DESIGN AND SIMULATION OF ELLIPTICAL SHAPED MULTIBAND MIMO ANTENNA FOR MILLIMETER WAVE APPLICATIONS

R. Nagendra, Neelima K, P.Madhu kumar, D. Harika

Assistant Professors, Department of ECE, Sree Vidyanikethan Engineering College, Tirupati

[1]rallanaga@gmail.com, [2]neelumtech17@gmail.com, [3]madhukumar.patnala@gmail.com and [4]Harikadondapati408@gmail.com

ABSTRACT

A Multi Input and Multi Output (MIMO) microstrip patch antenna with elliptical structure at 8GHz frequency is presented in this project. This antenna is designed to resonate at multiple frequencies in millimeter range. The radiating element is in the form of elliptical structure. The design is a flexible and transparent, due to the melinex substrate used in design. In this, Defective Ground Structure is used, due to which gain and bandwidth are enhanced. The melinex substrate element with permittivity of 2.9 was used to design these devices, for which it had a Directional radiation pattern with gain of 5.802dB. This report presents MIMO antennas with 1x2 and 2x2 antennas and the results are observed for these designs. The major design 2x2 had better results in the parameters like gain of 6.25dB, directivity of 7.61dB and VSWR of 1.8. The designs presented below have been tweaked a number of times to improve results, and improved characteristics have eventually been obtained at the peak end of simulation. Millimeter-wave (mmW) frequencies (30-300 GHz) are being used for many applications in the modern world. These applications include Radio, Astronomy, Sensing, Automative Radar, Military and the antenna is suitable with 5G and WLAN band in IoT applications.

Keywords: Patch antenna (PA), Gain, Bandwidth, VSWR, Ansys HFSS software v17.

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INTRODUCTON

In radio, multiple-input, multiple-output, or MIMO, is a technique for boosting a radio link's capacity by combining multiple broadcasts and receiving antennas to take advantage of multipath propagation[1]. MIMO is used in IEEE 802.11n (Wi-Fi), IEEE 802.11a, (Wi-Fi), HSPA+ (3G), WiMAX (4G), and LTE (Long-Term Evolution) (4G LTE). As part of the ITU G.hn standard and the Home Plug AV2 specification, MIMO has recently been employed in 3-wire power-line communication. In wireless communications, the term "MIMO" used to refer to the use of multiple antennas at the transmitter and receiver. In modern usage, "MIMO" refers to a practical method for simultaneously sending and receiving numerous data signals over the same radio channel[2].

LITERATURE SURVEY

Micro strip patch antennas are utilized in a variety of applications, including the Direct Broadcast Satellite (DBS) system, mobile communications, GPS, and different radar systems. Cheap profile, light weight, low cost, simplicity of manufacture, and integration with RF equipment are some of its benefits[3]. However, when used in the 2GHz or lower frequency band, they suffer from several issues like as multipath, interference, and fading[4].

These numerous phenomena have the potential to drastically limit the performance of modern satellite communication systems. Also, several strategies have been developed in recent years to improve the performance of communication networks. The use of antenna diversity to overcome performance limits imposed on the system is one of the antenna upgrades[5]. The frequency band is often believed to be fixed in these techniques, and the objective is to increase overall system performance for that band by using spatial properties of satellite applications[6][7].

The objective of this work is to make available an alternate ground plane solution for a flexible transparent MIMO planar monopole antenna[8][9]. The design of the antenna connected lines is vital for the overall performance under the significant manufacturing restrictions of a transparent antenna structure. With a flexible construction and a sheet impedance of 4 ohm/sq, the gain is 0.53 dBi and the efficiency is sufficient which is 41%. With numerical computation and experimental measurement research, a Wideband MIMO antenna with four elements which is flexible and transparent is suggested. The oxide material AgHT-4 and Melinex substrate are used as substrate material to achieve optical transparency. Indoor wireless devices like smart routers and repeaters could benefit from suggested flexible optically transparent antenna[10].

