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Research Article

Dolphin shaped patch antenna with edge and coaxial feeds

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Abstract

Microstrip patch antennas have evolved over the years to be implemented in different shapes and sizes. This paper presents a dolphin-shaped patch antenna for improved efficiency and gain. The chosen shape gives a reasonably high gain compared to a rectangular patch antenna structure due to excellent communication skills that originate in dolphin due to their body structure. The gain is further enhanced by increasing the size of the ground plane (double-ground and triple ground) to achieve a higher range. Two types of feeding techniques have been compared: edge feed (planar type feeding in the form of a stripline) and coaxial feed (non-planar feeding in the form of a probe through a hole in the ground plane). Parameters such as gain and efficiency have been compared and documented in this work.

Keywords: Microstrip Patch Antenna, edge, and coaxial feeding techniques, gain, patch.

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Introduction

Antennas play a crucial role in wireless communications. They are usually metal and have a wide variety of configurations. In the modern times, antennas are usually designed to operate at a specific frequency. Over the years, antennas have been developed in several methods for a wide variety of applications. The most commonly known antenna types are slot antenna, patch antenna, array antenna, short dipole antenna, and parabolic reflectors to name a few. There is a need for simple antenna structures which are easy to design, fabricate, and are also of reasonable cost at the same time. This paves way for use of simple planar antenna structures which have been studied and comprehensively researched in the past four decades. These planar antennas are called as microstrip patch antennas (MPAs) and are extremely simple in structure which makes them easy to fabricate. MPAs have a structure which composes of three main parts: a radiating patch, a ground plane, and a dielectric material (substrate) sandwiched between them. Microstrip patch antenna is one of the commonly known antennas which has the following main components: a radiating patch, a dielectric substrate, and a ground plane. The patch is usually rectangular in shape, and the dimensions of the patch decide the dimensions of the substrate and the ground plane. The dielectric substrate is sandwiched between the ground plane and the patch. The main principle of microstrip patch antennas or the main reason for the radiations from the patch is the fringing fields which are present in between the edge of the patch and the ground plane. There are several merits and demerits of microstrip patch antennas. Some of the advantages include low weight, low volume, low fabrication cost, possibility of linear and circular polarizations. Some of the disadvantages of using a microstrip patch antenna include low power handling capacity, comparatively lower gain and large ohmic loss in the feed structure of arrays. Power is fed to an antenna by employing several methods. The most commonly used feeding methods are the edge feeding method, coaxial feeding method, and aperture coupled feeding method, and the proximity coupled feeding method. Coaxial feed method is a popular feeding technique that has several advantages over other methods. One of the major advantages of coaxial feed is the freedom of placing the feed in multiple positions on the patch in order to achieve impedance matching. Edge feed is another popular feeding technique in which the feed can be etched on the same substrate to provide a planar structure. In practice, microstrip patches can be found commonly in rectangular, circular and triangular shapes. Each shape is known to produce reasonable results on the basis of parameters such as return loss, radiation efficiency and directivity. In this paper, an attempt to design a dolphin shaped patch is being presented. Dolphins are known for their ability of being able to communicate with their peers by the means of sonar radiations. The nose of the dolphin acts as a transceiver due to its peculiar tapering shape. Edge and coaxial feeding techniques have been used to compare results based on certain parameters such as efficiency, directivity and gain. The antenna is expected to operate at 2.4Ghz and provide an efficiency greater than 80%. Antennas operating at 2.4GHz have a number of applications that include Wi-fi and Bluetooth applications.

This paper is composed as follows. Section II surveys several recent papers on variations of patch antennas. In section III, the conventional coaxial and edge feeding techniques and the relative enhancements for optimal results are been discussed. Section IV represents the comparative analysis of existing and proposed strategy. The conclusion is made in Section V.

Literature review

Several researches are suggested by researchers in design of patch antennas. In this context, a brief review of the key contributions is presented.

Shibaji Chakraborty and Uddipan Mukherjee (Chakraborty & Mukherjee)described a comparative study of microstrip patch antenna using line feed and coaxial feed by the optimization of the resonant frequency and radiation resistance of the antenna along with other antenna parameters. The work represented several advantages of the two methods when compared with each other.

Ranjan Mishra (Rao, Singh, & Mishra) et al proposed the design of microstrip patch antenna in both rectangular and square shapes for increased gain and efficiency. Both the designs use microstrip line as a feeding method. The square shaped patch provides wider bandwidth and sufficient return loss. The antenna is lightweight, small in size and easy to fabricate. It operates in the X band of frequency. The antenna operates at a bandwidth of 500 MHz. Due to this high bandwidth property, it can be used in the X band.

(Khan, Sharawi, & Mittra, 2015) introduced a circular shaped patch antenna with multiple infused rectangular slots. The performance of conventional microstrip patch antenna is compared with this circular shaped patch antenna and is tabulated

Liling Sun et al (Tiwari, Singh, & Kanaujia, 2017)proposed a butterfly shaped wideband patch antenna for wireless communications and RFID systems. There are two symmetric quasi-circular arms and two round holes are introduced into the patch to improve the efficiency. The bandwidth of the prototype was found to be around 40.1%

Fan Zhang et al (Zhang, Zhang, Yang, & Zhang) proffered the idea of a bow-tie shaped microstrip patch antenna. The antenna was realized by stacking two substrate layers which are separated by a ground plane. The bow-tie shaped radiation patch is fed by a 50Ohm microstrip line, which is coupled to the microstrip feedline through a dumbbell-shaped aperture on the ground plane. The antenna operated in a frequency range of 2.7-3.5GHz

jingli Guo et al (Guo, Zou, & Liu, 2011) employed a method to introduce a novel wide-band crescent moon shaped patch antenna. The antenna consisted of two simple patch pairs with opposite phase feed. The coupling between two patches was utilized during the design. Measurement and simulation showed that the antenna provided about 87% bandwidth.

