International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 11 Nov 2023, pp: 420-423 www.ijaem.net ISSN: 2395-5252

Octagon Patch Antenna with Dumbell shaped patch for Millimeter Wave Applications

K. Vijaya Lakshmi[1], J.Gurunadhan[2], V.Vijaya Lakshmi[3] , K Manjunath[4]

ECE Department, AITS, Tirupati, Tirupati, India
ECE Department, AITS, Tirupati, Tirupati, India,
ECE Department, AITS, Tirupati, Tirupati, India,
ECE Department, SV University, Tirupati, India

Date of Submission: 01-12-2023 Date of Acceptance: 10-12-2023

ABSTRACT— In this paper, a octagon patch antenna with Dumbell shaped patch is proposed for millimeter wave applications. The proposed antenna has an operating frequency of 23.5, 27GHz which achieved return loss and gain of -19.13dB, -22.64 dB and 5.27dB, 5dB respectively. This antenna is designed using substrate FR4 with dielectric constant of 4.4 and loss tangent (tanδ) of 0.002. This antenna has a compact size of 25x15x1.6mm^3 and have a radiation efficiency of 73.5%.

Keywords— Millimeter wave, Fifth generation (5G), High Frequency Structure Simulator (HFSS), Internet of Things (IoT), Flame Retardant (FR4).

I. INTRODUCTION

Modern Society have a huge requirement of Huge Bandwidth and high speeds. Modern communications requires high speed data transfer and receive. Microstrip patch antenna fulfills all these requirements. The Communication systems evolved from 1G, 2G, 3G, 4G to 5G. 5G has major features like IoT, Self driving Cars Smart Environment, etc. A suitable Microstrip patch antenna is needed for data transmission and reception with faster data rates. The 5G mobile networks are started in the year 2020 [1]. 5G frequency bands are classified into three bands, low-band (less than 1GHz), mid-band (sub-6 GHz) and high-band (milllimeter-Wave) [2]. In order to get more bandwidth, the telecommunication industries have to concentrate on higher frequencies which has abundant spectrum. Rectangular and circular patch models are explained in reference [3]. The researchers have proposed lot of ways like arc shaped strips to increase the gain, increase the radiation efficiency and to obtain band notched characteristics [4], complimentary split ring resonator antenna [5][6]. Different shaped antennas performance comparison is exhibited out [7] [8].

The proposed antenna is designed in Ansys HFSS software because it is more accurate and perfect. In HFSS Finite element method is used to solve the designed antenna.

II. ANTENNA GEOMETRY

A monopole antenna with octagon patch is designed with radius 4mm and chosen various parameters as shown in Table I. Based on the antenna geometry which is shown in Table I the antenna with 25x15x1.6mm^3 dimensions is designed in HFSS. A substrate FR4 whose dielectric constant is 4.4 with thickness 1.6mm is sandwiched between the ground and patch which forms a microstrip patch antenna.

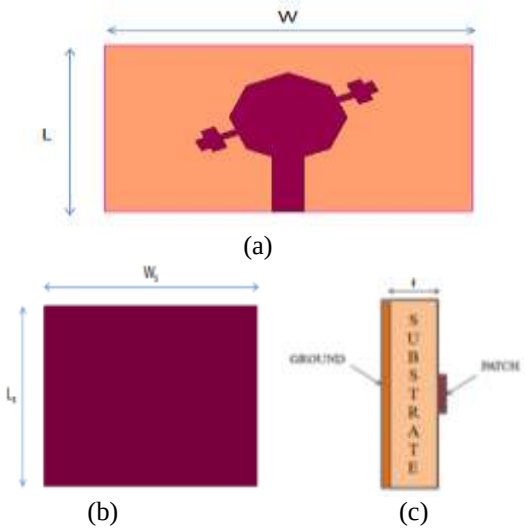

Fig. 1.octagon patch antenna with Dumbell shaped patch
(a) Top view (b) Backview (c) Side view

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 11 Nov 2023, pp: 420-423 www.ijaem.net ISSN: 2395-5252

A long rectangular patch of length 10mm and width 0.5mm is introduced at the center of the octagon horizontally with lightly tilted angle. Two small rectangular patch of height 2mm and width 1mm is introduced at two edges of long rectangular patch. The resultant antenna is a octagon patch antenna with Dumbell shaped patch which is shown in above Fig.1.