This study presents a MIMO antenna array for 5G/WLAN used in smart phones. They are dual-functional. By adding eight elements on the antenna, the suggested antenna can be employed in 808 and 4X4 MIMO systems over 18 LTE band 42 and 5.8-GHz WLAN band (of two types, FLA and CUA)[7]. Isolation can be improved by using quasi-orthogonal polarisation, balanced mode excitation, and pattern diversity approaches[11]. Also, a better isolation of greater than 17.1 dB, better ECCs of less than 0.045, and total efficiencies of more than 45 percent within the operation ranges can be achieved[9]. The ergodic channel capacity for the 8X8 MIMO (operating in LTE band 42) and 44 MIMO (functioning in the 5.8-GHzWLAN band) have been estimated[12][13]:

In this work a Dual-band four-element MIMO antenna based on the SRR-loaded slot-loops is proposed. This antenna resonates at the higher frequency of 3.66 GHz and 3.88 GHz. This antenna covers the entire sub 6 GHz 5G spectrum of 3.64 GHz, as well as current bands like LTE-TDD 42/43 and LTE-FDD 22. In addition to this, the loading of SRR results in resonating the antenna at lower frequency of 3.15 GHz, enabling the antenna to use for new applications such as radio-location[14][15]. This antenna is fabricated using a low-cost FR4 epoxy base, resulting in slightly reduced radiation efficiencies of 58.02 percent, 59.94 percent, and 67.43 percent respectively[16].

I. DESIGN CALCULATIONS

STEP- 0

The patch is intended for IOT applications and hence the frequency of operation was chosen to be 8GHz (f0). 1.6mm is maximum available height of antenna[17]. It's value ranges from 0.6mm to 1.6mm. So, let us consider the height of the substrate or thickness of substrate is 0.635mm (h). Consider substrate material as Melinex which has relative permittivity as 2.9

STEP- 1

$$W_s = \frac{1}{2f_0\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} = 38.04mm$$

Width of substrate is given by the following equation (ε_r).

…. *eq.1*

From the equation.1 , Width of the substrate can be calculated as 38.04mm.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} = 2.08$$

…. *eq.2*

From equation.2 , the effective Dielectric constant can be calculated as 2.08.

STEP- 2:

Width of the feed should be 1/4 to 1/5 times of Width of substrate. So, the width of the feed is 2.5mm (Wf). Placement of Defective Ground Structure from L and W of ground placed by λ/4, nλ/4.Therefore Width and Length of the defective ground structure are 40mm and 59.33mm.

STEP- 3:

The patch is constructed in the elliptical structure. So, The major and minor radius of the elliptical patch is given by equation 3. Minor radius is given by

$$a_2 = \frac{F}{\left(1 + \frac{2h}{\pi\varepsilon_{re}F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right)^{1/2}}$$

…. *eq.3*

$$b_e = b\left[1 + \frac{2h}{\varepsilon_r \pi b}\left\{\ln\left(\frac{b}{2h}\right) + (1.41\varepsilon_r + 1.77) + \frac{h}{b}(0.268\varepsilon_r + 1.65)\right\}\right]^{1/2}$$

….

Eq.4

Where ε_{re} is Dielectric constant of substrate, F is operating frequency of antenna, h is thickness of antenna.

Now, ε_{re} = 2.8, Outer ellipse radius = 14.8 mm, Inner ellipse radius = 12.8 mm, Width = Outer ellipse radius – inner ellipse radius =14.8 mm-12.8 mm =2 mm, Thickness (h) = 0.635 mm.

