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Novel Design of High Performance of MIMO antenna for 5G Bio-Telemetry applications

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Abstract—A MIMO antenna with 4 L-shaped elements and 2 E-shaped elements for the ISM band and also for wireless communication is proposed in the paper. This antenna contains 4 L slots in an H manner and 2 E slots are cut in the H slot. The dimensions of this proposed antenna are 40*30*1.6mm^3. The substrate used in this antenna is an FR4 substrate with a permittivity of 4.4. The operating frequency of this antenna is 2.4GHz and 5.1GHz. All four L-shaped elements are placed in an orthogonal manner. The maximum gain is -4.4dB and the minimum gain is -16.2. The efficiency of this proposed antenna is 2.45. The radiation efficiency is 2.45dB and 75%. Fed can be provided using CPW. There is no need to concentrate on the isolation issue as we do not have several notches. This antenna is probably the most efficient antenna for the ISM band and also for wireless communication as a single-notch antenna is able to resonate at both frequencies.

Keywords- MIMO-Multiple input Multiple outputs, CPW- Coplanar waveguide fed, DG - Directivity gain.

I. INTRODUCTION

With a boom within the range of clients, the frequency allotment is getting undersupplied due to confined channel bandwidth. With equivalent frequency bandwidth the wide variety of customers cannot go beyond precise restrictions [1-4]. Also, the co-channel obstructions will increase as the number of customers increase. later than the advancement of excessive definition (HD) and Quadruple High Definition (QHD) video definition, it turns into pretty hard for the hand-held gadgets to ship or receive large extent motion. Pictures on 3G and 4G frequency channels [3] It turns into a need tohave wider bandwidthanda rapid statistics fee for rapid broadcasting of excessive first-class multimedia wirelessly from one terminal to the alternative. To cater for this problem, 5G frequencies are underneath research because of their wider bandwidth. [6-8].

The emergence of 5G is crucial in meeting the growing demand for high-speed data transmission and handling the rising internet traffic [9]. As the frequency bands used by previous generations of communication technology became overcrowded, the Federal Communication Commission (FCC) allocated new frequency bands specifically for 5G communication. In this context, this project aims to develop a MIMO antenna that operates within one of the FCC's designated bands for 5G communication. Leveraging the advantages of MIMO technology, this antenna design will not only enable high transmission rates but also provide the capacity to accommodate the increasing data traffic.

A number of research studies have recently reported on the design and performance testing of implantable antennas, including dual-/multiple-band antennas [10], [11], and ultra wide band antennas [4]. However, the single-input-single-output (SISO) designs used in each of these experiments had rather high sizes. Additionally, these designs' spectrum efficiency isn't very high in a heterogeneous human context. Wideband antennas for high-data-rate transmission have recently been introduced. However, because the tissues of the human body are frequency-dependent, the Electro-Magnetic (EM) properties have a significant impact on an antenna's performance at high frequencies [13–16]. For instance, when the operating frequency raises, the tissues become more conductive and loss. Additionally when the operating frequency rises, the route loss increases as well, sharply reducing the communication range, particularly for high-data-rate transmission [17]. Additionally, implanted devices' broad functioning may cause interference with surrounding frequency bands. Wideband antennas are therefore not a good solution to the SISO topology's low spectral efficiency issue. Multiple-input-multiple-output (MIMO) systems have recently been

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developed to increase the spectrum efficiency of implanted antennas in order to address this limitation. [18]. Furthermore, without using any additional power or frequency assistance, the MIMO system increases the number of channels (CC) [19]. The spectrum effectiveness is increased in MIMO systems by using several antennas that combine to function as both transmitter and receiver. In fact, studies have shown that MIMO is better suited to generate larger capacity gain than SISO systems for capsule endoscopic application. ISM bands are parts of the radio spectrum that are set aside globally for industrial, scientific, and medical (ISM) uses, but not for telecommunications activities. Medical applications like biotelemetry, industrial and commercial purposes. This antenna can be used for body-centric communication for various parameters. For scientific and industrial purposes like cordless phones, Microwave ovens, and baby monitoring which are operating in 2.4GHz frequency.[20] For commercial purposes like wireless communication with long rang and moderate data rates and for short ranges, it is higher data rates.

