DESIGN AND IMPLEMENTATION OF MULTI ARRAY FRACTAL ANTENNA FOR 5G VEHICLE TO VEHICLE COMMUNICATION

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ELECTRONICS AND COMMUNICATION ENGINEERING

By

ABDUL RAHIM

41800713

Supervised By

Dr.PRAVEEN KUMAR MALIK

LOVELY PROFESSIONAL UNIVERSITY
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2021

DECLARATION

I hereby declare that this research work "Design and Implementation of multi array fractal antenna for 5G Vehicle to Vehicle Communication" has been composed solely by myself and has not been submitted anywhere. It was carried out by me for the degree of Doctor of Philosophy in Electronics and Electrical Engineering under the guidance and supervision of Prof. Dr. Praveen Kumar Malik, Lovely Professional University, Phagwara Punjab, India.

The interpretations put forth are based on my reading and understanding of the original texts and they are not published anywhere in the form of books, monographs or articles. The other books, articles and websites, which I have made use of are acknowledged at the respective place in the text.

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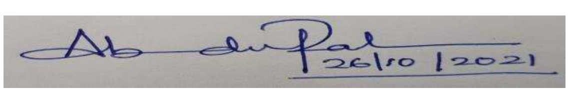

Date: 26/10/2021

Abdul Rahim
(41800713)

CERTIFICATE

This is to certify that the thesis entitled “**Design and Implementation of multi array fractal antenna for 5G Vehicle to Vehicle Communication”** being submitted by **Abdul Rahim** for the degree of Doctor of Philosophy in Engineering from Lovely Professional University, Jalandhar is a record of bonafide research work carried out by him under my supervision at the School of Electronics and Electrical Engineering. In our opinion, this is an authentic piece of work for submission for the degree of Doctor of Philosophy. To the best of our knowledge, the work has not been submitted to any other University or Institute for the award of any degree or diploma.

26/10/2021

Supervisor

Dr. Praveen Kumar Malik, Professor
School of Electrical and Electronics Engineering
Lovely Professional University, Phagwara, Punjab-144011
E-mail id: praveen.23314@lpu.co.in
Phone No: +91-9719437711

ABSTRACT

There exists an enormous growth in Vehicular communication applications as the technology is advances from fourth generation wireless communications to the fifth generation including milli meter wave applications. As the automobile industry is influenced with the concept of safety, security and comfort travel and to avoid road accidents, it is undeniable that there is a need of technology improvement such that it can support the autonomous and intelligent automobile units on roads. Research carried out in the past decade on vehicular communications came with various possible applications in the field of vehicular communications such as Vehicle-to- Vehicle Interface (V2V), Vehicle-to-Road side unit Interface (V2R), Vehicle-to-Pedestrian Interface(V2P), Vehicle-to-Infrastructure Interface(V2I) and Vehicle-to-Network Interface (V2N) which are designated as Vehicle-to-Everything Interface(V2X).

Wireless communications act as a backbone which supports these interfaces to exist in the automobiles for safe and comfort journey. The present fourth generation technology has limitations such as limited bandwidth, limited usage of available frequency, cross talk interference which are compounded as drastic stepback for vehicular communications. As Fifth generation wireless communication and milli meter wave communication promising of extended bandwidth, extended and dedicated frequency bands for specific applications, it brings an immediate requirement of accommodating multiple interfaces in Vehicular domain such that it fulfills the need of Automobile industry.

There is significant improvement on testing of the frequency bands for applications which brings an opening towards the antennas which can act as an important role for transferring the information and provide continuous communication between the node/ vehicle/ units. The requirements of the industry are that the antenna must be in compact size, cost effective, accommodate multiple application interfaces, resist for higher temperatures with efficient in all weather conditions and provide better communication in the domain. To full fill all the necessary requirements the best suitable antenna is an Microstrip patch antenna with lot of limitations.

The advantage of using the patch antenna is it is less cost, maintain low profile and requires very small portion of space and can handle all the weather conditions. The drawback of this type of antenna is that it is a narrow band and when frequency of operation is increased, the performance of antenna is degraded. The idea of the research work carried out is to design and fabricate a Microstrip patch antenna which overcomes the drawbacks and withstand the various needs of vehicular communications.