Structure of Single Element Antenna

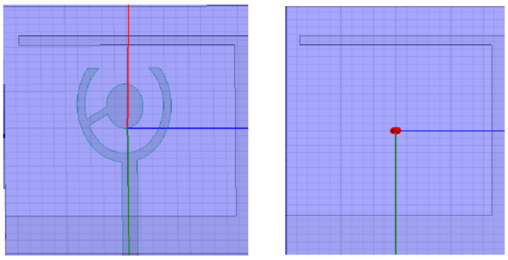

Figure 1: (a) Front view and (b) Bottom view of designed antenna

Table 1: Design Calculations at 8GHz

Antenna parameters	Values
Operating frequency	8GHz
Substrate height	0.635mm
Dielectric constant	2.9
Width of the patch	2mm
Length of the patch	8.42mm
Length of ground plane	59.33mm
Width of ground plane	40mm

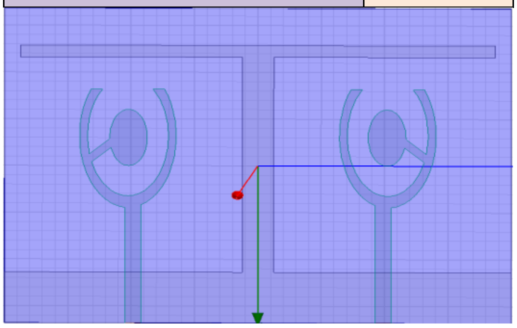

Figure 2: Design of 1x2 MIMO Antenna

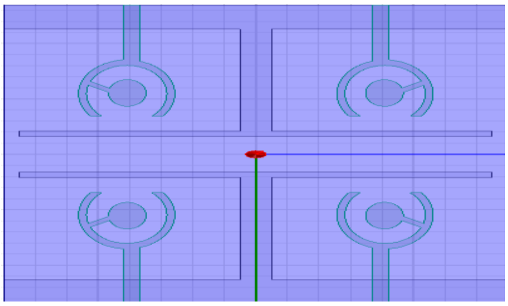

Figure 3: Design of 2X2 MIMO Antenna

II. RESULTS and DISCUSSIONS

Simulated Results of MIMO Antenna

In our design we used melinex substrate with line feeding technique and the design is shown in Figure 3 .

Return Loss

Return loss is a decibel-based logarithmic ratio that indicates the ratio of power fed into the antenna from transmission line to the power reflected back by the antenna without being radiated. An antenna's return loss reflects how well it resonates at a given frequency. This antenna has a return loss of -10.48dB and is designed to resonate at 8 GHz.

A return loss can also be stated as a mismatch. The antenna exhibits a return loss of -14.28dB, -19.49dB, -33dB, and -30dB for frequencies of 17GHz, 32GHz, 48GHz, and 63GHz. Antenna 1's return loss graph is a resonant graph shown in figure 4.

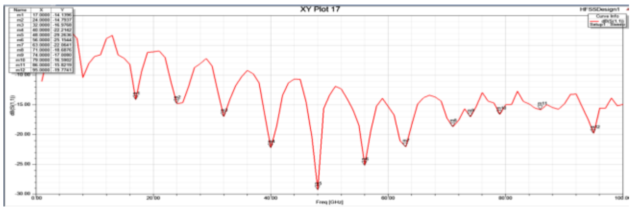

Figure 4: Return Loss S(1,1) of 1x2 antenna

The 2 antenna has return loss of -14.28dB, -19.49dB , -33dB,-30dB at frequencies 17GHz , 32GHz, 48GHz, 63GHz and return loss of S(1,1), S(2,2) below -10dB as shown in Figure 5.

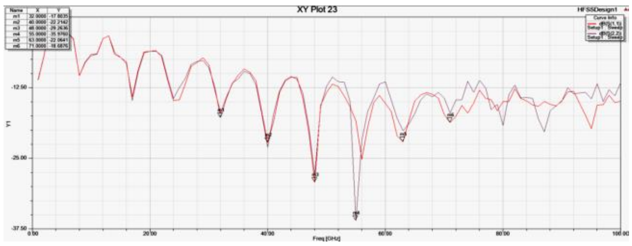

Figure 5: Return Loss S (1,1), S(2,2)

The S- parameters of the first antenna with respect to all the other antenna shows its isolation properties. And is shown in the Figure 6.