When there are many devices connected to a single antenna it will be difficult to operate in that situation. In such cases, we can operate at a 5GHz frequency this helps us to operate many devices using a single antenna. Commercial WIFI is also operated at 5GHz frequency[21].

This designed antenna helps in achieving perfect radiations at the required frequencies. The antenna is constructed using different elements subtracted on a single patch. The maximum gain obtained by this antenna is -4.4dB. The radiated power for this proposed antenna is 2.45dBW. This antenna can also be used in applications like body-centric communication because 2.45GHz of the ISM band is sufficient for body-centric communication.

II. LITERATURE SURVEY

Within the metallic printed structure due to the utilize of different radio ire the execution is influenced by the common coupling of radio wire. To decrease the coupling, a round and hollow dielectric resonator radio wire (CDRA) is presented in paper. In this paper the most center is with different recurrence headway of the CDRA by two diverse microstrip nourish lines.

Two strategies for accomplishing multiband in a round and hollow resonator radio wire are explored. The primary is to cut a space in a emanating component, and the moment is to in part ground it. Ready to see in fig.1 in part grounded DRA antenna.[18]

An 8-element MIMO antenna based on 5G connection is presented in the present investigation in [19]. The antenna is composed of two C-shaped spit ring resonators. To improve segregation, four lined spaces are offered in pairs and carved between the centres of two pieces. For applications like Bluetooth, WI-Fi, WiMAX, and WLAN, a spider-shaped antenna with multiple antennas is used. This antenna has a rectangular partial floor plane filled with a Y-shaped rear-plane and two spider-shaped radiation spots that are each individually driven by a microstrip feedline. The arms of the spider-shaped antenna enable multiband operation. Poor radiator correlation is accomplished due to the antenna's many bands. MIMO antennas in the shape of spiders are used for Bluetooth, Wi-Fi, WiMAX, and WLAN applications. This antenna has a rectangular partial floor plane filled with a Y-shaped rear-plane and two spider-shaped radiation spots that are each individually driven by a microstrip feedline. The arms of the spider-shaped antenna enable multiband operation. Poor radiator correlation is attained as a result of the antenna's various bands. [23].

Two patch antennas which are hexagon-shaped are divided by the use of a partial ground plane, with an E-shaped tree structure as well as a parasitic feature mounted in between them. TARC values are less than -10 dB, and separation exceeds 20 Db. [6] This paper presents an ultra-wide band MIMO antenna composed of two waveguide feeding staircase arrangements. For maximum solitary existence, a rectangular stub is angled at 45 degrees.[24].

The four-port MIMO super wide-band antenna with interference band mitigation is recorded in this manuscript. The antenna shown consists of four similar patches that are positioned orthogonally to one another. To keep the total antenna size down, a rectangular ground plane is put under the monopole structure of the radiating patch. Isolation is >20dB between the radiating elements. It is preserved without any form of isolation technique being used. [25] section.3 discusses on modeling of antenna parameters for new L-Structured E-shaped Antennas.

III.ANTENNA MODELLING

The antenna proposed in this paper is designed with different cuts on a single slot. This antenna is designed with three layers I.e the first ground layer is placed upon which the substrate layer is placed finally a path is placed on it. The dimensions of the antenna are 30*40*1.6mm^3. The substrate that we use here is FR4. The measurements of this substrate are width is 30mm, length is 40mm and the thickness is 1.6mm. The ground plate is also with same width and length.