Rajan Fotedar et al (Fotedar, Garia, Saini, Vidyarthi, & Gowri)proposed a work that showed design and performance comparison analysis of microstrip patch antennas with different patch conditions to obtain optimal condition. The resonant frequency is maintained at 2.4 GHz due to the high value of this measurement for wireless communication. The FR-4 dielectric substrate has been used for all designs. Rectangular lumps showed a loss of recovery of -40 dB which was below the triangular pool. Radiation efficiency was better than triangular and circular patch

G.V.P.Pranathi et al (Pranathi, Rani, Satyanarayana, & Rao, 2015) designed a patch antenna using the inset feeding techniques. Ground plane dimensions were altered using double ground and triple ground techniques in order to improve antenna parameters such as return loss, gain and VSWR. It was observed that the triple ground method rendered the maximum gain of 3.0524dB.

(Anitha, Reddy, & Prasad) proposed a small microstrip patch antenna with a convenient tuning option. The geometry is such that it allows considerable reduction in size. The slits in its circular shape allow for operation in two modes of polarization (both linear and circular). Tuning is possible by the rotation of another layer of patch of suitable shape (superstrate). Using another superstrate layer allows for configurable tuning.

The advantages and lacunas of the patch shaped antennas discussed are considered, a novel dolphin shaped antenna that would operate at a frequency of 2.4 GHz is been designed. Dolphins are known for their efficient communication techniques that originates from their body symmetry and structure. Keeping this in mind, the designed antenna renders better results with respect to the parameters obtained from a traditionally shaped patch antenna.

IMPLEMENTATION AND METHODOLOGY

The main motivation behind the idea of dolphin shaped patch is to develop a dolphin shaped patch antenna which operates at a frequency of 2.4 GHz. This makes the antenna suitable for wireless applications such and Wi-Fi and Bluetooth. The dolphin shaped patch helps in increasing the gain when used with a suitable sized ground plane, and the antenna can hence operate over longer range. The dolphin shaped patch antenna consists of the same three parts as that of a MPA. In this case, the patch is dolphin shaped with a nose, two fins, and a tail. The antenna is fed with power using two different feeding methods (edge feeding and coaxial feeding) and each of the parameters are compared. A choice between the two can be made depending on the requirement of the application.

There are various techniques in which a MPA can be fed with input power. Some of them are: edge feeding technique, coaxial feeding technique, aperture coupled feeding technique, and proximity coupled feeding technique. Here, the two techniques which are used in the proposed designs are discussed:

A. Feeding techniques used:

Microstrip Feed Line technique (MFL)

The MFL employs such that, the patch is fed i.e. the input power with the help of a stripline. The port (lumped) is rectangular in shape. This method of feeding is most commonly used and is very simple to fabricate. The structure is planar since the feedline lies in the same plane as that of the patch. It is very easy to use with arrays and it is also easy to obtain input match (impedance matching). This method is the simplest method of feeding input power into an antenna.

2. **Coaxial Feeding Technique (CFT):**

This feeding method involves drilling a hole into the ground plane. The input power is fed through a cylinder which goes all the way from the ground (through the hole) into the substrate. There are two conductors (inner and outer) which are separated with the help of a material such as Teflon. The coaxial feeding technique is advantageous when compared to the MFL technique, i.e. The CFT can be placed at any point of interest. The position of the line feed can be changed to result in an improved impedance matching. The CFT methodology is able to achieve a narrower bandwidth which is the need for a good antenna. The lacuna noted in this method is during fabrication of the antenna which requires skilled expertise as a hole has to be drilled to connect the feed line. Since the conductor protrudes outside the ground plane the structure is non-planar(Gangwar, Gangwar, & Kumar)

B. Proposed dolphin-shaped patch:

A dolphin-shaped patch antenna is conceived for WiFi and Bluetooth applications. This antenna operates at a resonant frequency of 2.4GHz. It is designed using Rogers RT Duroid 5880 tm having a dielectric constant = 2.2, the thickness of the substrate is 2.54mm. The basic patch antenna equations are used in the design of the substrate and scaling of the dolphin-shaped patch. The length and width of the dielectric substrate are calculated using (1), and (3).

$$W = \frac{c}{2_{f_0}\sqrt{\frac{\varepsilon_R + 1}{2}}}$$ equation (1)

$$\varepsilon_{eff} = \frac{\varepsilon_R + 1}{2} + \frac{\varepsilon_R - 1}{2}\left[\frac{1}{\sqrt{1 + 12\left(\frac{h}{W}\right)}}\right]$$ equation (2)

$$L = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0824h\left(\frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)}\right)$$ equation (3)

Where W represents the dielectric Patch width.
ε_{eff} is the effective dielectric constant
L represents the dielectric Patch length.
f_O represents the dielectric Patch resonant frequency.

h represents the dielectric Patch height

ε_R is the dielectric constant of the substrate

The length and height of the ground plane is calculated using (4) and (5).
$L_{eng} = 6h + L$ equation (4)

$W_{wig} = 6h + W$ equation (5)

Where L_{eng} and W_{wig} are the Length and Width of the substrate respectively.

The length and width of the ground are found to be L_{eng}= 55.97 mm and W_{wig} =64.64 mm.