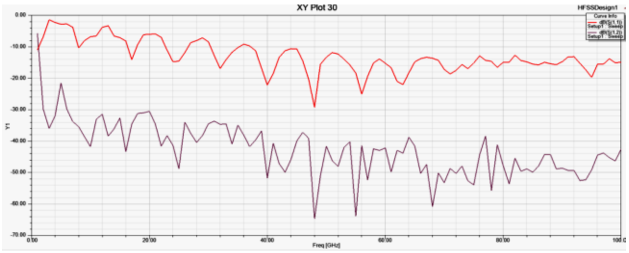

Figure 6: Return Loss S(1,1),S(1,2)

The S- parameters of the second antenna with respect to all the other antenna shows its isolation properties. And is shown in the Figure 7.

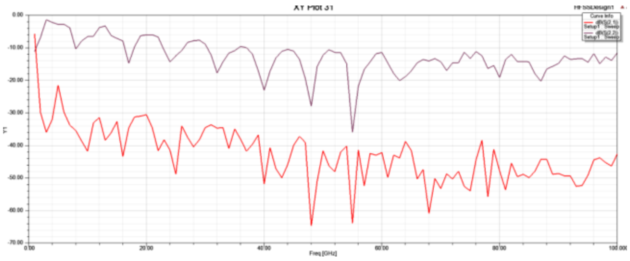

Figure.7: Return Loss S(2,1),S(2,2)

Radiation Pattern in 3D Polar Plot

The radiation pattern of antenna is defined as the radiation of power as a function of the direction away from the antenna.

Figure 8: Radiation Pattern of 1x2 antenna

VSWR

The VSWR is defined as a measure of how far the radio-frequency power is transmitted from power source to a load via transmission line. At 5.8 GHz, the intended antenna's VSWR is 1.0826, as shown in Figure 9.

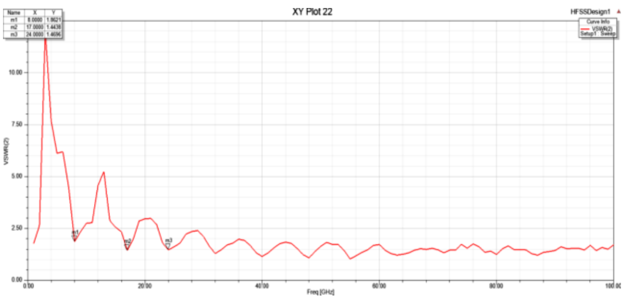

Figure 9: VSWR of 1x2 antenna

Gain

Gain is a parameter defined as the total power radiated from a peak source to an isotropic source within the direction of peak radiation. After modelling, the gain of the antenna is 5.7732dB at 8GHz, as illustrated in Figure 10.

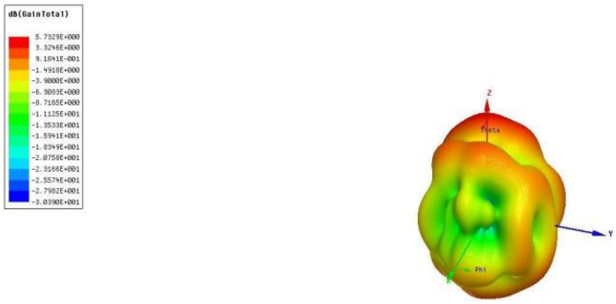

Figure 10: Gain of 1x2 antenna

The E-plane is any plane that contains the E-field and the direction of maximum radiation from the antenna. After Simulation 2D E-plane Radiation Pattern is shown in Figure 11.

