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A M Shaped Multi-Band MM-Wave Wariable Antenna with DGS For 5G and Wireless Application

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ABSTRACT

The rapid growth of wireless communication systems and the increasing demand for higher data rates have fueled the development of millimeter-wave (MM-wave) technology for 5G and other wireless applications. In this review paper discuss the different multi-band MM-wave wearable antenna. Millimeter wave (mm Wave) bands attract large research interest as they can potentially lead to data rate of almost 10Gbits/sec and huge available bandwidth where as the microwave frequencies are limited to 1Gbits/s. This paper presents a comprehensive review of millimeter wave communications, frequency bands proposed by ITU, applications of mm Waves, advantages, limitations, challenges and research directions. Various antennas proposed by researchers for mm Wave applications are described in detail. The described models are analyzed and compared with common antenna parameters.

Keywords: Frequency reconfigurability, polarization reconfigurability, axial ratio bandwidth (AR B.W.), tuning range (TR), fractional bandwdith change (FBWC), PIN diodes, varactors.

I. INTRODUCTION

Fifth-generation (5G) networks have emerged as a result of the quick development of wireless communication technology, and they promise to completely transform the way we connect and interact. To meet the growing need for larger data speeds and low-latency applications, 5G networks have been designed to function in greater-frequency bands, such as the millimeter-wave (mm-wave) spectrum. A distinct set of difficulties arises when constructing transmitters for mm-wave bands because of wavelengths that are shorter and higher transmission loss.

Antenna a wide impedance spectrum, excellent radiation properties, multi-band operation, and ease of construction are just a few of the characteristics required for antennas in the 5G era or D2D communication. A number of structural modifications, including the use of defective ground structure methods (DGS) as well as electromagnetic band gap structures (EBG), may be made to printed

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antennas to meet these criteria. A linear (LP) radiation pattern is the norm for these antennas. In addition, they try to emit a circularly polarized (CP) wave of radiation. Satellites, sensors, radar, radio frequency identification (RFID), and navigation all use the CP antennas in some capacity. If a printed mono-pole antenna can make both (LP) and (CP) waves at the same time, it will make a lot of progress in its applications.

The dynamic development of wireless communication derives coexisted multiple standards that increase the demand for multi-functional antennas. Because of the large bandwidth available at mm-wave frequency, numerous applications such as wireless networks, mobile communication, and internet of things, wireless human monitoring systems, and machine-to-machine communications will be facilitated and become more prevalent in the band for the next-generation technologies. In the case of human monitoring systems, networks in the band are critical because they allow data transmission over small ranges of cellular systems.

The mm-wave band is part of the radio frequency spectrum between 30 and 300 GHz, corresponding to a free space wavelength ranging from 10 to 1 mm. As the photon energy is insufficient to take an electron from an atom, the radiation from this band is not ionized. Instead, the absorption of electromagnetic mm-wave energy by tissues results in the primary physiologic consequence of heat. An antenna designed using theoretically derived parameters does not provide sufficient performance to meet real-world communication requirements. It is a complex and time-consuming procedure to find the parameters of any antenna using simple intuition, experience, and practical measurements.

Frequency bands, antenna types, conformal structures, changeable systems, corresponding connections, energy structures, and their performance measurement must all be carefully taken into account while designing these antennas. Architects may produce designs that accomplish the demanding requirements of applications in 5G while keeping high efficiency as well as versatility by taking these factors into consideration.

In this paper, the main concepts and factors for linear multi-band mm-wave flexible transmitters geared towards 5G use cases. [10] [11]. Beginning with the identification of spectrum bands and antenna types suited for mm-wave operation, we will go over all stages of the antenna design process. We will discuss symmetrical integration's difficulties, such as retaining the greatest efficiency on surfaces that are curved or inside normal radomes.

The concept of changeable antennas and various techniques that can be used to dynamically modify the operational frequency bands will also be explored in this study. We'll go over the benefits and drawbacks of several tuning strategies, including using varactor diodes, MEMS switches, or other programmable ways.