The dolphin shape is scaled according to the patch dimensions approximately according and mounted on the dielectric substrate. Fig. 1 shows the dimensions of the optimized dolphin patch. The ground and the substrate have the same dimensions. The feed is given in the two different ways mentioned previously: Microstrip feed line (edge feeding technique) and coaxial feed (probe feeding technique).(Kumar, Pawar, & Ranjan, 2009)

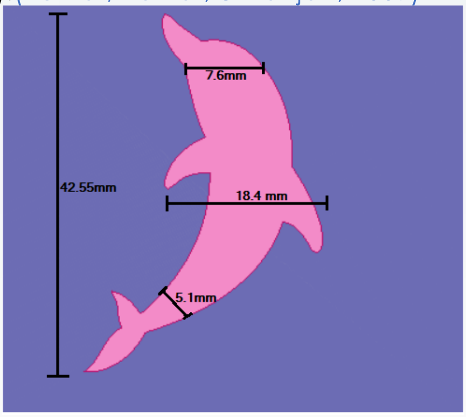


Figure 1: dolphin dimensions

C. HFSS Implementation:

Coaxial feed: The dimensions of outer and inner conductor diameters have been calculated using the formulae mentioned above. The structure of the coaxial feed as shown in fig.2 consists of 3 layers namely the outer conductor, the inner conductor, and an insulating band separating them.

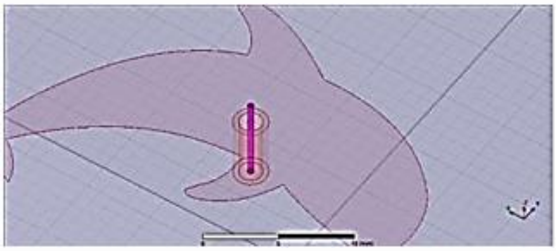


Figure 2. Coaxial feed illustration

The inner conductor passes through the ground and the substrate and has contact with the dolphin patch through which it provides power to the patch. The lumped port excitation is given to the outer Teflon face. The patch and the ground are assigned as a perfect E material.

Edge feed: Fig. 3 depicts the Edge feed technique. The dimensions of the strip have been as 2 mm as mentioned above. The stripline connects the patch to the lumped port (through which the power is fed). The patch and stripline are united (Boolean unite) and given a perfect E configuration. The ground is also assigned a perfect E configuration.

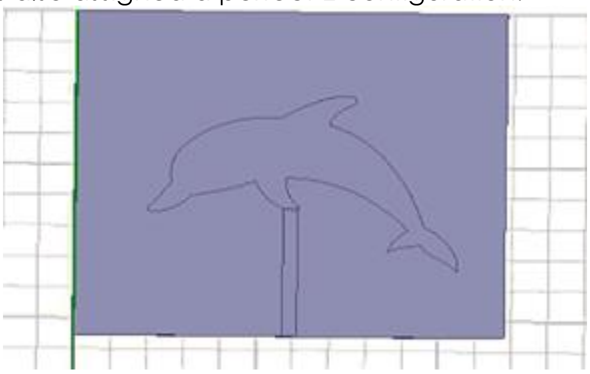


Figure 3. Edge feed illustration

IV. RESULTS AND DISCUSSIONS

A Primary designs

The size of the dolphin patch is approximated by keeping in mind the size of the rectangular patch, by giving an appropriate scaling factor to scale up/down the size accordingly. The dolphin-shaped patch antenna is found to operate at a frequency of 2.4 GHz with a gain of 4.7703 dBi (edge feed) and 4.04dBi (coax feed).

Edge feed: The dolphin-shaped patch antenna operates at a frequency of 2.4 GHz, with a gain of 4.7703 dBi and a return loss of -23.28 dB and VSWR of 1.19, which indicates excellent impedance matching. The efficiency percentage is 96.82%. Fig.4 depicts the primary edge feed design.

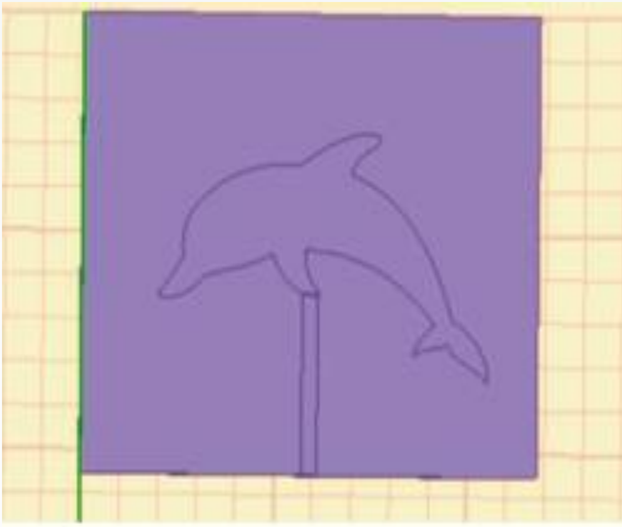


Figure.4 Edge feed design (primary)

The frequency dip, Smith chart, VSWR, and radiation pattern of the design obtained are displayed in fig. 5, fig, 6, and fig. 7 respectively.