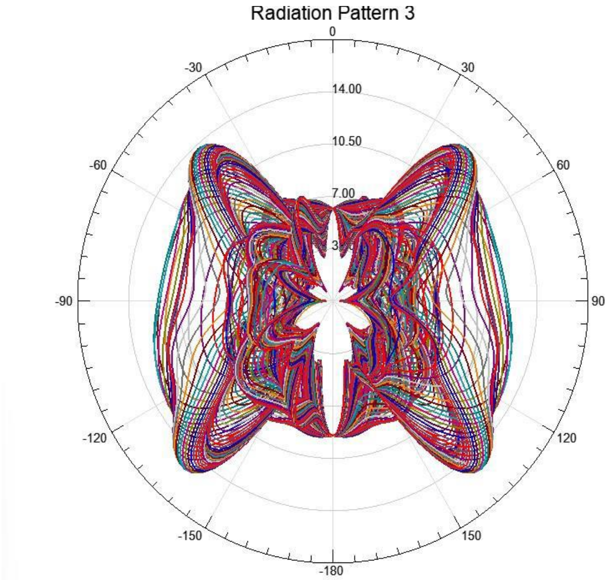

Figure 11: E-plane Radiation Pattern

Final Antenna Results

In our design we used melinex substrate with line feeding technique and the design is shown in Figure 3.

Return Loss

Return loss is the ratio of power fed into the antenna from the transmission line and the power reflected by the antenna. The return loss plot reveals that with a MIMO antenna, specifically in this design, there are four antennas that have a coplanar interaction with the other antennas. It's possible that this is referred to as an isolation plot.

The antenna has a return loss of - 14.28dB, -19.49dB,-33dB,-30dB for frequencies of 17GHz, 32GHz, 48GHz, and 63GHz. The return loss S(1,1) of an antenna is shown in Figure 12 which is less than -10dB.

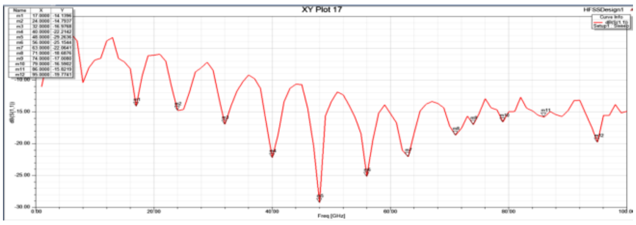

Figure 12: Return Loss S (1, 1)

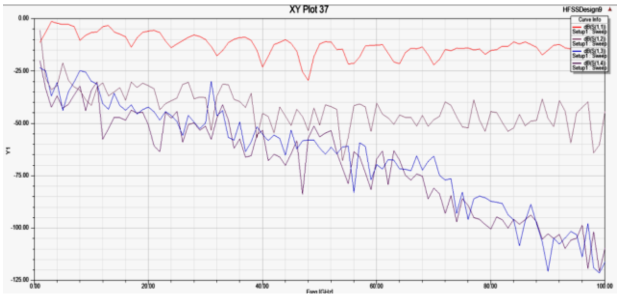

Figure 13: Return Loss S(1,1),S(1,2),S(1,3),S(1,4)

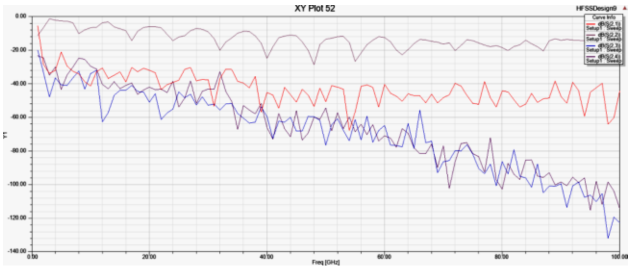

Figure 14: Return Loss S(2,1),S(2,2),S(2,3),S(2,4)

The S- parameters of the second and third antenna with respect to all the other antennas shows its isolation properties. And is shown in the Figures 14 and 15.