The MSA (Micro strip Antenna) can be excited directly and indirectly. Directly by a homocentric probe or by a Microstrip line and indirectly by mistreatment magnetic attraction coupling or aperture coupling and a planar conductor feed, wherever there's no direct antimonial contact between the feed line and also the patch Feeding technique influences the input electric resistance and characteristics of the antenna, and is a vital style parameter

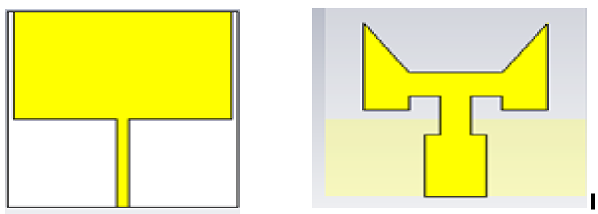

Fig 1 Monopole Micro-strip Patch Antenna for 5G Application

II. Literature Survey

Arebu Dejen et.al.(2023) - This research work presented, a dual band microstrip antenna optimization for mm-wave mobile applications. The engineered antenna was resonated at 39.1 GHz and 50.2 GHz whereas the reference model was resonated only at 39.0 GHz. To that purpose, a genetically modified micro-strip antenna performed admirably in the operating band of interest. The optimized antenna have achieved 1.6 GHz bandwidth and 7.6 dB gain at 39.1 GHz and 3.3 GHz bandwidth, 7.4 dB gain at 50.2 GHz center frequency. This work can also compared with other related works and the proposed reference antenna in mmwave frequency. The proposed antenna performs brilliantly in terms of bandwidth and other far-field properties, which makes the antenna practical for mm-wave communication [01].

R. Krishnamoorthy et.al. (2023) - This research work presented, a meta material-inspired four-port dual-band MIMO antenna is suggested for use in applications operating at mm-wave frequencies at 38 GHz. In a design with a common ground plane, the antenna achieves a measured port isolation of greater than 25 decibels without the need of any decoupling device. In addition to this, it achieves acceptable antenna gains at both frequency bands while also achieving satisfactory ECC and CCL diversity performance values. In addition, the suggested tiny MIMO antenna is planar and has dimensions of 15 mm X 15 mm, making it suitable for incorporation into many 5G wireless devices [02].

Amandeep Kaur Sidhu et. al. (2023) - This research work presented ,a hybrid fractal shaped two-port MIMO antenna with stub loaded ground plane has been presented in this manuscript for 5G wireless applications. The performance of the proposed hybrid MIMO antenna with different ground planes has been compared and it found that the antenna with modified ground plane is better in terms of improved bandwidth, reflection coefficient, and reduction in mutual coupling. The proposed MIMO antenna reveals the wider impedance bandwidth of 20. 4GHz (1. 0 to 21. 4GHz) and 6. 10GHz (23. 9 to 30GHz) with a fractional bandwidth of 182. 14% and 22. 63% respectively. Diversity performance parameters such as CCL, DG, ECC, and TARC are within reasonable limits. The proposed hybrid fractal MIMO antenna is a proficient candidate for 5G 3. 5GHz band (3. 4 – 3. 6GHz), 5G NR (New Radio) frequency bands (3. 3 – 5. 0GHz), LTE band 46 (5. 15 – 5. 925GHz), EU (European Union) 5G frequency band (5. 9 – 6. 4GHz), UWB applications (3. 1 – 10. 6GHz), 5G 26GHz frequency band, and the other applications in the obtained operational frequency range (1 – 21. 4GHz and 23. 9 – 30GHz) [03].