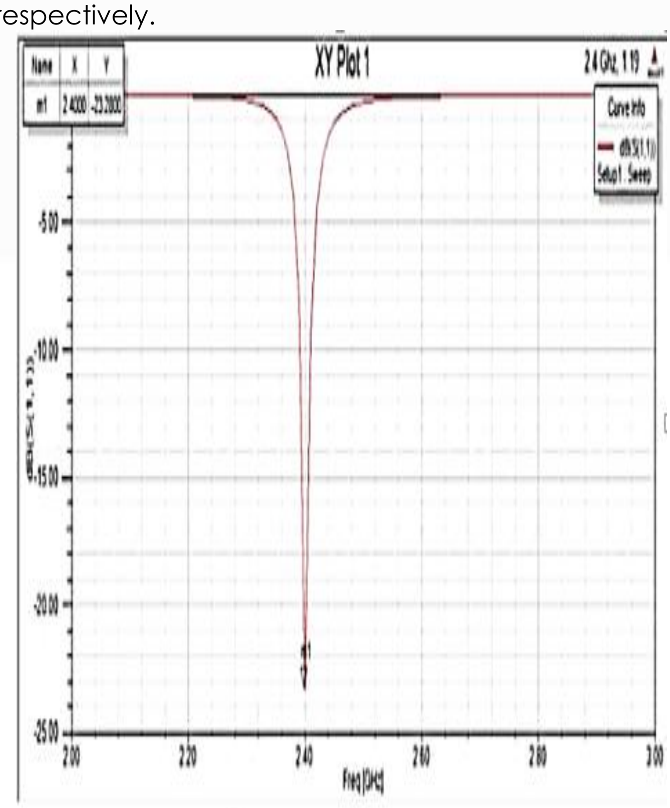


Fig. 5: Frequency dip and return loss (Edge feed)

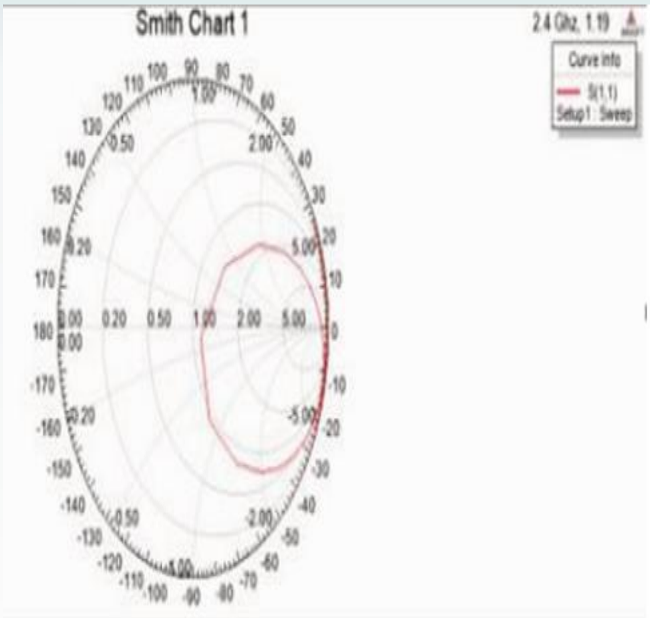


Figure. 6 Smith chart (Edge feed)

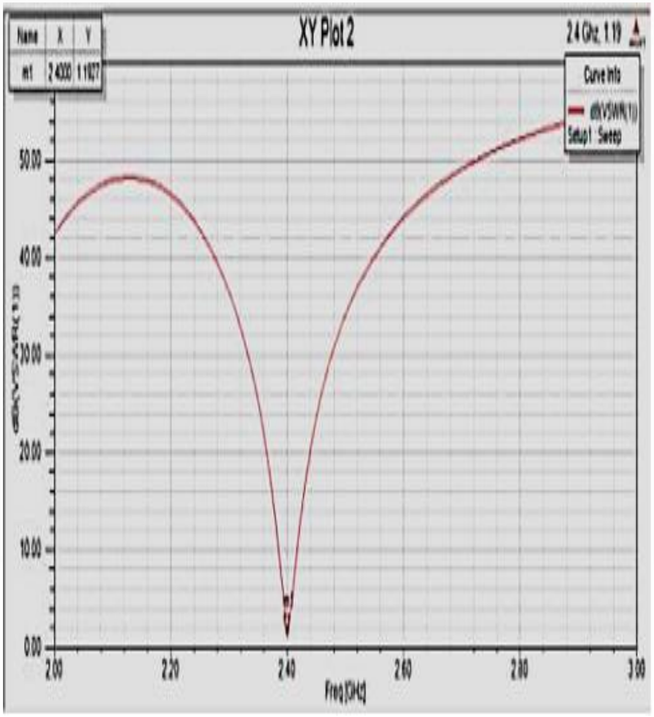


Figure. 7 VSWR (Edge feed)

(Ganesh & Kusagur, 2018)Analysis of the smith chart and VSWR depicted in figure 6, and 7, gives an insight of the Gain plot of the edge feeding technique. And it is observed from figure 8.a and 8.b. that the magnitude of gain RHCP is greater than the magnitude of gain LHCP at theta=0 degrees, which implies that the antenna is right hand circularly polarized.