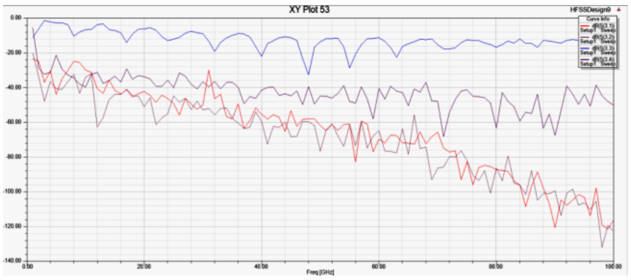

Figure 15: Return Loss S(3,1),S(3,2),S(3,3),S(3,4)

The S- parameters of the fourth antenna with respect to all the other antennas shows its isolation properties. And is shown in the Figure 16.

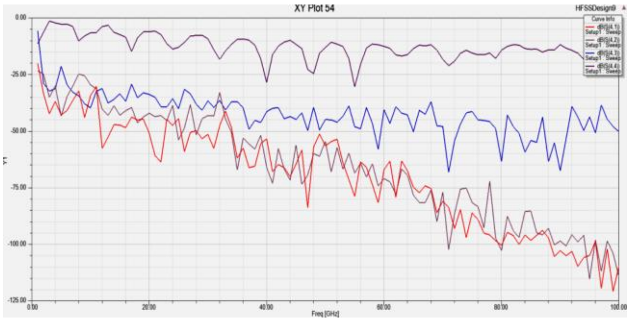

Figure 16: Return Loss S(4,1),S(4,2),S(4,3),S(4,4)

Beam Area

The solid angle is the angle over which the antenna's power is radiated into the air interface. all the beam area is the f would stream if Power remained at its greatest value over A and was zero elsewhere. The beam area of the planned antenna is shown in Figure 17 below.

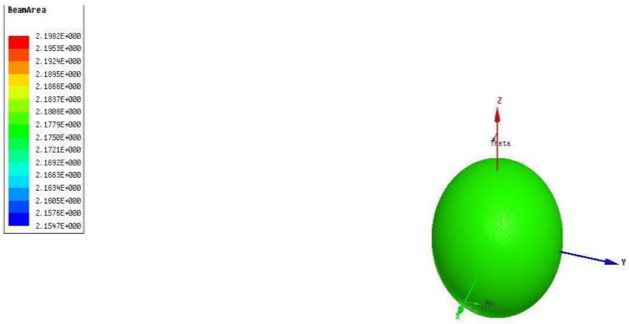

Figure.17: Beam Area of 2x2 antenna

Radiation Pattern in 3D Polar Plot

The power radiated by an antenna as a function of the direction away from the antenna is defined by the radiation pattern.

Figure 18: Radiation Pattern of 2x2 antenna

VSWR

The VSWR is a measurement of how successfully radio-frequency power is transferred via a transmission line from a power source to a load. At a frequency of 5.8GHz, the projected antenna's VSWR is 1.0826, as illustrated in Figure 19.

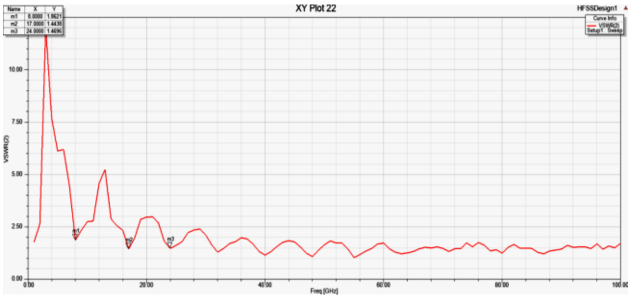

Figure 19: VSWR 2x 2 antennas

Gain

The gain of the antenna after simulations at 8GHz is 5.7732dB which is illustrated in Figure 20.