Muhammad Aamer Shahzad et.al. (2021) - This research work presented, A dual-band AMC-backed miniaturized antenna was designed for ISM frequency bands of 2.45 and 5.8 GHz. Roger 3003C (3, 0.0019) is used as a substrate to utilize its flexibility. The proposed antenna was designed with smaller dimensions of 28.81 × 19.22 × 1.58 mm^3. The antenna demonstrated an almost identical performance on a smart watch strap. A unit cell was designed having a size of 19.19 × 19.19 ×1.58 mm^3 to mitigate the effect of back radiation and to increase gain. The antenna‘s SAR value was tested and found to be within the FCC and ICINPR acceptable limits to ensure that the proposed antenna is safe to be used as wearable device. Because the antenna was designed to be wearable, the effect of bending was also evaluated and found to be an insignificant influence on antenna performance. The antenna is compact and has high gain, making it suitable for wireless data transfer and wearable electronics. The SAR values were calculated to be 0.19 and 1.18 W/kg at the designed ISM frequencies, and are less than the limits set by the FCC and ICINPR. Results of the bended analysis proved that bending along the x- and y-axes had a negligible effect on the antenna‘s performance, and the antenna showed excellent performance in the test of human proximity. The measured results of the fabricated antenna were comparable with the simulated results. Furthermore, the antenna achieved good measurement results and is a perfect candidate for smart watch wireless IoT applications. The antenna can be used to wirelessly transmit and receive data in wearable applications [04].

Bowen Lyu et.al. (2021) - This research work presented, A quasi-Yagi antenna for ultra-wideband mm-wave operation has been designed and analyzed numerically in this paper. The proposed antenna makes use of a relatively simple structure and small size to offer a huge -10 dB bandwidth ranging from 24-70 GHz. The antenna employs a flexible LCP substrate to ensure human body conformity while achieving good radiation coverage, high gain (greater than 6 dBi in most of the operating bandwidth) and greater than 70% of efficiency. These features make the proposed antenna a good candidate solution for ultra-wideband operation for 5G and beyond systems working at mm-wave frequencies [05].

Achilles D. Boursianis et.al, (2021) - In this research work presented, Three emerging swarm intelligence algorithms, namely the GWO, the WOA, and the SSA were investigated. To this end, several well-known test functions were utilized to assess the performance of the selected algorithms. Moreover, two different design cases, the design of a 50-element linear antenna array and the design of an aperture-coupled E-shaped patch antenna, were carried out to evaluate the operation of the SI Algorithms. To further estimate their effectiveness, two independent statistical tests were applied, the Friedman test and the Wilcox on signed-rank test. Numerical results demonstrated that the WOA outperforms the other algorithms in terms of average ranking as well as in 8 out of 10 well-known test functions. From the design case of the linear antenna array, we concluded that the best pSLL value was achieved by the GWO algorithm; yet the other SI algorithms exhibited satisfactorily competitive results. The employment of the WOA to the optimization problem of an aperture-coupled E-shaped antenna revealed the capability of the algorithm to design complex (a large number of parameters to be optimized) and compact (small size) structures as applications in antenna design optimization problems [06].

Arpan Desai et.al. (2021) - In this research work presented, a flexible transparent wideband four-element MIMO antenna with a connected ground plane is proposed with numerical computation and experimental measurement studies. The optical transparency is obtained using flexible conductive oxide material AgHT-4 and Melinex substrate. The radiating elements are in the form of circular stub-loaded C-shaped resonators, which are positioned in a carefully structured flexible Melinex substrate with an interconnected partial ground plane structured in the form of an L-shaped resonator, attaining an overall antenna size of 0.33λ× 0.48λ at the lowest operating frequency. The proposed antenna spans over a –10 dB impedance bandwidth of 2.21-6 GHz (92.32%) with an isolation level greater than 15dB among all elements. The maximum gain is 0.53dBi with a minimum efficiency of 41%, respectively which is satisfactory considering flexible structure and sheet impedance of 4• /sq. MIMO antenna parameters in terms of the envelope correlation coefficient (ECC) and diversity gain (DG) are also extracted where all the values are satisfactory for MIMO applications. The bending analysis of the proposed transparent MIMO antenna along the X and Y axis has revealed good performance in terms of scattering parameters and radiation pattern along with MIMO diversity performance. All of these technical points make the flexible MIMO antenna suitable for smart devices using sub-6 GHz 5G and WLAN band in IoT applications where visual clutter and co-site location issues need to be mitigated with the integration ease of conformal placement on the curved component/device surfaces [07].