The research is carried out focusing mainly on high bandwidth and for providing multiple options for automobile industry for using in vehicular communication applications. In the process with the help of literature survey, fractal geometry is one of the prominent techniques which have direct impact on bandwidth and the narrow band can be translated to broad band and multi band antenna. To provide good reflection coefficient, literature survey shown the path of using defected ground structure and various feeds which provides better performance of antenna for desired applications.

Main purpose of this thesis is to present and propose Microstrip patch antennas which are compact in size, yet provides better bandwidth, better reflection coefficient and better gain. The proposed antennas are based on purely non deterministic fractal geometry to enhance the parameters and to experiment on the defected ground structures. Rectangular and circular fractal shapes are used for the proposed antennas with random defected ground structure. The proposed antennas are designed and simulated using Ansys HFSS v15 software tool, and later with the help of computer numeric control (CNC) are fabricated.

The testing of the proposed antennas is carried out using Agilent Technologies N5247A Vector Network Analyzer. The substrate materials used for the design are rigid in nature and can sustain all the weather conditions. The materials are Rogers RO4003™ and Rogers RT duroid 5880™. The proposed antennas are designed such a way that both single band and multi band applications can be carried out in vehicular communication applications. Three designs are discussed in this thesis work, the first two designs are fabricated with Rogers RO4003™ and later is fabricated using Rogers RT duroid 5880™. The first proposed design is a single band and later designs are multi band antennas. The first two proposed antennas are constructed using defected ground structure whereas the last proposed antenna is combine approach of single patch and multiple patch with 2×2 design. The proposed antennas are operated at the lower band 5G frequency ranging between 25GHz and 35GHz. The proposed antennas are designed in order to achieve parameters such as reflection coefficient, VSWR, Total Gain, Impedance, Current Distribution and Radiation pattern.

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Throughout the writing of this dissertation I have received a great deal of support and assistance.

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Acronyms and Abbreviations

Acronyms	Description
2-D	Two Dimensional
2G	2nd Generation
3-D	Three Dimensional
3GPP	3^{rd} Generation Partnership Project
4G	4^{th} generation
5G	5^{th} generation
AF	Audio Frequency
AMC	Artificial Magnetic Conductor
AMPS	Advanced Mobile Phone Service
AR	Axial Ratio
ARBW	Axial Ratio Bandwidth
AUT	Antenna Under Test
BPF	Band Pass Filter
BW	Bandwidth
CP	Circular Polarization
CPW	Coplanar Waveguide
CRO	Cathode-Ray Oscilloscope
CRT	Cathode-Ray Tube

CSMA/CA	Carrier Sense Multiple Access/ Collision Avoidance
CST	Computer Simulation Technology
DGS	Defected Ground Structures
DUT	Device Under Test
EBG	Electromagnetic Bandgap
EDGE	Enhanced Data for Global Evolution
EDR	Enhanced Data Rate
EIRP	Equivalent Isotopically Radiated Power
ETSI	European Telecommunications Standards Institute
FDGS	Fractal Defected Ground Structure
FDTD	Finite Difference Time Domain
FEM	Finite Element Method
FFT	Fast Fourier Transform
FHSS	Frequency Hopping Spread Spectrum
FR4	Flame Retardant 4
FSA	Fibonacci spiral antenna
FSPL	Free Space Path loss
GNSS	Global Navigation Satellite System
GPA	Ground plane aperture
GPS	Global Positioning System
GSM	Global System for Mobile
GUI	Graphical User Interface
HA	Hybrid Antenna

HFSS	High Frequency Structure Simulator
HIPERMAN	High Performance Radio Metropolitan Area Network
HORYU-IV	High Voltage Technology Demonstration Satellite-4
HPBW	Half Power Beam Width
IE3D	Integral Equation Three-Dimensional
IEEE	Institute of Electrical and Electronics Engineers
IFS	Iterated Function System
IoT	Internet of Things
ISM	Industrial Scientific and Medical
LEO	Low Earth Orbit
LHCP	Left Hand Circular Polarized
LoRA	Long Range
LPDA	Log-Periodic Antenna
LPWAN	Low-Power Wide-Area Network
LSNA	Linear Sensor Node Array
LTE	Long Term Evolution
M2M	Machine 2 Machine
MAC	Media Access Control
MIMO	Multiple input Multiple Output
MM	Metamaterial
MMOG	Multi Media Online Gaming
MNM	Multiport Network Model
MoM	Method of Moments