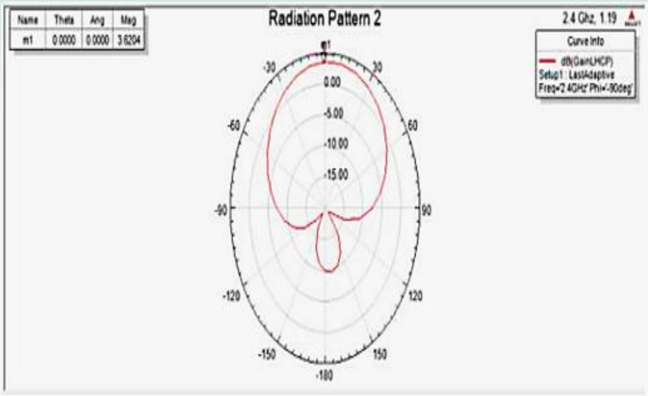


Figure. 8.a: Gain plot of RHCP edge feed

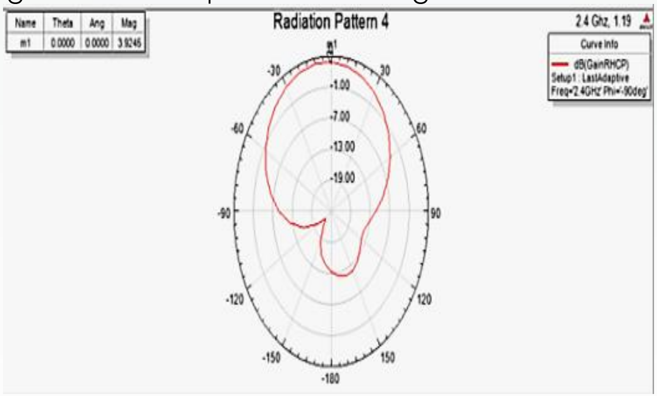
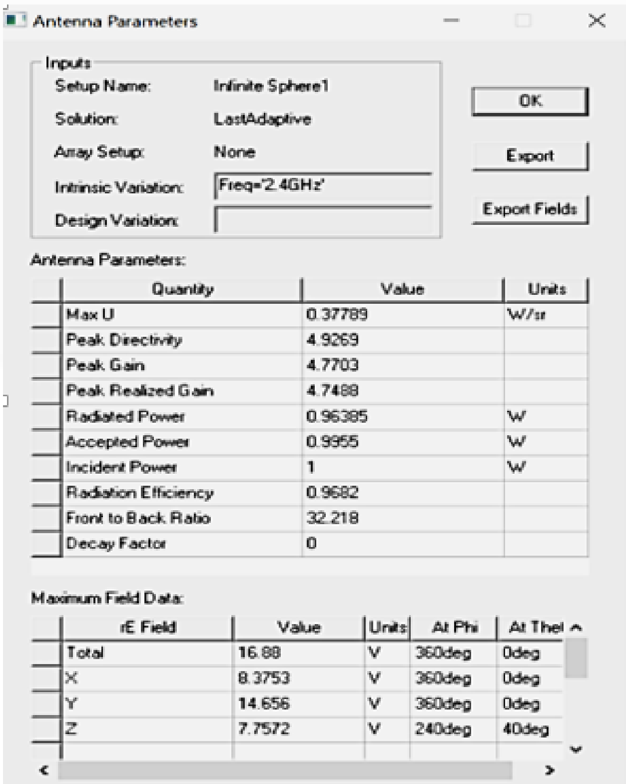


Figure. 8.b: Gain plot of LHCP edge feed

Figure. 8 Gain plot of edge feed (RHCP and LHCP)

Following are the values of different antenna parameters:


Antenna Parameters

Inputs

Setup Name:	Infinite Sphere1
Solution:	LastAdaptive
Array Setup:	None
Intrinsic Variation:	Freq='2.4GHz'
Design Variation:	

OK | Export | Export Fields

Antenna Parameters:

Quantity	Value	Units
Max U	0.37789	W/sr
Peak Directivity	4.9269	
Peak Gain	4.7703	
Peak Realized Gain	4.7488	
Radiated Power	0.96385	W
Accepted Power	0.9955	W
Incident Power	1	W
Radiation Efficiency	0.9682	
Front to Back Ratio	32.218	
Decay Factor	0	

Maximum Field Data:

rE Field	Value	Units	At Phi	At Thet
Total	16.88	V	360deg	0deg
X	8.3753	V	360deg	0deg
Y	14.656	V	360deg	0deg
Z	7.7572	V	240deg	40deg

Fig. 8 Antenna parameters in edge feed

Coaxial feed: The dolphin-shaped patch antenna shown in fig. 9, operates at a frequency of 2.381 GHz, with a gain of 4.7703 dBi and a return loss of -21.16 dB and VSWR of 1.52, which indicates decent impedance matching. The efficiency percentage is 92.5%.

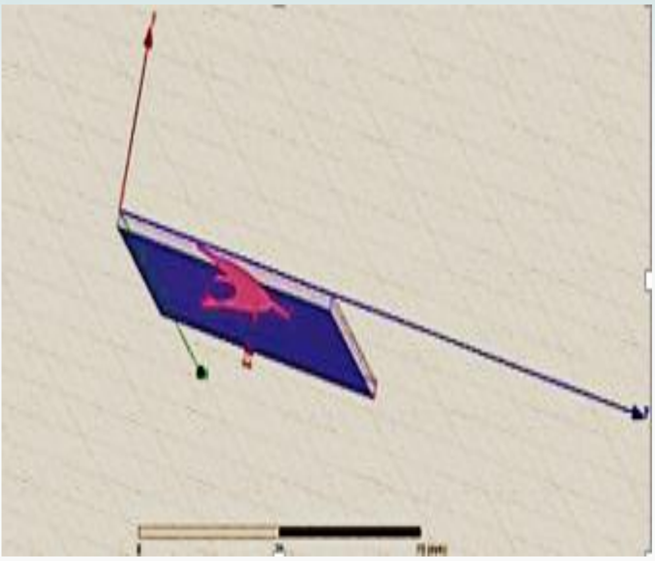


Figure. 9 Coaxial feed design (Primary)

The frequency dip, Smith chart, VSWR, and radiation pattern of the design are as follows:

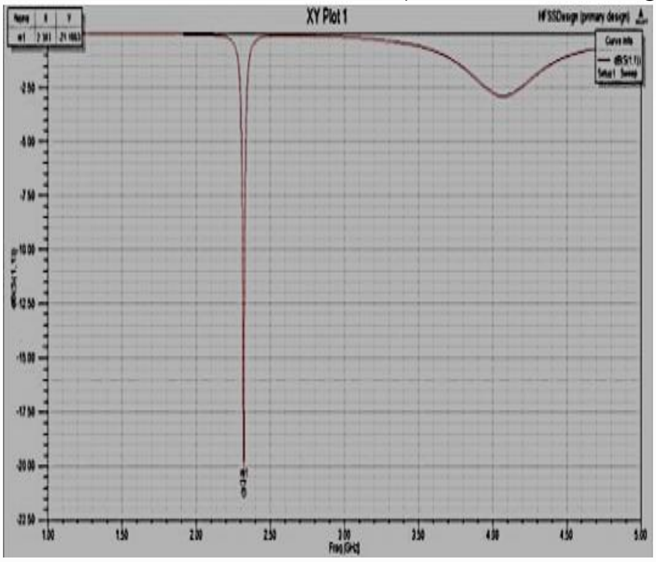


Figure.10 Frequency dip and return loss (coaxial feed)