Shahid M. Ali et.al. (2020) - In this research work presented, the demand for wearable technologies has grown tremendously in recent years. Wearable antennas are used for various applications, in many cases within the context of wireless body area networks (WBAN). In WBAN, the presence of the human body poses a significant challenge to the wearable antennas. Specifically, such requirements are required to be considered on a priority basis in the wearable antennas, such as structural deformation, precision, and accuracy in fabrication methods and their size. Various researchers are active in this field and, accordingly, some significant progress has been achieved recently. This article attempts to critically review the wearable antennas especially in light of new materials and fabrication methods, and novel designs, such as miniaturized button antennas and miniaturized single and multi-band antennas, and their unique smart applications in WBAN. Finally, the conclusion has-been drawn with respect to some future directions [08].

III.PROPOSED METHOD

Based on the operating frequency, 5G communication applications can be broadly separated into two categories: Microwave frequencies below 6 GHz and mm-wave frequencies over 6 GHz are the first and second frequency ranges for communication systems, respectively.

There exist some frequency bands where the atmospheric attenuation is comparatively lower. These frequency bands are 35, 94, 140, and 220 GHz. These frequency bands are the obvious choice for long-distance communication. There are other wavelengths in the millimeter-wave range where there is a lot of air attenuation. The radio frequencies in question are sixty, one hundred twelve, and one hundred eighty Gigahertz .They are employed for nearby communication.

In the research work present a modified truncated flexible T shape patch antenna, it is good step for flexible technology. The demand of flexible antenna is increasing rapidly due to its good properties such an easy to fabricate, easy to fit any communication device and also use in different places where require flexible technology structure. For the flexible technology in antenna use different type of substrates such as Grapheme copper indium gallium .The next generation of technology is based on flexible electronics, for the growth of this technology, proposed flexible antenna shows a vital role. Use the RT5880 Rogger substrate (r-2.2) to develop the 5G monopole micro-strip patch antenna. At 25 GHz, the antenna height is 0.125 mm, with a resonant frequency of 36.78 GHz

A. Microstrip Patch Antenna

Design of simple micro strip patch antenna require some mathematical calculation. The square patch is easily designed widely used simple to analyze and easy to manufacture. To design square patch following method are used.

Frequency of operation (f0): The antenna resonance frequency must be chosen appropriately. Communication systems using the frequency range of 1 to 6 GHz at different wireless frequency range. The selected resonance frequency for proposed design is 1 to 6 GHz. Di-electric constant of the substrate (εr): The di-electric constant of the substrate material plays an important role in the design of the patch antenna. So there is a compromise between size and performance of the patch antenna. In this thesis, use flexible Rogers RT duriod 5880 substrate with di-electric constant 2.2

Height of di-electric substrate (h): The height of the di-electric substrate must be less. In this thesis substrate height is taken 0.497 mm.

To design a rectangular micro-strip patch antenna according to parameters such as di-electric constant (εr), the resonance frequency (fo) and the height (h) are taken into consideration for the calculation of the length and width of the room.

Step 1: Calculation of Width (W)

For efficient radiator, the practical width which leads to a good radiation efficiency is:

$$W = \frac{c}{2fo\sqrt{\frac{\varepsilon r+1}{2}}}$$

Where c is the speed of the free area of the light

Step 2: Di-electric Coefficient value calculation (ε reff)

The effectiveness of the di-electric constant (ε reff), using the same geometry (W h), but is surrounded by a homogeneous di-electric ε reff the effective permittivity whose value is determined by assessing the ability of the fringe field.

