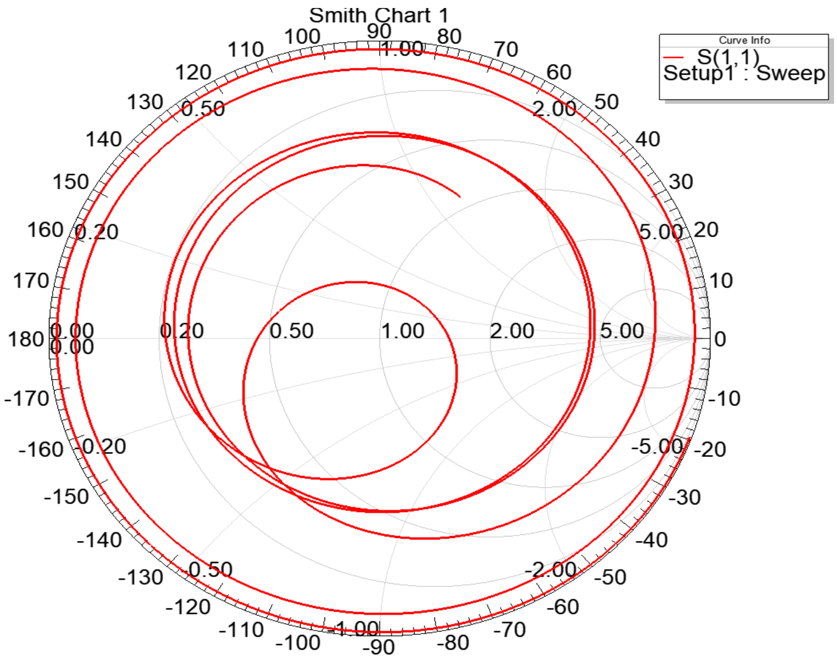

Fig.15: Smith Chart of SISO antenn

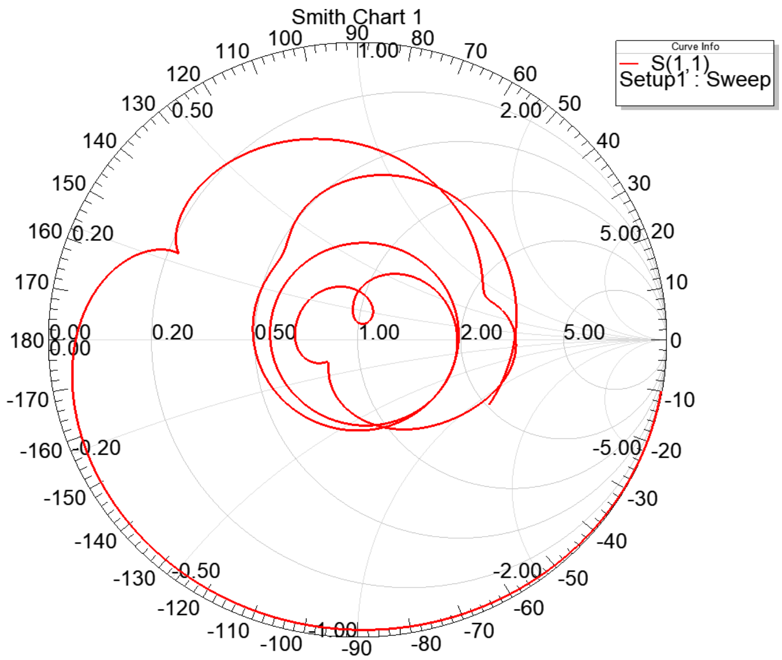

Fig.16: Smith Chart for S(1,1) of MIMO antenna

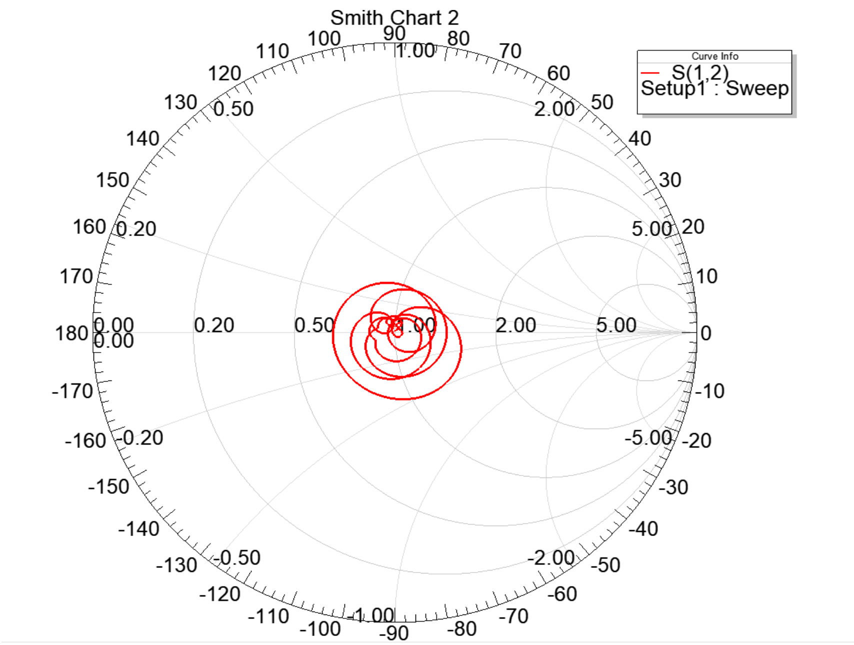

Fig.17: Smith Chart for S(1,2) of MIMO antenna

3.9. Antenna Parameters:

some of the proposed design MIMO array parameters are reported in the figures 18 and 19.