L slots are cut in an orthogonal manner. This antenna contains two slots one upper and the other lower. Both the upper and the lower slots contain 2 L slots cut on them. The length of the upper L slot in the vertical direction is 9mm and in the horizontal direction is 4.4mm. Both the L slots are mirror images of each other. Similarly, the lower slot also contains 2 slots with lengths in the vertical direction are 10mm and in the horizontal direction are 5mm each. The two L slots are also mirrored images to each other and also mirror images to the upper slot. The width of each slot is 1mm.

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In the upper slot and in the lower slot in order to reduce the radiating area on the patch, we have cut two different E slots on both upper slots as well as on the lower slot. The E slots are cut with length in the horizontal direction of length 8mm and in the vertical direction its length is 4mm. Both the E slots are in 180-degree rotation and they appear to be like mirror images. The overall size of the patch in terms of length is 23mm and in terms of width is 24mm which is depicted in the figure.

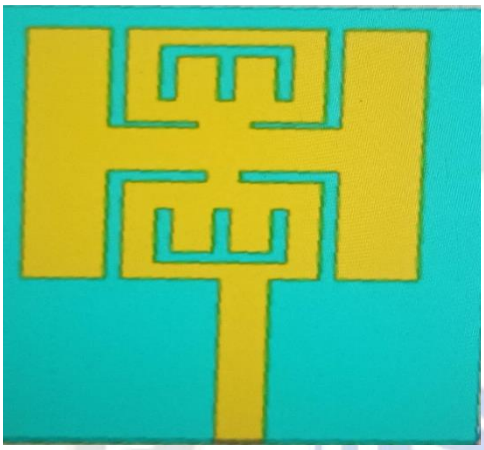

Figure: 1 Four L elements & Two E elements antenna

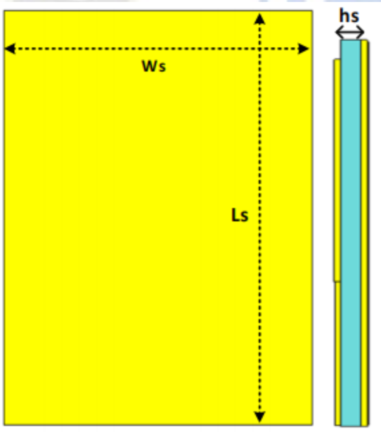

Figure: 2 (a) Back layer , (b)Side view

Table 1: All the values of the cuts

parameters	Values(mm)	parameters	Values(mm)
LS	40	WS	30
LF	15	WF	3
L1	23	W1	12
L2	10	W2	5
L3	9	W3	4.4
L4	9	W4	5
L5	8	W5	1
L6	4	W6	1
g1	0.5	g2	1
LHS	2	UHS	3.2

Here LS= length of the total antenna
WS=width of the total antenna
LF= length of the feed line
WF= width of the feed line
UHF= Upper horizontal slot
LHF= Lower horizontal slot

The remaining values are the lengths of the different slots that were cut on the patch.

$$Wp = \frac{\lambda_o}{2(\sqrt{0.5(\varepsilon_r+1)})} \quad (1)$$

$$Lp = \frac{c_o}{2f_o\sqrt{\varepsilon_{eff}}} - 2\Delta L_p \quad (2)$$

Theoretically, the values of the width and length of the patch can be calculated as mentioned in the formulas. ΔLp value and the εe f f values are to be calculated first. In order to calculate this, we have to more formulae

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(\frac{1}{\sqrt{1+12\frac{hs}{W_p}}}\right) \quad (3)$$

$$\Delta Lp = 0.421\mathrm{h}_s\frac{(\varepsilon_{eff}+0.300)(\frac{W_p}{hs}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W_p}{hs}+0.813)} \quad (4)$$

ΔLp = patch length change
εe f f = effective dielectric constant
hs= height of the antenna z direction =1.6mm
Lp= length of the patch=23
Wp=width of the patch=24
Co=λo=velocity of light=3*10^8.