TABLE I. ANTENNA PARAMETERS

Parameters	Dimension(mm)
Ground Width (W)	25
Ground Length (L)	15
Feed Line Width (W_f)	2.15
Feed Line Length (L_f)	5
Substrate Thickness (t)	1.6
Dielectric constant of the	4.4
Substrate Width (W_s)	25
Substrate Length (L_s)	15
Octagon Radius (r)	4

Various methods can be implemented to increase the gain. A slot in antenna patch the can increases gain [9][10]. On Ground side by creating defective ground plane the bandwidth increases [11]. An elliptical slot patch radiator with sub-6GHz frequency range for wider band response is designed [12]. A 30GHz square patch microstrip antenna with for 5G network is designed which shown high gain, great radiation efficiency, good VSWR and reasonable bandwidth [13]. A Circular slot circular microstrip patch antenna with improved bandwidth rectified the issues of narrow bandwidth [14]. A Circular microstrip patch antenna is implemented on space crafts and microwave circuitry using cavity model [15]. The mutual coupling reduction can improve the doppler radar antenna performance.

III. ANTENNA DESIGN PROCEDURE

To design a octagon patch antenna with Dumbell shaped patch the radius of the octagon patch is calculated using equation (1) [3].

$$r = \frac{F}{\{1 + \frac{2h}{\varepsilon_r \pi F}(\ln\left(\frac{\pi F}{2h}\right) + 1.7726)\}^{1/2}} \qquad (1)$$

Where

$$F = \frac{8.791 * 10^9}{f_c\sqrt{\varepsilon_r}} \qquad (2)$$

Due to fringing effect, the patch becomes larger electrically, So, the effective radius of patch is utilized and is given by

$$r_e = r\{1 + \frac{2h}{\varepsilon_r \pi F}(\ln\left(\frac{\pi F}{2h}\right) + 1.7726)\}^{1/2} \qquad (3)$$

ε_r- Substrate Dielectric constant
h- Substrate Height
f_r- Resonant frequency
r- Patch Radius
r_e- Effective Radius

The frequency fc=25 GHz is the desired center frequency of the antenna which is to be designed. The proposed antenna is designed using substrate FR4with relative permeability εr = 4.4 and thickness t=1.6mm. These values are substituted in the above equations. After substituting we get a radius of 1.67mm for operating frequency 23.5GHz, 27GHz. In order to get more gain, the parametric analysis is carried out for radius. The radius 4mm has given good results. So radius 4mm is chosen.

IV. RESULTS AND DISCUSSION

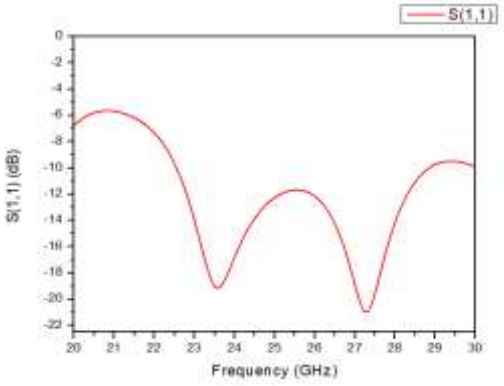

Fig. 2. Antenna Return Loss

After designing and simulation, the return loss S11 of -25.6dB is obtained which is shown in figure 2. The operating frequency is 23.5GHz, 27GHz.

The proposed antenna's VSWR is shown in the Fig. 3 below. It has achieved required VSWR for the 25MHz operating frequency.