MPA	Microstrip Patch Antenna
MS	Meta Surface
MTA	Microwave Transition Analyzer
OFDM	Orthogonal Frequency Division Multiplexing
PAN	Personal Area Network
PBG	Photonic Band Gap
PCB	Printed Circuit Board
PHY	Physical Layer
PIFA	Planar Inverted F-Antenna
PMPA	Planer Microstrip Patch Antenna
RADAR	Radio Detection and Ranging
RCR	Cherenkov radiation
RF	Radio frequency
RFID	Radio Frequency Identification
RHCP	Right-Hand Circular Polarized
RL	Return Loss
RSL	Received Signal Level
SDT	Spectral Domain Technique
SIG	Special Interest Group
SMA	Sub-Miniature version A
SNA	Sliced Notch Antenna
SRR	Split Ring Resonator
TCDA	Tightly Coupled Dipole Array

TDMA	Time Division Multiple Access
TEM	Transverse Electric Magnetic
TL	Total Loss
TV	Television
UHF	Ultra-High Frequency
UMTS	Universal Mobile Telecommunications System
VNA	Vector Network Analyzer
VSWR	Voltage Standing Wave Ratio
WBAN	Wireless Body Area Networks
WCS	Wireless Communication Services
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
ZOR	Zeroth-order Resonator

List of Symbols

Symbol	Description
H	Efficiency
Γ	reflection coefficient
ε_r	relative permittivity
tan δ	loss tangent
λ	Wavelength
c	speed of light
f_r	resonating frequency
Z0	Characteristics Impedance
λg	Guided Wave length

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION TO VEHICULAR COMMUNICATIONS:

Vehicular communications is one of the wireless applications which has prominently grown in the past decade. The concept and model was proposed in-order to increase the safety, security and comfort while travelling on highways and to make the design more towards an autonomous in nature to avoid human errors while travelling. The first model was concentrating more on data transfer between moving vehicle using wireless communications. Researchers have shown a lot of interest in this field which can be enhanced and advanced towards the needs of the vehicle over manual control. As development was progressed, number of features were added which includes "Vehicle to Vehicle (V2V)", "Vehicle to Infrastructure (V2I)", "Vehicle to Road side unit (V2RSU)" and "Vehicle to pedestrian (V2P)" communications. In order to provide guidance towards these communications, sensors, road side units, Internet, Intranet, fog networks, cloud and wireless support were added to the Vehicular Communications, which is also called as "Vehicle to Everything (V2X)" [1]. The objective is to provide a hassle free, comfort, road safety along with reduction in road accidents, fuel efficient and reducing carbon emission and to save time and offer a very advanced driving comfort. Figure 1.1 provides the "Vehicle to Everything (V2X)" scenario in Vehicular communications.