According to the theoretical values, the antenna is designed. Accordingly, the antenna is simulated and the operating frequency is observed as 2.44 GHz and 5.1GHz. These two frequency ranges are the operating frequencies in the ISM band. The below graph shows the S11 parameter of the designed antenna. The fed line is provided using the CPW which means Co-planar wave-guide fed. Here in this antenna we are not only providing the ground for the feed line but also for the entire antenna its dimensions are 30*40*1.6^3mm. When the ground is just provided to the feed line, the antenna is not resonating in different frequencies. Keeping all these parameters in mind we have provided the ground plate to the complete antenna.

Radiation intensity can be calculated using the below formula theoretically

$$U = r^2 W_{rad} = B_0 F(\theta,\phi) \simeq \frac{r^2}{2\eta} \times \left[|E_\theta(r,\theta,\phi)|^2 + |E_\phi(r,\theta,\phi)|^2\right]$$

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Directivity D (θ , φ) $$D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}} = \frac{4\pi}{\Omega_A}$$

Maximum Directivity $$D_{\max} = D_0 = \frac{U_{\max}}{U_0} = \frac{4\pi U_{\max}}{P_{rad}}$$

Gain G (θ, φ) $$G = \frac{4\pi U(\theta, \phi)}{P_{in}}$$

Total antenna efficiency

$$e_0 = e_r e_c e_d = e_r e_{cd} = (1 - |\Gamma|^2) e_{cd}$$

Antenna Impedance

$$Z_A = R_A + jX_A = (R_r + R_L) + jX_A$$

IV.RESULTS

The final proposed antenna illustrated with dimensions is 40×30×1.6mm3 and is fabricated on FR-4 substrate. S-parameter (port1) characteristics are illustrated in below Fig: 3.

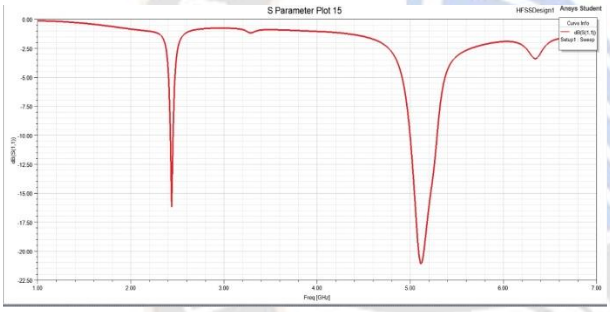

Figure: 3. S-Parameter Characteristics of MIMO Antenna with E & L Slots

Its dimensions are 40 x 30 x 1.6 mm3 and it is prototyped on a FR-4 substrate with a dielectric constant of 4.4. Wide impedance band (S11 10dB) of 17.9GHz from 2.4GHz to 5.11GHz was attained by the suggested antenna. The suggested 4-element Omni directional MIMO antenna may be verified for UWB applications because there is good correlation between the measured and simulated dispersion component properties in each case. The 3D polar plot of the element MIMO antenna is also observed and shown in Fig: 4 and 5.