SISO: The Efficiency of SISO antenna is 59.876% which is very low and are depicted in the figure 18

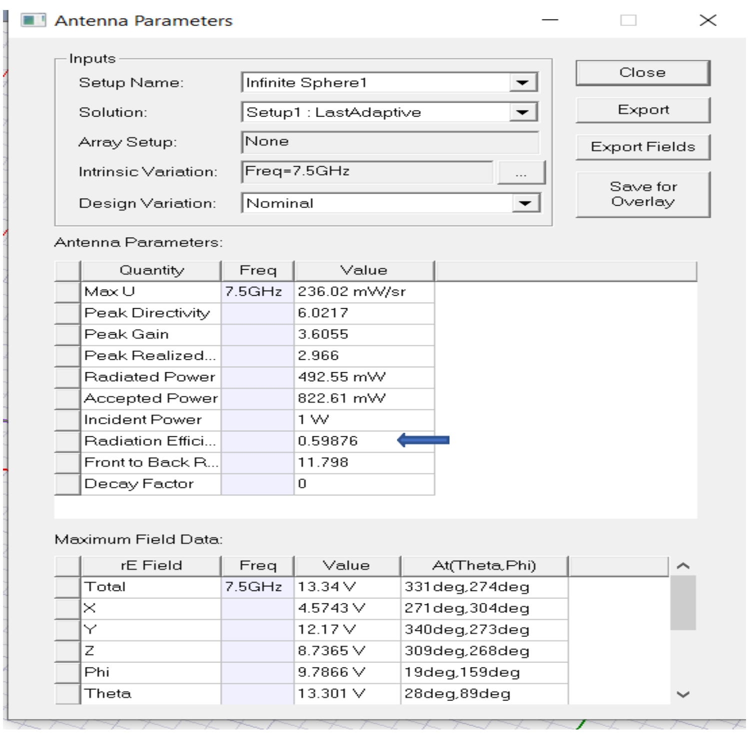

Fig.18: SISO antenna parameters

MIMO: The Efficiency of MIMO antenna is 88.594% which is very desirable for an antenna.

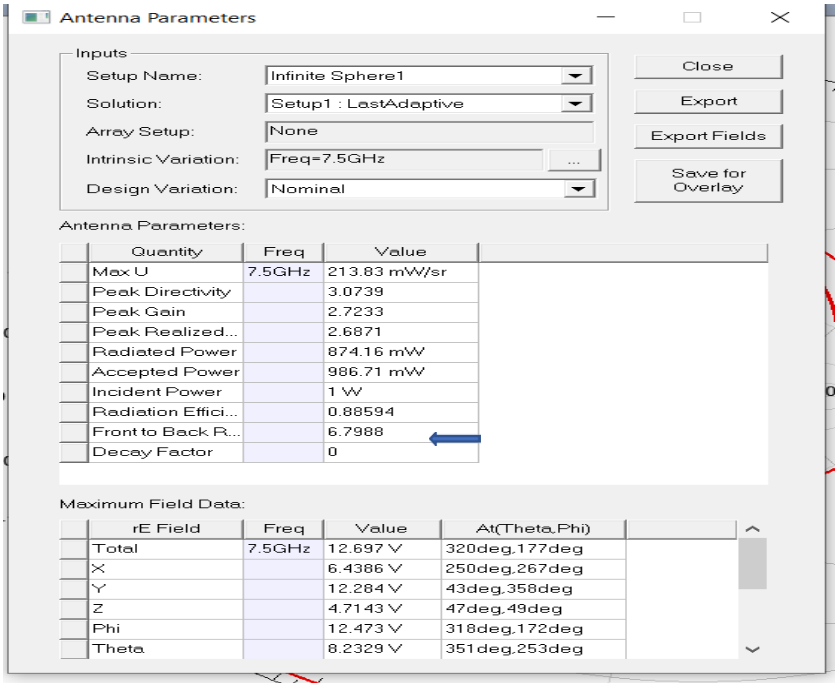

Fig.19: MIMO antenna parameters

3.10. SISO vs MIMO:

Comparison of Single and MIMO array is depicted in the table-3 and is demonstrated. The MIMO antenna has given better performance characteristics compared to SISO antenna.

Table-3: Comparison between SISO and MIMO

S.No.	Parameter	SISO	MIMO
1.	Frequency	Operated at single frequency	Operated at UWB range of Frequency
2.	Return loss	-8.0906 dB at 7.5 GHz	-25.1231 at 7.5 GHz
3.	Reflection Coefficient(S12)	---	-32.7079 dB at 3.94 GHz, -23.2562 dB at 5.74 GHz, -31.744 dB at 6.77 GHz and -36.7792 dB at 9.57 GHz.
4.	VSWR	2.507	1.189
5.	Gain	2.6711dB	9.339dB
6.	Efficiency	59.876%	88.594%
7.	Operating Bandwidth	0.4GHz	3.1GHz-10.6GHz

IV. CONCLUSION

The proposed design of Umbrella shape with T-slot MIMO array antenna with DGS is used for the range of 3.1-10.6 GHz frequency spectrum for UWB applications and SISO antenna at a frequency 7.5 GHz with FR4-epoxy as a substrate material are simulated using HFSS software. The Gain and Efficiency of SISO antenna are 2.87dBand 59.876% respectively. The Gain and Efficiency of MIMO antenna are 5dB and 88.594% which are very better compared to SISO antenna. Compared to SISO antenna MIMO antenna has better transmission speed and channel capacity which are well suited to boost the performance of wireless communication systems. Return loss, isolation and VSWR are also very good in the UWB range of 3.1-10.6 GHz for MIMO array which are acceptable values foran antenna.

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