OCTAL SHAPE SLOTTED PATCH ANTENNA FOR MILLIMETER WAVE 5G BAND

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ABSTRACT

A slotted octal shape microstrip patch antenna is presented for millimeter wave applications. The prospective octal shape microstrip patch antenna consists of a slotted patch radiator and defected ground plane. The presenting antenna is constructed on an over-all foot print of 6×6.25×0.787 mm^3 Roger 5880 substrate whose relative dielectric constant (ε_r) is 2.20 with loss tangent ($\tan\partial$) of 0.0009. The presented antenna is optimized for the frequency range of 26 GHz to 28 GHz ($S_{11} \leq$ -10 dB) and demonstrates 6.9 dBi gain at operating band. The developed antenna shows wide impedance bandwidth (2 GHz) that is suitable for new 5G radio frequency bands for millimeter-wave communication. The prospective design is highly miniaturized and low profile which eases its integration with the modern communication gadgets for millimeter wave applications.

Index Terms—Millimeter-wave, 5G, Octal shape, slotted patch, 26-28 GHz.

I. INTRODUCTION

Due to fast development of wireless communication and demand of numerous bandwidths with the ultrafast speed, 5th generation comes in picture to fulfill the demand of current era. Millimeter-wave offers wide range of frequency that can be used in various fields such as in automotive radar, Telecommunication, Medical, Business, sport and more. The millimeter-wave range is above from microwave and bellow from infrared waves. According to ITU (International Telecommunication Union) standardization 2019 the frequency range of mm-wave is 24 GHz to 100 GHz, so that the size of antenna is being minimized for this frequency range. According to users demand, the researchers have been proposed various compact and flexible antennas with sufficient bandwidth for mm-wave applications such as Patch antennas, aperture coupled antennas, slot antennas, dipole antennas and array antennas [1]-[4]. In future, communication with mm-wave the allocated frequency range is 24 GHz to 86 GHz [5]. In mm-wave applications till date various antennas have been designed for different frequencies like 24 GHz, 28 GHz, 38 GHz, 60 GHz, and 77 GHz [6]-[11]. Although numerous advantages of mm-wave band the absorption of oxygen in the path is drawback [12] of the 5G antennas. In mm-wave technology the problem of spectrum congestion is resolved due to the new development of 5G communication [13]. In wireless communication, there are various factors that can affect the performances of the microstrip patch antennas; shape of the patch is one of them most important factors [14]. In present scenario of wireless communication, size reduction is the major issue to design a microstrip patch antenna [15]. The purpose of this paper

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is to design and analysis of a simple and miniaturized patch of the antenna for mm wave application. In this design line feed is used due to less space consumption and easy to feed for compact antenna. This paper presents a reduced patch size 6×6.25×0.787mm^3 on Rogers substrate. The dielectric material rogers is best for mm-wave application, it is Glass microfiber Reinforced PTFE composite produced by Rogers corporation. RT Duroid is low loss tangent, excellent chemical resistance and easy in fabrication. In this article reader can understand the flexibility of the patch for the range of mm wave application. In this article, a new shape of patch antenna is proposed for 26 GHz to 28 GHz with improved gain and other parameters. The microstrip patch antenna is suitable for wireless communication system due to light weight, compact and integrated into the circuit. Proposed octal shape microstrip patch antenna for mm-wave offers better performances as compare to the traditional MPA. The main attractions of this antenna design are compact, low profile, enhanced gain, and resolve the problem of spectrum congestion that for latest demand of the users.