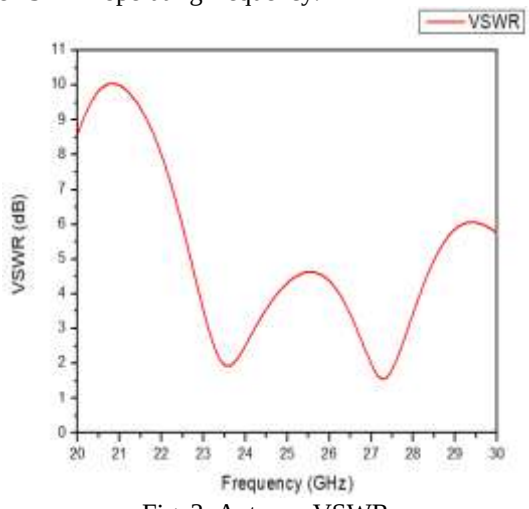

Fig. 3. Antenna VSWR

International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 11 Nov 2023, pp: 420-423 www.ijaem.net ISSN: 2395-5252

The gain plots are shown in Fig. 4. The designed antenna has a overall gain of 5.05dB. Fig. 5,6 shows the designed antenna's simulated radiation patterns at 23.5GHz and 27.2GHz .

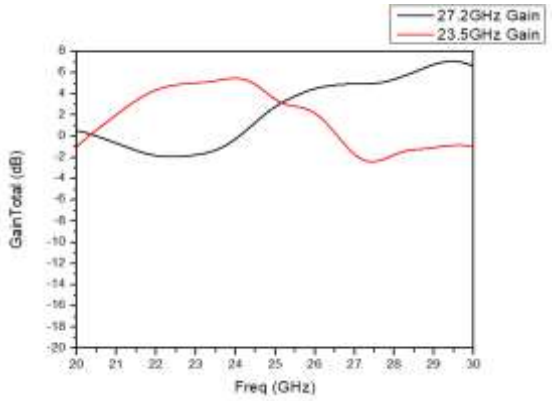

Fig. 4. Antenna gain

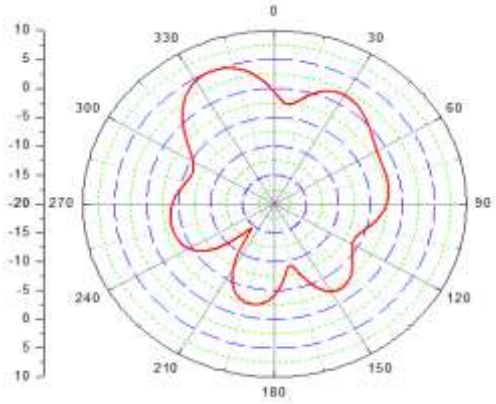

Fig. 5. Radiation Pattern for 23.5GHz

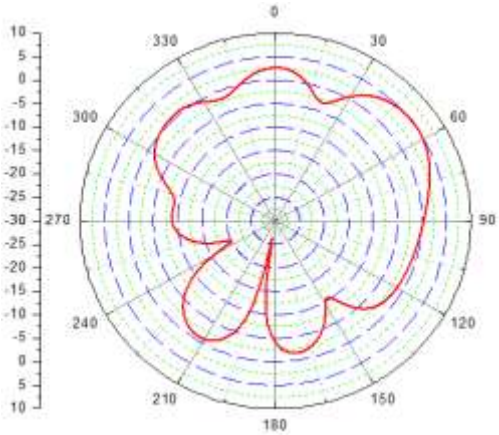

Fig. 6. Radiation Pattern for 27.2GHz

The gain of the proposed antenna is 5.27dB and 5dB.

TABLE II. ANTENNA RESULTS

Parameters	**Results**
Operating Frequency	23.5GHz,
VSWR	1.94, 1.56
Peak Gain	5.27dB, 5dB
Radiation Efficiency	73.5%
Front To Back Ratio	21.40
Return Loss	-19.13dB, -

Table II shows the simulated results of the 23.5GHz, 27GHz octagon patch antenna with Dumbell shaped patch for various parameters like bandwidth, gain, Radiation efficiency, front to back ratio and return loss. The IEEE allocated 18 to 27GHz frequency range as K-band. So, this antenna is best suited for K-band applications. United States allocated different frequency spectrums for different applications. In this, the 24GHz spectrum is allocated for ISM Services. Since this antenna allows 24GHz spectrum, it can be used.