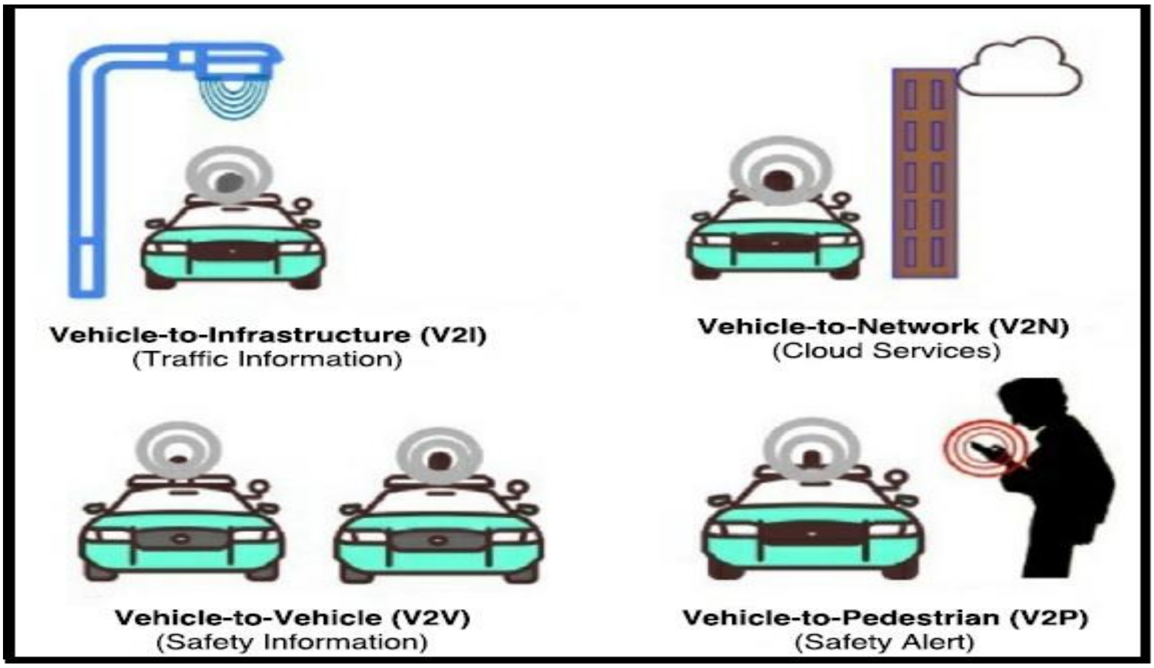


Fig 1.1: Vehicle to Everything (V2X) Scenario in Vehicular Communications [1]

“The Vehicular system should accommodate in GSM-1800/1900,along with DCS-1800 (Digital Communication System), PCS-1900(Personal Communication Service), UMTS(Universal Mobile Telecommunications System), LTE2600(Long-Term Evolu-tion), Radio band ISM 2.4G(Industrial, Scientific, and Medical), WLAN (Wireless local area network), Bluetooth, WiMAX (World Interoperability for Microwave Ac-cess), IEEE802.11p protocol based Vehicle-to-everything, DSRC (Dedicated short-range communications) and WAVE (Wireless Access in Vehicular Environments) communication bands” [2]. These standards are used in previous generation of vehicular communications which are referred as fourth Generation. Latest technology advanced towards the fifth generation which includes the milli-meter wave communications with the futuristic frequencies which are under proposal for usage in fifth generation. World-wide many countries came forward to work on fifth generation and were successful for bringing up the technology for vehicular communications. Table 1.1 provides the geographical summary of (country-by-country) projects carried out for vehicular autonomous projects.

Table 1.1: Geographical Summary of (country-by-country) projects carried out [3].

Continent	Country	Projects	Total by Continent
Asia	China	10	90
	India	1	
	Israel	6	
	Japan	45	
	Singapore	4	
	South Korea	17	
	Taiwan	6	
	Turkey	1	
Europe	Austria	2	172
	Belgium	10	
	Finland	2	
	Germany	46	
	Greece	2	
	Italy	12	
	Netherlands	21	
	Norway	2	
	Others	75	

North America	Canada	6	176
	USA	170	
Oceania	Australia	8	10
	NewZeland	2	
Grand Total			448

Total of 448 huge projects are carried out across the world, which states the importance of vehicular communications, and the research work going on which drives towards contributing my work on vehicular communications [4].

Vehicular communications are majorly classified into safety applications and non-safety applications. Safety applications are based on the support provided for the driver to prevent the road accidents such as fog, high dense snow information, unexpected animal crossing, and vehicle coming in wrong directions and so on. On the other hand non-safety applications are completely related to add on services such as mobility, environmental, infotainment and others such as E-Toll, Parking [5].

Figure 1.2 provides a complete information regarding these two applications in vehicular communications which consist vehicular to vehicular based and vehicular to infrastructure based along with other non-safety applications. These applications are fulfilled using a technology which can be having a very high bandwidth. Existing technology can only provide very few applications out of complete vehicular technology applications due to non-availability of proper wireless communications which provides continuous connectivity and bandwidth which can accommodate the applications needed to fulfil the technology for autonomous vehicles [6].