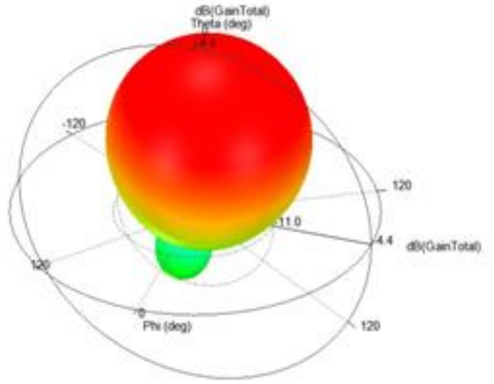

Figure: 4 Gain plot of the antenna

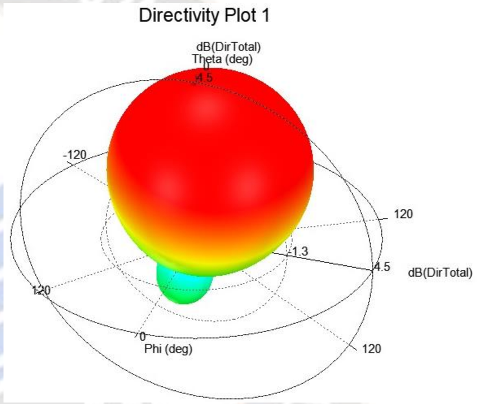

Figure: 5 Directivity plot of the antenna

The radiation pattern of MIMO antenna is also observed from which gain is maximum at 900can be concluded. Omni directional patterns are also observed in the antenna to make it efficient.

V CURRENT DISTRIBUTIONS

At the peak frequencies, the suggested 4-element MIMO antenna's surface current distributions are examined. The operational band wavelengths include 2.41GHz, 5.11GHz, 5.8GHz, and 10GHz for a two-element bidirectional MIMO antenna. The resulting opposite currents cancel each other out, resulting in relatively little net resultant radiation at peak frequencies.

Fig: 6&7 illustrates the surface current distribution at 2.41GHz and Fig: 8&9 illustrates the surface current distribution at 5.11GHz with individual ports excitation. It is evident from these figures that coupling among the elements M1, M2, M3 and M4 is very less and hence the proposed 4-element MIMO antenna hassuperior diversity characteristics.

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Figure: 6 E FIELD at 2.41GHz