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2} \; [1 + 12\frac{h}{w}]^{1/2}$$

Step 3: Effective Length Design Equation (L eff)

IV.

$$Leff = \frac{c}{2fo\sqrt{\varepsilon reff}}$$

Step 4: Actual Length of Patch (L) Equation

The length of patch calculated by given below equation

V. $$L = Leff - 2\Delta L$$

Step 5 : Calculation of length of the micro-strip feed line

Free-space wavelength (λo):

$$\lambda o \;=\; c \,/\, f$$

VI. SIMULATION RESULT

The simulation and result of the proposed antenna. In this proposed antenna flexible substrate technique as well as multi-layer substrate are used for enhance the bandwidth, return loss (S-11) and other properties of antenna. The proposed multi layer bow tie patch antenna is design for Giga hertz (GHz) frequency range up to 40 GHz. The proposed frequency where this frequency range accommodate in the various band in between 10 GHz to 40GHz in between the Wi-FI and Wi-Max range. The multi-layer flexible patch based microstrip patch antennas have gaining importance in the applications of 5G communication and internet of things application. The simulated results such as Return Loss (S11), VSWR and Radiation Pattern, Bandwidth and Mesh field. The details of the result antenna designs and simulated results are presented.There is good agreement by the simulated results of software CST. Design has been simulated. All the comparable results of the software's are achieved by simulation and approximation for proposed design

A. CST Design environment

The basic view of CST software. The proposed design in the CST 2016 version. The system for designing used is core i-5 4thG processor. The main part of proposed design is substrate (S), patch (P), ground (G) and feeding system (Waveguide feed). In this design using a wave guide wave port for feeding system. In general there are two type of feeding systems first one is wave guide port and second one is the wave guide port.

CST contain different window for different task. Navigation tree shows the different design parts and different result parameters of the antenna. The complete design simulated on Time domain analysis.

B.Result Parameters

There are different parameters of antenna which are utilized to examine the efficient functioning of the antenna

1 .Return Loss:

Return loss (S-11) is an important parameter for performance measurement of antenna that is measure is DB. It is the Return loss measure in Db. It is defined as the ratio of output verse input power received by transmitter. The return loss is expressed by –

$$S11\ dB \;=10\log{(Pr/pi)}$$

P_r = Received power of the antenna

P_i = input power of the antenna

2. Voltage Standing Wave Ratio (VSWR):

The VSWR is also an important parameter for analysis of antenna design. Ideal value of VSWR 1 to 2. For particle system is near to 2. In ideal case VSWR is 1.

$$VSWR = (1 + ד/1 - ד)$$

Where ד is the reflection coefficient of the antenna

3. Gain: Gain is representing as a ratio of radiation intensity in particular direction to total input power transmitted by antenna.

$$Gain\ G \;=\; 4\pi\ (\text{ radiation intensity/ P total})$$

$$GdBi = 10.\log 10(G)$$

$$GdBd = GdBi - 2.5\ dB$$

Where G is denoted Gain, G_{dBi} is the isotropic gain of antenna. There are the major result parameters. Now discuss the result outcome of proposed method. Also compare the proposed method with different previous methods.

4. Bandwidth (B.W)

Bandwidth of the antenna is an important parameter for result measurement. In the below equation shows the bandwidth of antenna

$$B.W. = \ (fH - fL/\ fc)\ \times 100$$

$$fc\ =\ (fH + fL/\ 2)$$

f_H = Higher frequency

f_L = Lower frequency

f_c = center frequency

5. Number of bands

The total number of bands of any antenna is shows that the working of any antenna in the different range.

C. Results of Proposed Design

Table -1 Antenna Parameters for Design Assumed

S.No.	Antenna Parameters	Parameters
1	Dielectric Constant of the Substrate (εr)	εr – 2.2
2	Height of the substrate (h)	1.6 mm
3	Width of Ground Plan	12 mm
4	Patch Dimension	4mmX6mm
5	Length of the strip Feed Line	1X5 mm

1 Return Loss (S-11) Analysis ;- In the below figure cleanly see that the return loss (S-11) of proposed antenna that is measure in below -10DB that is -42.187Db.