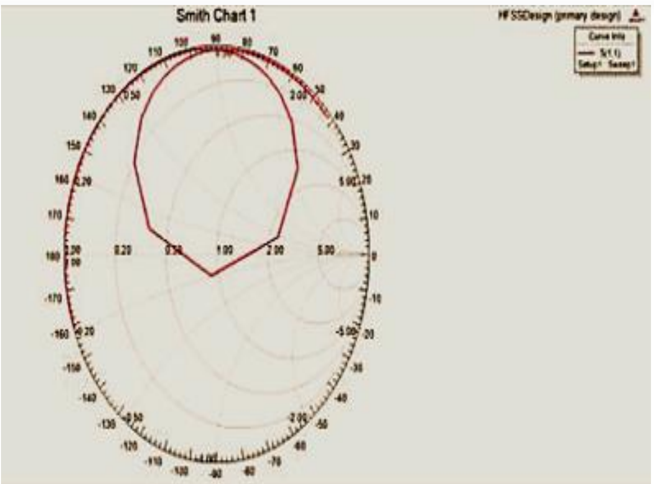


Figure.11 Smith chart (coaxial feed)

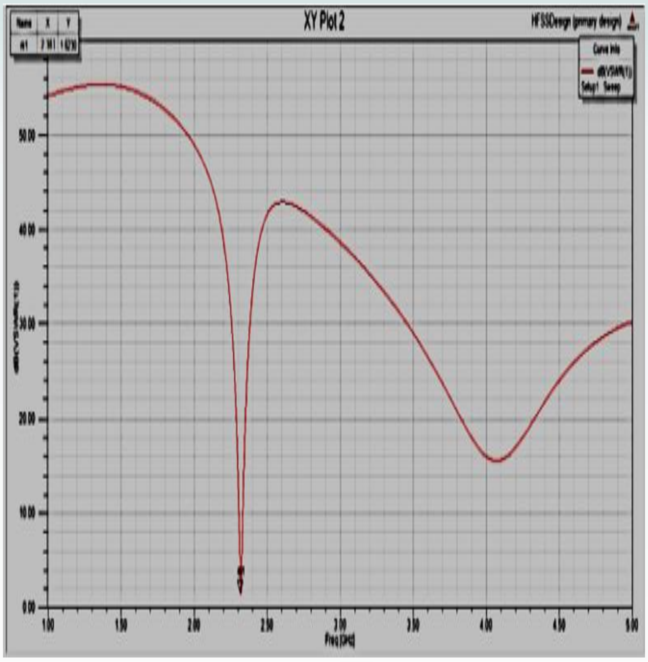


Figure.12: VSWR (coaxial feed)

The Magnitude of gain as shown in figure 13 implies that LHCP is greater than the magnitude of gain RHCP at theta=0 degrees , which implies that the antenna is left hand circularly polarized.