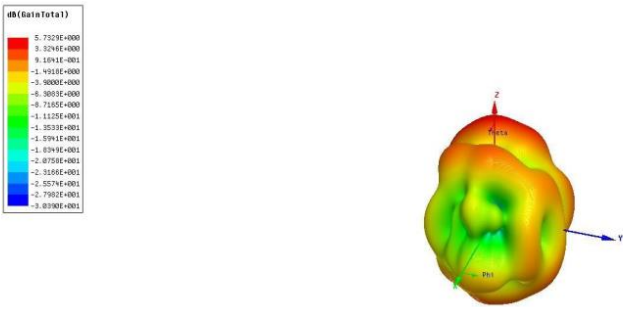

Figure 20: Gain of 2x2 Antenna

Radiation Pattern in Rectangular Plot

The fluctuation of the power radiated by an antenna as a function of the direction away from the antenna is known as a radiation pattern. Any plane that contains the H-field and the antenna's maximum radiation direction is called the H-plane. Figure 21 shows the 2D H-plane Radiation Pattern after simulation.

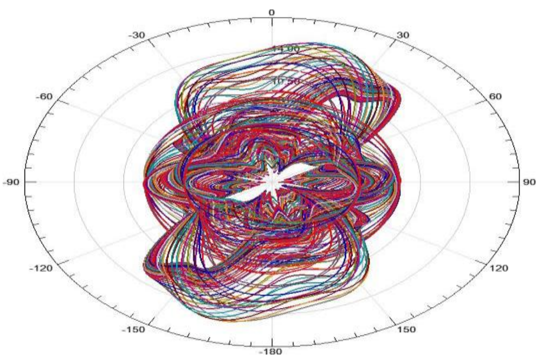

Figure 21: H-Plane Radiation Pattern

Any plane that contains the E-field and the antenna's maximum radiation direction is called the E-plane. Figure 22 shows the 2D E-plane Radiation Pattern after simulation.

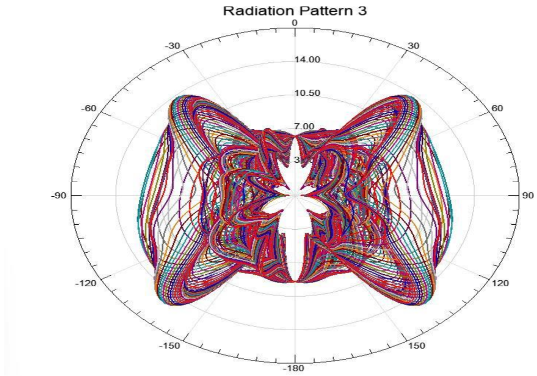

Figure 22: E-plane Radiation Pattern

Comparison table of 1x2 Antenna and MIMO

Table 2: Comparison of 1x2 Antenna and MIMO

Parameters	1x2 antenna at 8GHz	MIMO at 8GHz
Gain(dB)	5.7	6.25
Directivity(dB)	7.04	7.61
VSWR	1.86	1.85
Return loss(dB)	-10.4302	-10.4711
Peak directivity(dB)	5.06	5.78
Peak gain(dB)	3.743	4.24
Peak realized gain(dB)	3.41	3.83
Beam area	2.48	2.17
Radiated power(w)	6.7	6.6
Accepted power(w)	9.1	9.0
Incident power(w)	1.00	1.00
Radiation efficiency	0.75	0.73

Table.2 shows the comparison of 1x2 and 2X2 MIMO antennas and their performance regarding the above parameters. In the first column we can see that the gain we got is only 5.7dB and the directivity is 7.04dB. Basically, these are comparable results compared to the present generation antennas for 5G application.

We went to MIMO to make even better transmission and performance. As results of that we got a gain of 6.25dB and directivity of 7.61dB. Through MIMO we reduced the VSWR and many other factors are also been improved.

CONCLUSION

An elliptical structure based mimo antenna for millimetre wave applications is developed and simulated using hfss software. The proposed antenna has got considerable gain, good return loss and vswr values at 8ghz. Simulation results of the final system created proved the advantages of the antenna based on millimetre wave applications, which provides a good alternative for wireless communications systems such as 5g and linked objects. Only the simulation results disclose the design's minor results. Using the mimo antenna results, we may move on with the manufacturing of the suggested mimo antenna. The findings may or may not be similar to the simulated results after fabrication due to factors like as fabrication material purity, measurement considerations, and environment. For iot, a mimo antenna is designed and simulated.

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