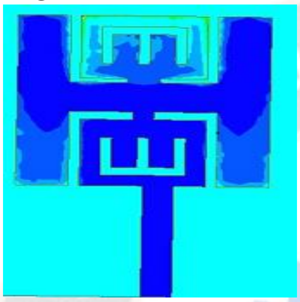

Figure: 7 E FIELD at 2.45GHz

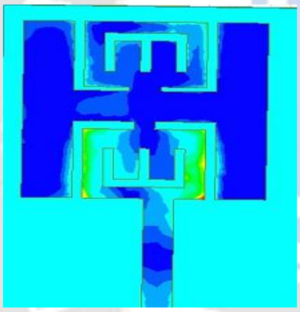

Figure: 8 E FIELD at 5.11GHz

VI: RADIATION PATTERNS

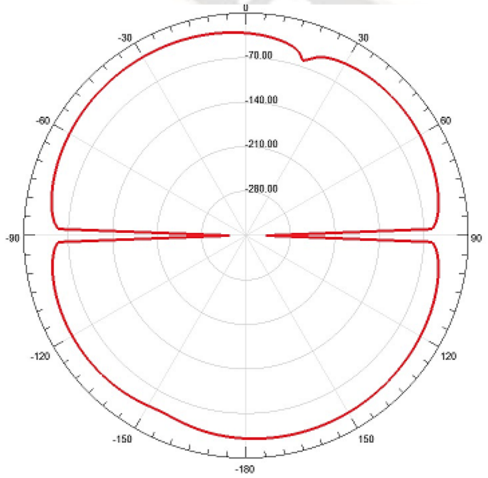

Figure: 10 X plane radiation at 2.45GHz and 180^0

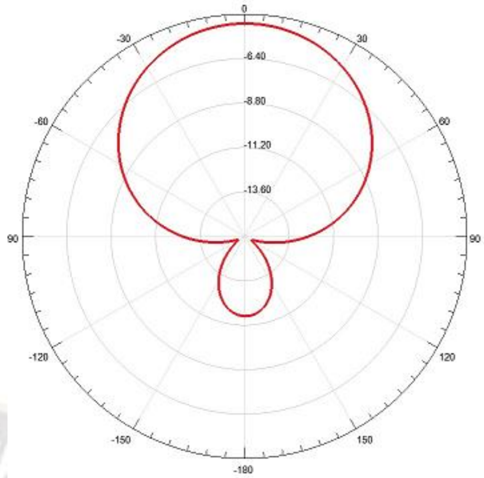

Figure: 11 Y plane radiation at 2.45GHz and 180^0

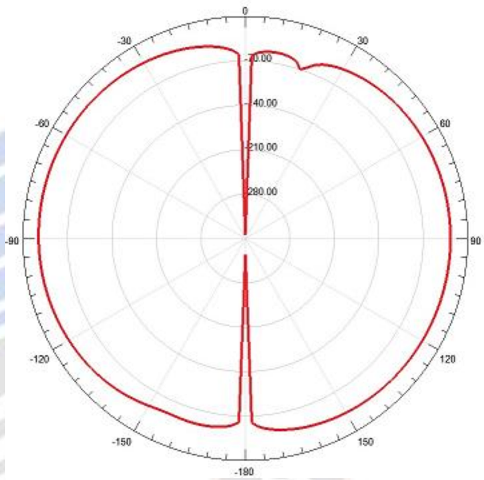

Figure: 12 Z plane radiation at 2.45GHz and 180^0

Size of the antenna is 30*40*1.6mm3, the length and width of the antenna after fabrication is shown in the Figure: 13.

Figure: 13 Front and Back View of Proposed Antenna

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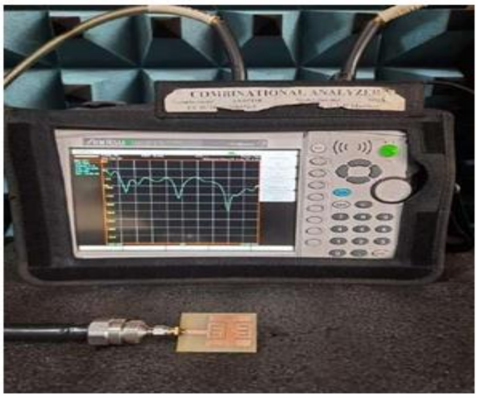

Figure: 14 Antenna Test with VNA

Figure 14 shows the antenna Measurement with a Vector Network Analyzer (VNA). A VNA is the device of choice to measure the impedance of an antenna, in order to access the electrical match of the antenna to its feed (usually 50 Ohm), and to devise a matching circuit to optimize this match so the operating frequency is obtained at 5.11GHz.

VI. ARTIFICIAL NEURAL NETWORKS

Artificial networks are the networks that are trending in the present technology. These are also simply called neural networks which work similarly to the biological networks. These networks are inspired by the animal neural networks where several nodes are interconnected to each other, i.e. from different parts or nodes of the body. In similar passion, these neural networks also contain several inter connected shown in below Figure: 15.

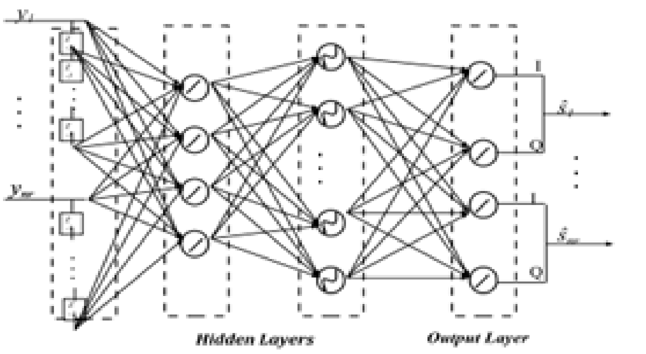

Figure: 15 ANN Basic Block Diagram

These networks are used in supervised learning. These networks are mainly designed to emulate the relationship's inset data. Artificial neural networks are the networks that are used to generate the predictive outputs of the given inputs. Any ANN network contains different layers involved in it. These layers are called hidden layers. Whatever the pattern of the input provided to the antenna all these patterns will be trained to the network and then the test case is provided to it. This helps in providing the predicted outputs to the given inputs. The algorithm used here is the Back propagation algorithm. The training algorithm that is used here is the Leven berg-Marquardt algorithm.