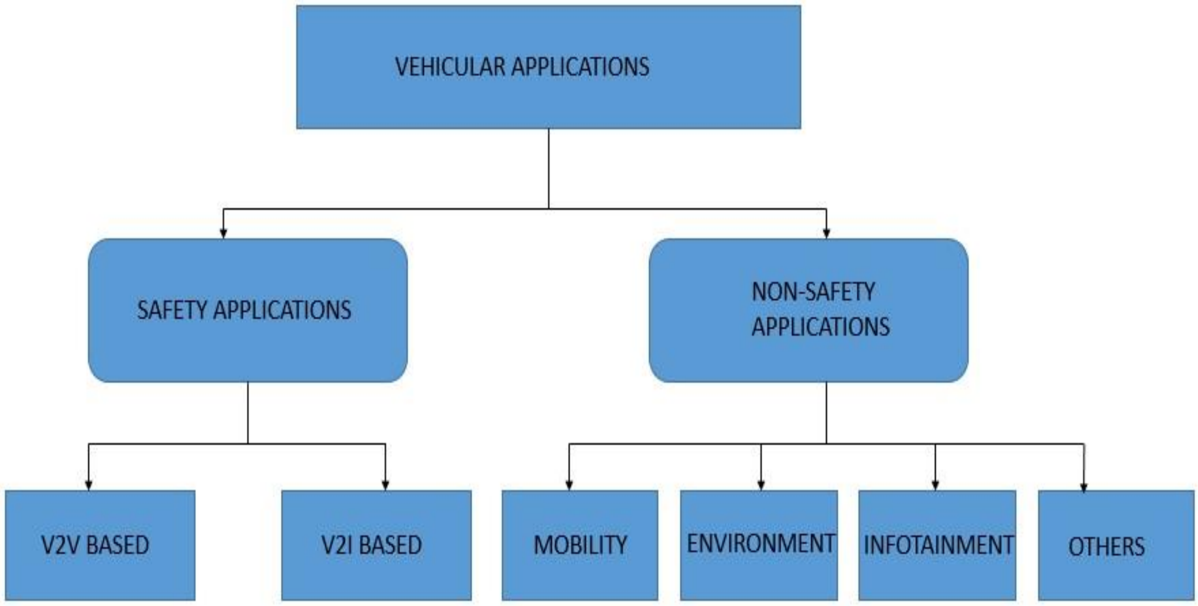


Fig 1.2: Connected Vehicle Applications[5]

In the next session, the details of latest wireless technology is discussed which will full fill the bandwidth, connectivity and multi hop technology which are needed for vehicular applications.

1.2 FIFTH GENERATION COMMUNICATIONS:

Almost all the automobile industry such as General Motors, KIA motors, Toyota, Nissan, BMW, Mercedes are already experimenting both the safety and non-safety based applications depending on the technology available in wireless world. Some of the present technologies uses 4G/LTE-A, 3GPP, Radio access technology, DSRC and cellular networks. Along with the protocols such as IEEE 802.11p, wireless access in vehicular environments (WAVE) protocol stack [7]. Some of the manufactures uses Visible light technology which captures the images of side lights and breaking lights. Radio Regulations which is an international treaty which includes the "International Telecommunications Union" (ITU), which specifically provides the radio spectrum for worldwide use and regulatory bandwidth allocations for various applications including vehicular communications [8]. In 2020, this regulatory unit provided some of the frequency bands for the development of various applications with existing and futuristic technologies in various areas which uses wireless communications.

Table 1.2 provides the channel usage for these projects to carry out under 5G and milli-meter wave communications. These proposed frequencies are assigned for the purpose of projects carried out in the world under autonomous vehicular standards [9].

Table 1.2 Proposed spectrum under 5G Environment for various Countries[9]

Countries	**Channel-1**	**Channel-2**	**Channel-3**	**Channel-4**
US Proposed Spectrum	24.25 to 27.5 GHz	31.8 to 33.4 GHz	37 to 40.5 GHz	40.5 to 42.5 GHz
EUROPE Proposed Spectrum	27.5 to 29.5 GHz	37 to 40.5 GHz	47.2 to 50.2 GHz	50.4 to 52.6 GHz
SOUTH KOREA Proposed Spectrum	28.4 to 32.4GHz	41.25 to 43.75GHz	59.3 to 71 GHz	-------------
CHINA Proposed Spectrum	31.75 to 33.54GHz	45 to 47GHz	59 to 64GHz	-------------

As per the table 1.2, the frequencies are under testing environment, and by 2022 these frequency channels will be provided for the countries after the successful work carried out by the researchers and developers from world radio communication conference (WRCs).

Some of the 5G services which will come into existence are Intelligence, Omnipresence, Autonomy, Publicness and Immersiveness [10]. Out of these various services one of the important service is the autonomy which provides smart transportation such as Robot, Drone and Teleportation. These services are very much helpful to incorporate in vehicular communications. Figure 1.3 provides the 5G services coming into existence by 2022 which provides domination towards the autonomous vehicles.