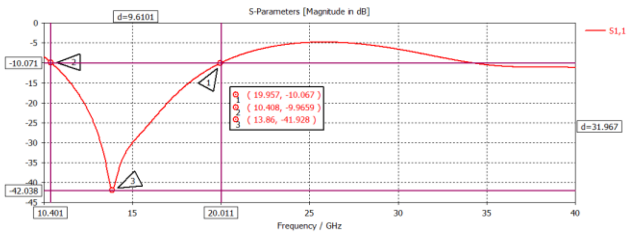

Fig. 2 Return Loss (S-11) -10DB that is -41.928 Db.

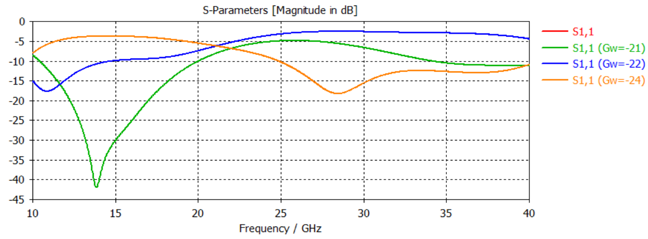

Fig. 3 Return Loss (S-11) result of proposed design on 24 and 21 mm

2 VSWR Analyses

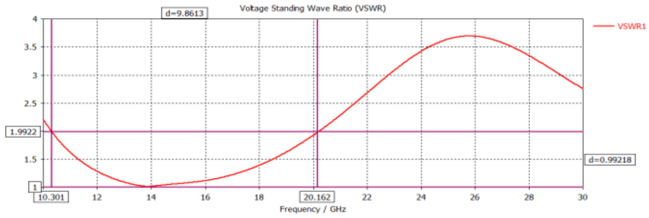

Fig. 4 VSWR of proposed design

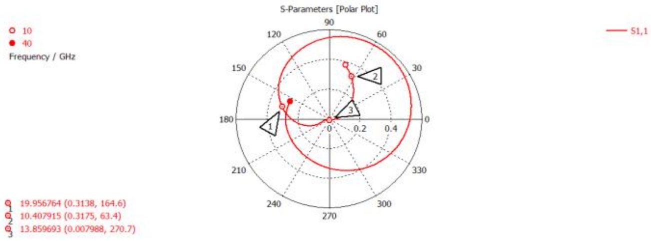

Fig. 5 Shows Polar plot of proposed antenna

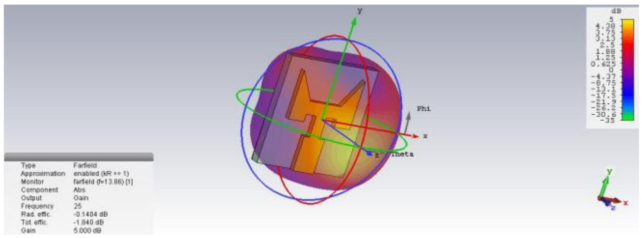

Fig. 6 (a) shows the gain plot at 25GHz (5db)

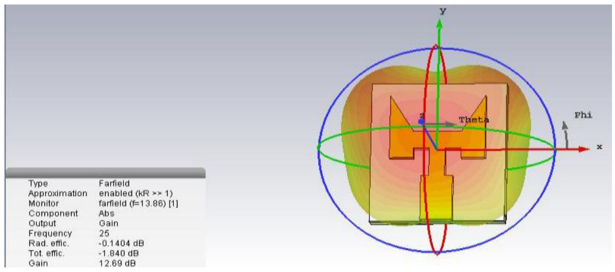

Fig. 6 (b) shows the gain plot at 25GHz absolute (12.69dB)