II. ANTENNA GEOMETRY AND DESIGN

In this work, an octal shape microstrip patch antenna is proposed for mm wave application on HFSS-17 software. This new slotted octal patch shape is designed on Rogers 5880 whose dielectric constant is 2.2 and thickness 0.787 mm. The overall dimensions of this work are given in table I and respective diagrams of proposed designs are shown in figure 2. The patch parameters control the resonance frequency due to fringing effect at the edge of patch [22]. The patch dimensions are calculated using basic equations of antenna design for mm-wave frequency band. Firstly a 3×3 mm^2 square shape patch is designed on Rogers 5880 substrate. This square shape patch antenna polarized for 27 GHz with gain of 6 dBi and return loss -20 dB. After that this designed is modified by a octal shape on the same substrate and this octal shape antenna is polarized for 26 GHz to 28 GHz with gain of 6.9 dBi and maximum peak in return loss -24 dB. The microstrip patch design minimizes the excitation of other undesired modes and these designs with various shapes are easy to design. This proposed design can fulfill the demand of compact size and ultra speed in 5G communications in mm- wave frequency band and other various applications. There are various parameters which affect the performance of the antenna such as height of the substrate, material of dielectric, feed length, feed point and patch shape. The main aim of this paper is to present a simple and new patch shape for mm wave applications with Rogers substrate material. Presenting antenna designs show the polarized frequency is varied with the change of patch shape from 26 GHz to 30 GHz with improved parameters; these frequencies are used in 5 G applications. Bandwidth of the proposed design is 2 GHz to all three presenting antennas. There are various feed techniques are used in microstrip patch designs, feed line is the simplest among all techniques due to various advantages of this feed method such as easy to design, compact in size and easy integration with various circuit. For 5G wireless communication this simplest feed method is used in the proposed designs. The line feed parameter is also an important factor to improve the performance of the presenting antenna for 5 G applications. The substrate material RT5880 Rogers is best for mm-wave frequency band, with relative permittivity 2.2 and thickness 0.785

mm is used for the proposed design. Now many researchers have used this Rogers substrate material for 5G communication. In starting, to design an antenna for 5G communication FR4 dielectric material is used but result was not as good as with Rogers substrate. The proposed antenna design is simulated and analyzed on high frequency structure simulator (HFSS) version 17, this software is very popular in antenna design, more updated version of this software are available in the market of antenna design. This HFSS software is easy to understand to the users, various feature of designing is available, and optimum results are obtained with maximum accuracy. Millimeter-wave frequency range for 5G communication provides low-profile antenna for reliable and free from interference. The proposed designs are most reliable for millimeter-wave frequency range.

Table I. Dimensions of the Proposed Antenna

Parameters	L	W	p	q	h	x	f	r	m	n
Values (mm)	6.25	6	0.9	0.7	0.785	0.2	2.15	0.7	1.06	1.45

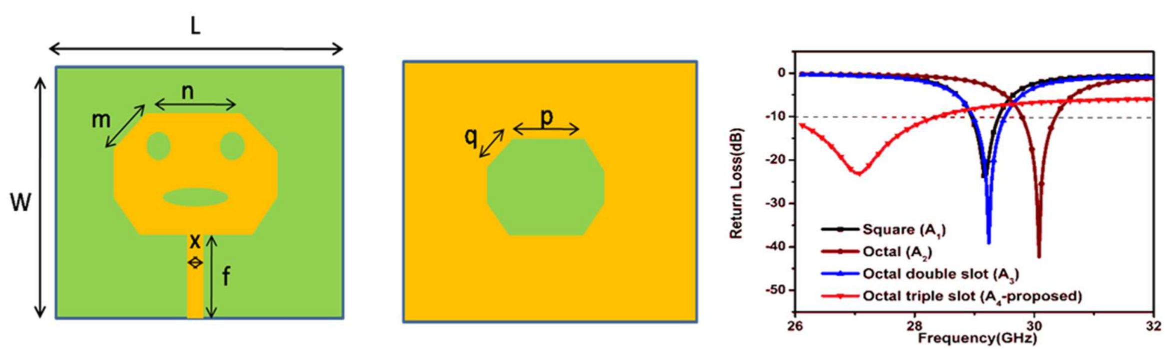


Fig.1. Geometry of the proposed Antenna (a) Top view (b) Bottom of the antenna (c) comparative graph of different antennas