V. CONCLUSION

In this Paper, a octagon patch antenna with Dumbell shaped patch is designed and simulated at 23.5GHz, 27GHz. The use of Dumbell patch increased the gain. This antenna achieved radiation efficiency of 73.5%. This antenna can be utilized in Inter satellite services, Fixed satellite services, Mobile services, Earth Exploration Satellite services Scientific, Industrial and Medical services. This antenna is very useful in this digital world whose thirst for data rates is very much high.

REFERENCES

[1]. Osseiran Afif, Monserrat F. Jose, Marsch Patrick (2016), "5G Mobile and Wireless Communications Technology".

[2]. https://www.gsma.com/spectrum/wp-content/uploads/2021/04/5G-Spectrum-Positions.pdf,"5G Spectrum GSMA Public Policy Position March 2021".

[3]. Constantine A. Balanis, "Antenna theory analysis and design," John Wiley & Sons, Inc., Publication Third Edition, 2015.

[4]. J.H. Yoon, S.J. Ha, Y.C. Rhee, "A novel monopole antenna with two arc-shaped strips for WLAN/WiMAX application", J. Electromagn. Eng. Sci. 15, 2015, 6–13.

[5]. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya, "Compact Band Notch Ultra-Wide Band MicrostripAntenna for Short distance wireless Applications", The International Conference on

InventiveCommunication and Computational Technologies (ICICCT 2017) sponsored by IEEE, organized on 10-11, March 2017 by the Ranganathan Engineering College at, REC Kalvi Nagar, Thondamuthur,Coimbatore, India. DOI: 10.1109/ICICCT.2017.7975161

[6]. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya, "Compact CSRR Etched UWB Microstrip Antenna with Quadruple Band Refusal Characteristics for Short Distance Wireless Communication Applications", Progress in electromagnetics research letters, Volume 82, 139-146, 2019.

[7]. Dr. Jabir S. Aziz , Haider A. Sabti, "Design of a Dual Band GPS Micro-strip Patch Antenna", International Journal of Electrical and Electronics Research, Vol. 2, Issue 2, pp: (92-95), Month: April - June 2014.

[8]. Shailender Gupta, Bharat Bhushan, Sanjeev Sharma and Preet Kaur,"Performance Comparison of Micro-strip Antennas with Different Shape of the Patch", InternationalJournal of u- and e- Service, Science and Technology, Vol. 6, No. 3, June, 2013.

[9]. Ragini Mishra, R. Kalyan, Y. M. Dubey, "Miniaturized W slot ultra-wide band microstrip antenna for short distance communication", The International Conference of Electronics, Communication and aerospace technology (ICECA) sponsored by IEEE, organized on 20-22, April 2017, Coimbatore, India. DOI: 10.1109/ICECA.2017.8212828.

[10]. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya, "Novel UWB Microstrip Antenna with Dual Band-Notched characteristics for Short Distance Wireless Applications", Journal of engineering and technology.

[11]. R. Kalyan, Dr. K. T. V. Reddy, Dr. K. Padma Priya, "Compact UWB Microstrip Antenna with Quadruple Band-Notched characteristics for Short Distance Wireless Telecommunication Applications",International journal of engineering and technology, Volume-7, Number-1, 2018, DOI:10.14419/ijet.v7i1.8822.

[12]. Ankush Kapoor, Ranjan Mishra, Pradeep Kumar, "Wideband miniaturized patch radiator for Sub-6 GHz 5G devices", Published by Elsevier, September 2021, doi.org/10.1016/j.heliyon.2021.e07931

[13]. David okwum, Joshua Abolarinwa, Opeyemi Osanaiye,"A 30GHz Microstrip Square Patch Antenna Array for 5G Network",International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS)-2020, IEEE10.1109/ICMCECS47690.2020.247138.

[14]. [14] Ayyappan , Jagadish Chandran, Manoj.B2 , "Design and Analysis of Circular Microstrip Antenna at 5.8 GHz with Fr-4 Substrate", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 5, Special Issue 4, March 2016.

[15]. [15] B. J. Kwaha, P. Amalu, O. N Inyang, "The Circular Microstrip Patch Antenna – Design And Implementation", IJRRAS, Vol. 8, Issue 1, July 2011.