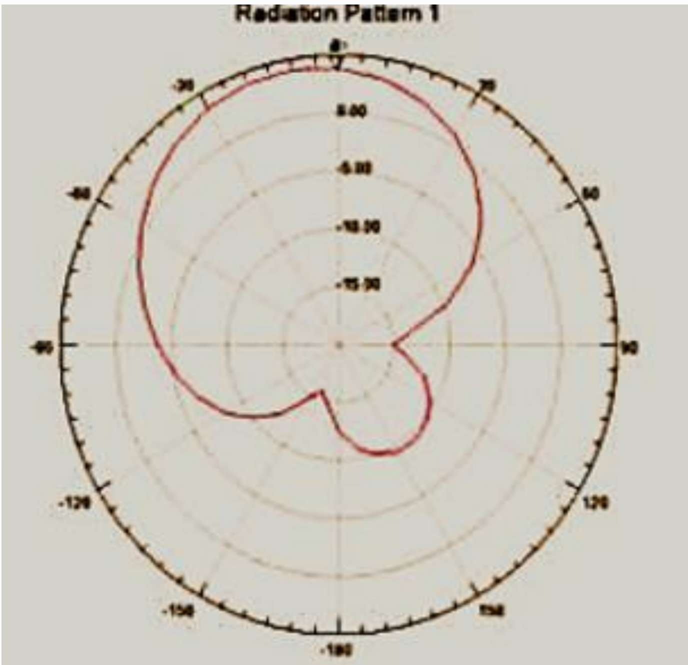


Figure. 13.a: Gain plot of RHCP coaxial feed

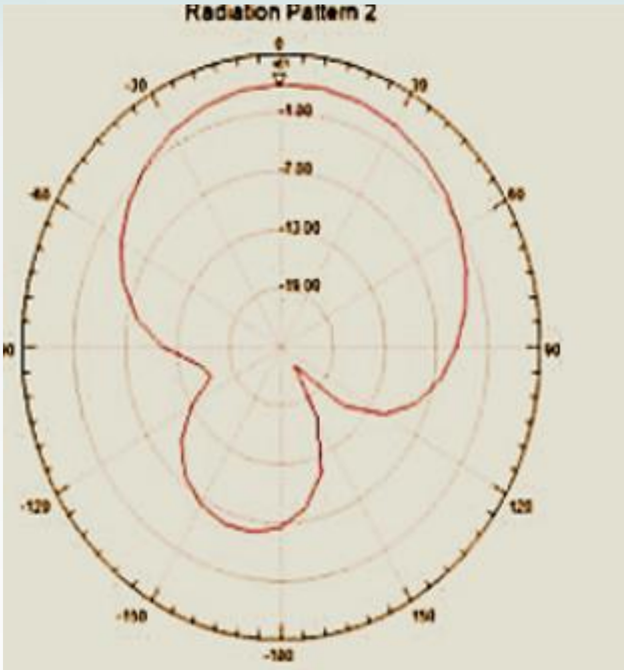
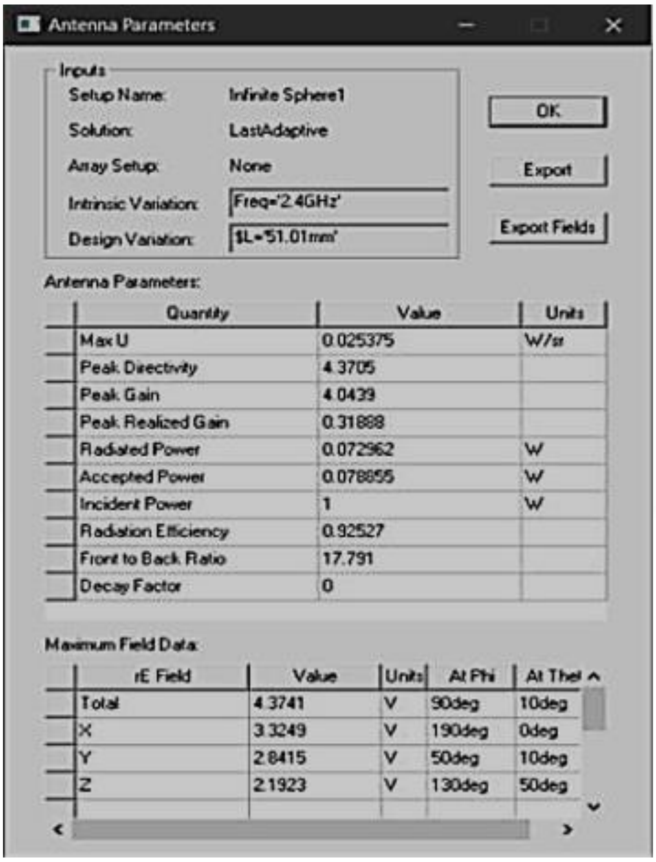


Figure. 13.b: Gain plot of LHCP coaxial feed

Figure.13 Gain plot in the coaxial feed (RHCP and LHCP)



Antenna Parameters

Inputs

Setup Name:	Infinite Sphere1
Solution:	LastAdaptive
Array Setup:	None
Intrinsic Variation:	Freq='2.4GHz'
Design Variation:	$L='51.01mm'

OK | Export | Export Fields

Antenna Parameters:

Quantity	Value	Units
Max U	0.025375	W/sr
Peak Directivity	4.3705	
Peak Gain	4.0439	
Peak Realized Gain	0.31888	
Radiated Power	0.072962	W
Accepted Power	0.078855	W
Incident Power	1	W
Radiation Efficiency	0.92527	
Front to Back Ratio	17.791	
Decay Factor	0	

Maximum Field Data:

rE Field	Value	Units	At Phi	At Thet
Total	4.3741	V	90deg	10deg
X	3.3249	V	190deg	0deg
Y	2.8415	V	50deg	10deg
Z	2.1923	V	130deg	50deg

Figure.14 Antenna parameters in coaxial feed

B. Ground Variations

G.V.P.Pranathi et al (Bokhari, Zurcher, Mosig, & Gardiol, 1996; Pranathi et al., 2015) have concluded that the ground plane dimensions act as an important parameter for antenna optimization. The work suggests that increase in the ground plane dimensions increase the gain significantly. The same method has been employed for the primary design as well.

a) Double ground:

Edge feed: Increase in the size of the ground plane is expected to increase the gain of the antenna. The dimensions of the ground plane were taken as 2L and 2W of the substrate (approximately). This considerably improved the gain of the dolphin antenna.fig.15 shows the HFSS implementation of Double ground.

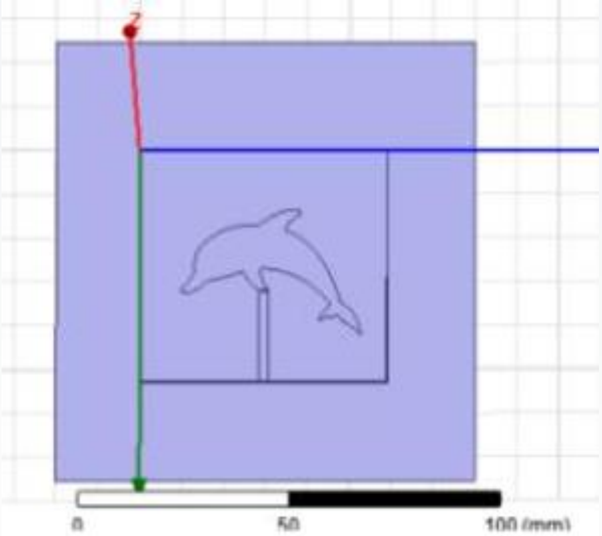


Figure. 15 Edge fed antenna with double ground structure

The gain of the antenna was now found to be 5.7 dBi with directivity of 5.98 dBi. The efficiency percentage was 95.21%.