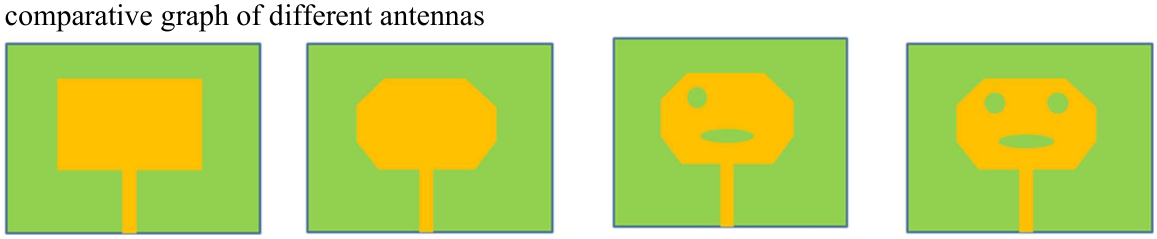


Fig.2. Flow diagram of the prospective antenna designs (a) Antenna 1(b) Antenna 2 (c) Antenna 3 (d) Proposed antenna

III. MEASURMENT RESULTS AND DISCOUSION

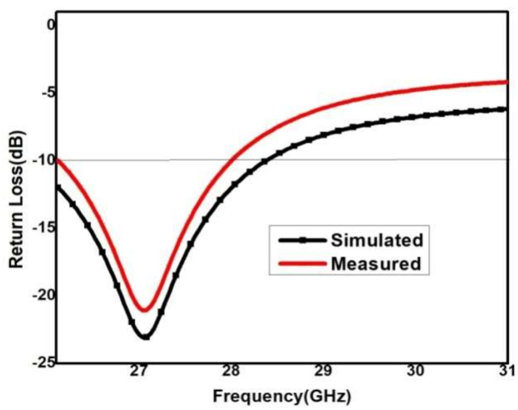
The proposed octal shape Patch Antenna design is simulated, to validate simulation results a octal shape patch antenna is fabricated and measured. The analysis was created on gain, S-Parameter, VSWR, E plane and H plane radiation pattern and 3D radiation pattern for the frequency range 26 GHz to 28 GHz, which are shown in figure3 –figure6. The photographs of fabricated octal antenna are shown in fig. 7.

1. Impedance performance

A octal shape patch antenna is simulated and fabricated shown in fig.7. The S11 parameters of simulation and fabrication are shown in fig. 3. The fabricated antenna is measured with vector network analyzer. The measured reflection coefficient of proposed antenna shows better performance for 26-28 GHz below -10 dB line. This is proved that fabricated antenna can be used for 5 G applications.

2. **Gain**

The gain of proposed design is shown in fig.4, as seen in figure the gain of simulated and measured is agreed for 26 GHz to 28 GHz. The maximum gain is 6.9 dBi for simulated design and for measured it is 5.8 dBi. The proposed octal antenna has better performance for the frequency range 26 GHz to 28 GHz.



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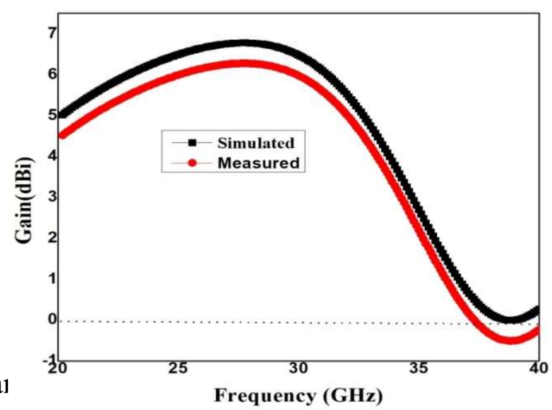
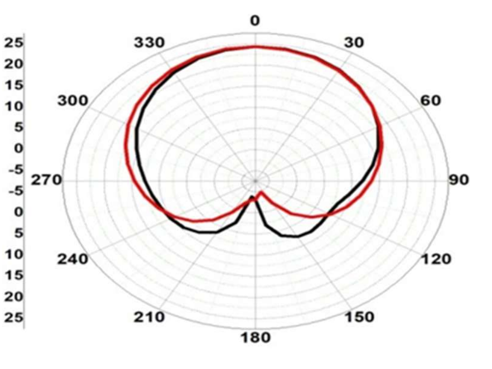
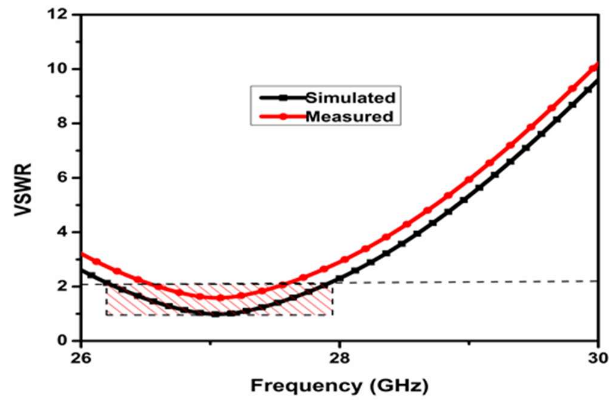