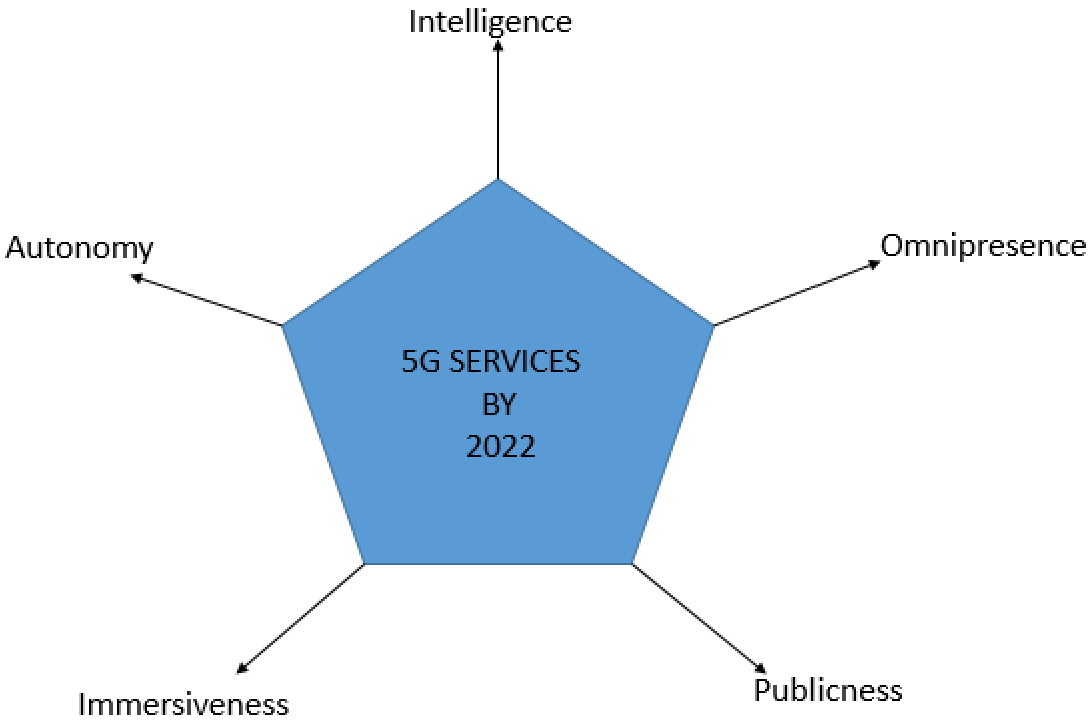


Fig 1.3: 5G services coming into existence by 2022

The 5G development and establishment will be commenced in two phases, phase-I and phase-II [11].Phase-I includes usage of new spectrum above 6GHz which includes mm waves ranging up to 100GHz, Advanced Beam forming, Massive MIMO, and enhanced frame structure [12]. In Phase-II it is expected that features like Network Slicing, Software defined networks, multi-vendor interoperability will be included.

IEEE has formed some of the standards for transportation in vehicular communication field such as IEEE 1609 family for ITS, IEEE 802.3 for Connectivity, IEEE P2040 series for Connected, Automated and Intelligent Vehicles, IEEE 2030 Series for transportation Electrification and IEEE 1512 for Traffic Safety [13]. These standards are going to provide reliable, efficient, fault tolerant, load balancing, connection oriented for high speed vehicles, safety and security for the vehicular communications worldwide. Other prominent advancements can be seen are usage of both single hop and multi hop in vehicular networks with good synchronization, discovery of vehicles, Resource allocation, Interference management and Security [14].

IEEE 1609 provides the on board system requirements for vehicle to vehicle safety communications unit such as minimum hardware, sensors and ability for both transmitting and receiving the information in mm wave standards. Along with this, it provides Object Identifier (OI) and Provider Service Identifier (PSID) which are provided to various sensors available in vehicles and the main unit for establishing communication with other on board vehicles [15].

Some of the studies which were carried out at New York suggested that usage of mm wave at around 28GHz has provided better connectivity with a distance of 75 meters to 125 meters in urban area with both line of sight channel(LOS) and non-line of sight(NLOS) channel with a path loss of only 2.55 [16].

Table 1.3 provides mm Wave Propagation characteristics for various 5G frequency bands for both LOS and NLOS channels.