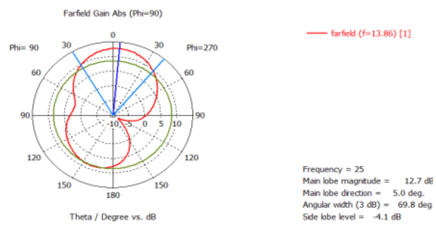

Fig. 6 (c) Show the Main lobe and side lobe of proposed antenna

4 Far Field Pattern

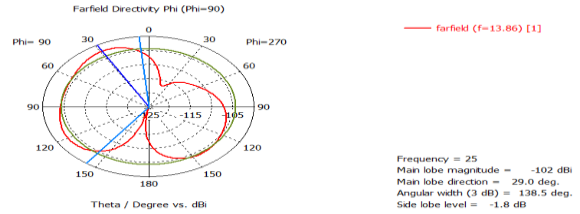

Fig. 7 Far field pattern 2D

5 Current Flow Analysis

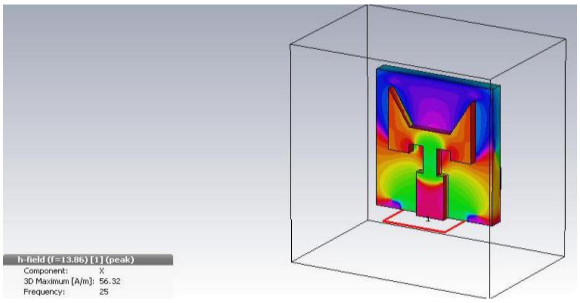

Fig. 8 Current flow analysis of proposed antenna

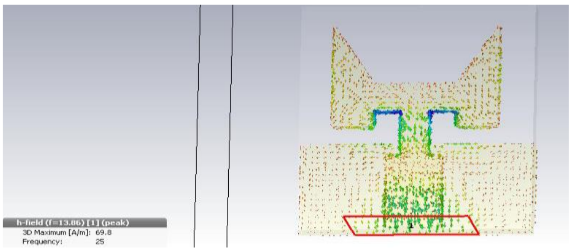

Fig 9 Current flow vector diagram

Table -2 Result comparison of proposed method with base paper

Year/Reference	Geometry	Frequency range (GHz)	Return loss(S-11) in dB	No. of bands	Bandwidth (B.W.)	Size in length and width	Application
2023/ Proposed	**T Shape with Octa-gone Cut (Proposed)**	10-40	-42 & -18.33	9.532 & 14.91	2	4mmX6mm	5G communication system
2022/ [01]	Square mono-pole antenna	3-9	5GHz = - 32	1	3.0 GHz	10mm×19.5mm	Breast cancer detection
2020/ [02]	T Shaped Monopole	2.3 – 5.7	2.6GHz= -175.6GHz =-20	2	0.6 GHz and 0.45 GHz	7.3m.m×3.5m.m	Internet of things (IoT)
2019/ [03]	Monopole with Fork Slotted EBG	3.1-10.6	3.9GHz=-28	1	7.4GHz	20 mm.×25mm	Wearable Application
2018/ [04]	Monopole Antenna	0.69 – 3.35	---------------	1	4.86 GHz	11.5m.m.×19.2mm	Wi-Fi and Wi-MAX
2017/ [05]	Mushroom-Shape Monopole with DGS	12-33	13.6GHz = -24.9222.1GHz =-1628GHz=-11.6	3	6.6 GHz, 1.5 GHz, 2 GHz,	8.5m.m ×10m.m.	5G and Wi-Fi Applications
2017/ [06]	Omni directional circularly polarized	27-28.5	27.5 GHz = -17	1	1.5GHz	3.44 mm × 3.44 mm × 1 mm	5G cellular system

V. CONCLUSION

An RT 5880 substrate is to be used for antenna design in this project. By comparing the suggested design to the basis article as well as earlier methodologies, the new design achieves superior results. Antenna designers will find Duriod to be a useful ally. Antennas are shown to cover the frequencies of 9.5 to 14.91GHz. As well as being able to work in the WLAN range, these Micro strip Patch Antennas can also be used for high-power radio applications as well as for military use. The suggested architecture may be used for a variety of 5G gadgets. This is because the patch antenna covers a wide variety of frequencies and bands. Apply the suggested antenna design to military antennas since multi-band antennas are needed in the defence system. attempt to expand the frequency range; the final design now suggested works in the 10 to 40 GHz range of frequencies. an attempt to compensate for the suggested design's VSWR and return loss shortcomings.

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