3. VSWR

Voltage standing wave ratio is the measure of mismatch between antenna and feed line, it should be 1to 2 for proper communication. The VSWR of proposed antenna lies in between 1 to 2 for the 26 to 28 GHz frequency range. So the presenting designs offer better result for mm-wave applications and from figure of VSWR it is seen that maximum power is delivered to the antenna.



(a)



(b)

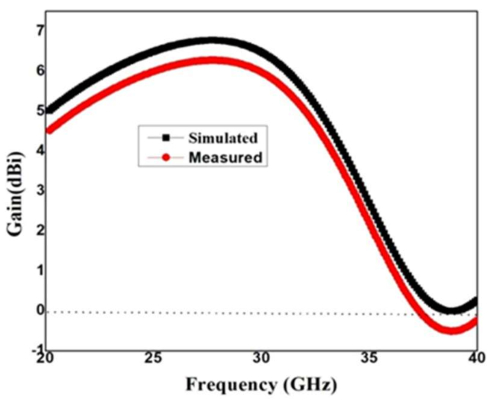
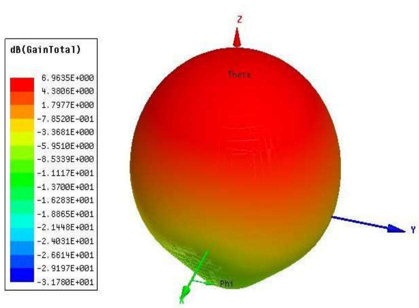
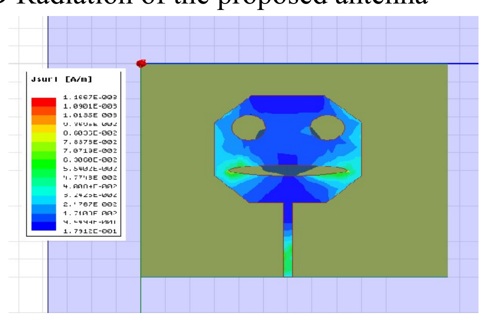


Fig.5. (a) Graph of 2-D Radiation (b) Graph of 3-D Radiation of the proposed antenna



(a)



(b)