Coaxial feed: The same procedure was repeated with coaxial feed

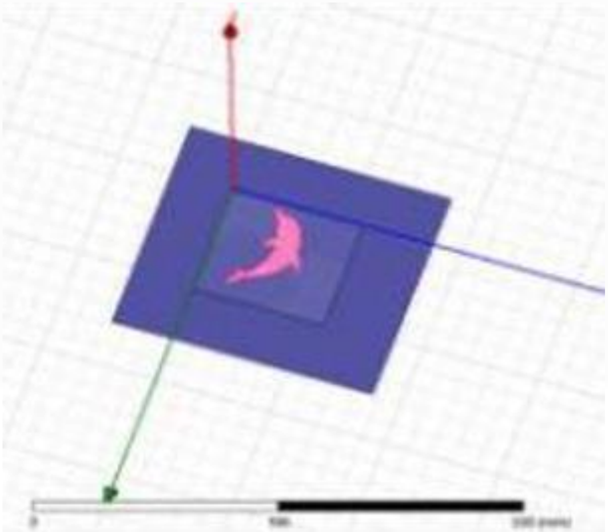


Figure. 16 Coaxial fed antenna with double ground structure

The gain of the antenna is now increased to 4.7 dBi, with an improved directivity of 5.02 dBi, the efficiency percentage was 95.17%. fig.16 shows the HFSS implementation of Double ground

b) Triple ground

Edge feed: The ground dimensions are now taken as 3L and 3W (approximately) w.r.t the dimensions of the substrate. This is expected to further increase the gain of the antenna. The gain of the antenna is now increased to 6.40 dBi, with an improved directivity of 6.69 dBi, with an efficiency percentage of 95.7%. fig.17 shows the HFSS implementation of Double ground for edge feed

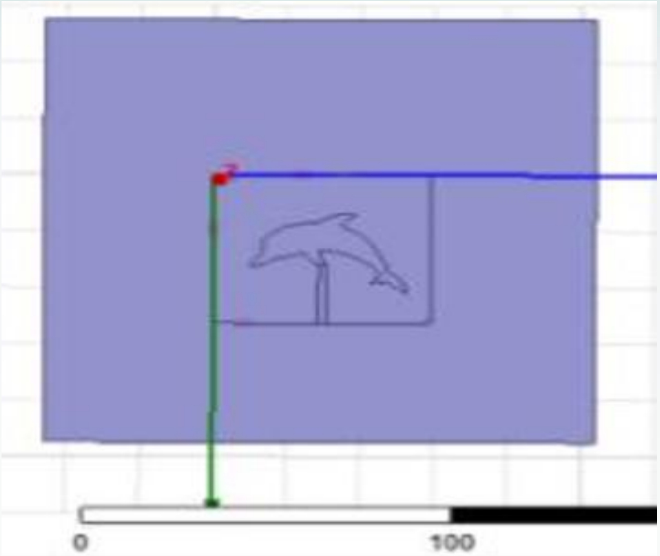


Figure. 17 Edge fed antenna with triple ground structure

Coaxial feed: The same procedure was repeated with coaxial feed. The gain of the antenna is now increased to 5.25 dBi, with an improved directivity of 5.54 dBi, with an efficiency percentage of 94.64%. fig.18 shows the HFSS implementation of Double ground for coaxial feed

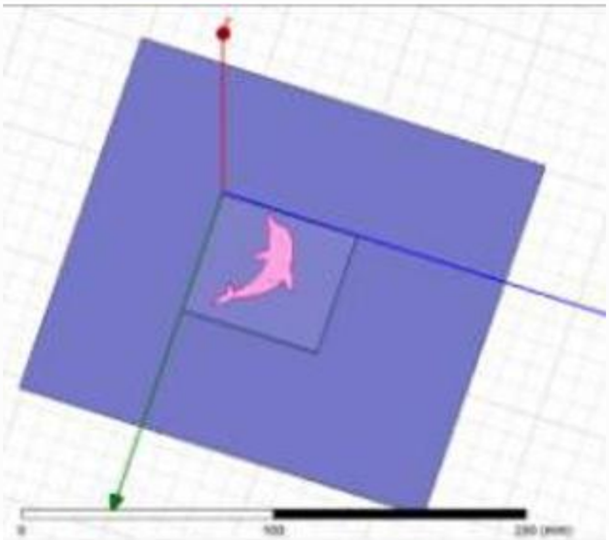


Figure. 18 Coaxial fed antenna with triple ground structure

CONCLUSION

The design of a dolphin-shaped patch antenna at WIFI frequency of 2.4GHz has been implemented. Various feed techniques such as edge and coaxial feeds have been designed and compared. Figure 18 portrays the comparison results of various feed techniques As the gain was one of the most important aspects of the design, it can be observed that the edge feed design with the triple ground variation rendered the maximum gain of 6.4dBi. The coaxial feed designed with the triple ground structure rendered a maximum gain of 5.25dBi. Feeds have been implemented at tapered positions such as the nose and fin of the dolphin and are observed to have increased gain. Further, ideal values for other antenna parameters such as VSWR, return loss, radiation efficiency, and directivity have also been obtained.

Parameter	Ideal values for a regular patch antenna	Dolphin shaped patch antenna (Edge feed)	Dolphin shaped patch antenna (Coaxial feed)
Gain	3-5dB	6.4dB (Triple ground)	5.25dB (Triple ground)
Return loss	<= -18dB	-23.28 dB (Primary design)	-21.16dB (Primary design)
Frequency dip	WiFi = 2.4GHz	2.4GHz (Optimised)	2.381GHz (Optimised)
VSWR	1 (Theoretical)	1.19	1.42
Efficiency	100% (Theoretical)	96.82%	92.5%
Directivity	5-8 dB	4.92dB	4.37dB

Figure 18: Comparison of feed techniques for the dolphin antenna

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