Table 2. Tabulated values of different lengths and widths

S.NO	LENGTHS	WIDTHS	FREQUENCY (GHz)
1	10	5.1	2.995
2	10.25	4.12	5.215
3	10.5	3.14	5.56
4	10.75	2.16	3.475
5	11	1.18	5.32
6	11.25	5.25	2.905
7	11.5	4.26	5.245
8	11.75	3.28	5.5
9	12	2.24	5.29
10	12.25	1.22	3.445
11	12.5	5.46	5.185
12	12.75	4.44	5.245
13	13	3.42	5.245
14	13.25	2.48	5.235
15	13.5	1.4	5.29
16	13.75	5.6	5.155
17	14	4.62	5.35
18	14.25	3.64	5.23
19	14.5	2.66	5.365
20	14.75	1.68	5.185
21	15	5.8	4.66
22	15.25	4.82	5.575
23	15.5	2.86	5.32
24	15.75	3.84	5.545
25	16	1.88	5.635
26	16.25	5.76	4.93
27	16.5	4.72	5.38
28	16.75	3.74	5.56
29	17	2.78	5.62
30	17.25	1.7	5.23

This ANN model here contains 2 hidden layers. The input is provided to the network that is Y1. All these inputs are passed to the first hidden layer, after calculating the mean at this stage this first hidden layer output is passed to the second layer as input. The inputs were providing for this antenna are different lengths and widths. The desired outputs are the corresponding frequencies. The Table: 2 show the values of the different lengths and widths and operating Frequencies.

Table: 3 Tabulated values for the test purpose.

S.NO	LENGTHS	WIDTHS	FREQUENCY(GHz)
1	17.5	5.34	5.215
2	17.75	4.32	5.005
3	18	3.34	5.335
3	18.25	2.36	3.31
5	18.5	1.38	3.16
6	18.75	5.9	5.14

7	19	4.92	5.53
8	19.25	3.94	5.335
9	19.5	2.96	5.545
10	19.75	1.98	5.275

Table: 4 Tabulated values for the test purpose

S.No	Length	Width	Desired Frequency(GHz)	ANN simulate Frequency(GHz)	Absolute error
1	12.25	1.22	3.4445	3.20	0.245
2	10.75	2.16	3.47	3.1372	0.3328
3	16.5	4.72	5.3800	4.9888	0.3912
4	15.25	4.82	5.575	4.7826	0.79
5	19.5	2.96	5.5450	5.1167	0.4283
6	16.5	3.79	5.5600	4.8033	0.3912
7	18	3.34	5.335	4.9376	0.3975
8	19.75	1.98	5.275	4.9339	0.3411
9	19.25	3.94	5.3350	5.2945	0.0405
10	19	4.92	5.5300	5.4672	0.0628

This proposed antenna is being operated at two different frequencies that are at 2.4GHz and 5GHz. So this antenna can be applicable in wireless communications also this can be applicable in biotelemetry because we just require 2.4GHz.

VII. CONCLUSIONS

This designed antenna can be preferred because of its high performance. This proposed antenna is operated at 2.44GHz and 5.1GHz frequencies. The maximum Directivity gain of this antenna is +4.5dB and the minimum -7.3dB. The maximum gain of this proposed antenna is -4.4dB and the minimum gain is -16.2dB. Compared to the antennas that are existing for biomedical applications and for wifi modules this proposed antenna in this paper achieves high gain and higher data rates. This antenna also achieves high performance with reduced size. So this proposed antenna is compatible with both Medical purposes and also for Wifi modules. Radiated power of this antenna is -9.1764dBW. Radiation efficiency is 0.1286. Total efficiency is 0.1209. Peak gain is -4.3997dB. System efficiency is 0.1209.

VIII. Compliance with Ethical Standards

Conflict of interest

The authors declare that they have no conflict of interest.

Human and Animal Rights

This article does not contain any studies with human or animal subjects performed by any of the authors.

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