Fig.6. (a) VSWR (b) Surface E-field distribution of octal patch antenna

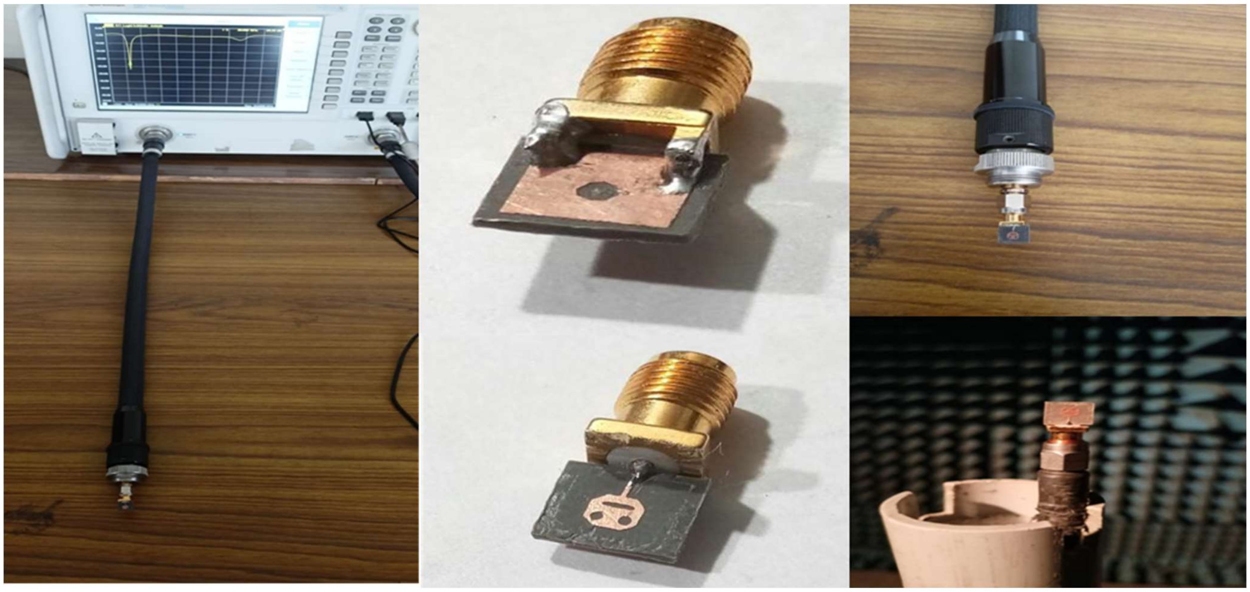


Fig.7. Photographs of fabricated slotted octal patch antenna

Table II. COMPARATIVE ANALYSIS OF DIFFRENRT 5G APPLICATION ANTENNAS WITH ROGER SUBSTRATE.

Dielectric material	Central(GHz) Frequency	Bandwidth (GHz)	Gain (dBi)	Return Loss (dB)	Area (mm^2)	Ref.
Rogers 5880	28	------	8.03	-34.5	19×19	[16]
Rogers 5880	59.93	4.03	5.48	-40	8×8	[17]
Rogers 5880	28.5	1.42	12.2	------	25×30	[18]
Rogers 5880	60	6.5	12.2	-------	14×13.5	[19]
Rogers 5880	26.9	3.52	8.08	-14.22	19.2×19.2	[20]
Rogers 5880	30	2.09	10.19	-12.50	9.4×12	[21]
Rogers 5880	28	------	13.8	-17	30.25× 9.5	[22]
Rogers 5880	27	2.5	6.9	-24	6×6.25	Proposed work

The comparison of proposed antenna with other works is shown in table II. The Octal shape patch antenna is better than tabulated antennas in different parameters with rogers substrate for

5G application band. In comparison with ref [16]-[22] the proposed work has compact in size; dual band square patch antenna [16] has about three times size of the proposed antenna. Compact antipodal tapered slot antenna [18] has more complex in design, large in size and lower bandwidth than slotted octal patch antenna. Slot antenna [19] is double in size than proposed antenna. The gain of proposed work is good as compare to Single band low profile antenna ref [17]. The return loss of reported antenna is better than ref antennas [20], [21] and [22].

IV. CONCLUSIONS

In summary, a slotted octal shape patch radiator of overall foot print of 6×6.25×0.787 mm^3 is presented for 26 GHz to 28 GHz band for 5G communications. The prospective design is printed and simulated on rogers 5880 substrate materials. An octal shape is etched out on the ground to enhance the gain of the octal antenna. Three different shaped and sized slot has been etched out from the main radiator for achieve desired operating band. Presenting antenna is very simple and miniaturized than reference antennas. The gain of the octal antenna is high as compare to reference antennas.   The simulated and measured results are found in the good agreement.

V. FUTURE SCOPE

The future scope of this antenna design is to increase the bandwidth for millimeter wave application by adding some other features. This design can be modified with array antenna for various applications.

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