Table 1.3: mm Wave propagation Characteristics at 5G Frequencies [17]

Frequency Band	Scenario	28GHz	38GHz	60GHz	73GHz
Path Loss Exponent	LOS Scenario	1.8 ~ 1.9	1.9 ~ 2.0	2.23	2
	NLOS Scenario	4.5 ~ 4.6	2.7 ~ 3.8	4.19	2.45 ~ 2.69
Rain Attenuation at 200m	5mm/H	0.18dB	0.26dB	2dB	2.4dB
	25mm/H	0.9dB	1.4dB	2dB	2.4dB
Oxygen Absorption at 200m		0.04dB	0.03dB	3.2dB	0.09dB

1.3 MOTIVATION:

With a huge growth of technology in autonomous vehicles and communication between them, and progressive growth in 5G Technology including mm Wave for the futuristic frequencies, their-exist an opportunity to work in the upcoming technology in wireless communications. For the enhanced technology, the frequency of operation is far greater than the fourth generation which was limited up to 5GHz [18]. The mm Wave suggested that the frequency can reach up to 100 GHz which is categorised into four channels and the work is carried in the first two channels [19]. For vehicular communications it is necessary to shift the present technology to fifth generation, which provides better connectivity, better security, and better efficiency and can be used for multiple applications simultaneously for single hop and multiple hop communication for vehicle to vehicle, vehicle to infrastructure, vehicle to road side unit and vehicle to pedestrian. For using various standards, installing multiple sensors and transferring data continuously in wireless communications, their-exist an immediate need of antenna which can be suitable for the vehicular communications under the 5G environment [20]. There is a huge demand for the antennas which possesses the various needs in vehicular communications.

The dimensions of the antenna purely depends on the frequency of operation, Impedance and wavelength and for vehicular communications one of the antenna which provides low profile, better gain and compact in nature is a micro strip patch antenna, but the antenna is considered as only narrow band antenna with a maximum bandwidth around 750MHz [21]. To overcome the issue of bandwidth, in literature, superfluity of techniques are proposed out of which two techniques can be introduced for vehicular communications. The first one is to use multiple antennas for increasing the bandwidth (multi array antenna's), and the second technique is to introduce fractal geometry which is self-similar in nature and compact in size. For the first technique to implement in vehicular communications, the size will become solitary constraint as multi array antennas occupy larger geographical space which is one of the limitation in vehicles. The second option is best suitable for vehicular communications as it provides better bandwidth and the size is compact. Along with fractal geometry implementation of patch, miss match of ground provides better radiations [22]. This miss match can be possible by introducing Defected (Recessed) Ground Structures (DGS) which imbalance the structure such that the voltage levels can fluctuate in-order to provide better radiations. Combination of Fractal geometry on the patch and Defected ground structure for the ground plate provides a lethal combination for improving band width and radiation efficiency such that the antenna can be best suitable for vehicular communications under 5G environment.

1.4 THESIS OUTLINE:

The thesis report provides detailed outline and explanation about the micro strip patch antenna, various substrates, fractal geometry, Defected ground structure and multi patch array antenna for vehicular communications. Literature review provides various methods in which the objectives can be achieved under 5G environment.

Chapter-1: It provides detailed report on vehicular applications, types of applications used for providing safety, security and avoid road accidents. It also provides details regarding the futuristic frequencies for fifth generation including mm Wave communication for Vehicular communications. It also provides the problem statement, aim and motivation of thesis along with objectives of present work carried out is explained in detail in this chapter.

Chapter-2: This chapter presents, the overview of antenna, antenna performance parameters like Reflection coefficient, Voltage standing wave ration, Total Gain, Impedance, Bandwidth etc. It also provides information regarding various types of feeds that can be provided to the microstrip patch antenna. Further, it provides the complete details on the fractal geometry and types of shapes that can be used to implement the patch. It finally explains about the defected ground structures that can be implemented on the ground structure of microstrip patch antenna.

Chapter-3: This chapter provides the literature review on vehicular communications, 5G wireless communications and microstrip patch antennas with various configurations. It provides detail explanation of various techniques that are incorporated for achieving better antenna parameters which change in patch design, modifications of ground structure and various substrates that can be proposed for the desire applications.

Chapter-4: This chapter explains about the first proposed antenna which is a single band high bandwidth fractal geometry based microstrip patch antenna with defected ground. The antenna is Fabricated using the substrate material of Rogers RO4003™ and the proposed antenna design, simulation, fabrication and testing is discussed in this chapter.

Chapter-5: This chapter provides the design, simulation, fabrication and testing of the second proposed antenna which is a multi band fractal geometry based microstrip patch antenna with defected ground and coaxial feed line. The antenna is Fabricated using the substrate material of Rogers RO4003™ and the proposed antenna resonated at four different frequency positions.

Chapter-6: This Chapter explains about the design, simulation, fabrication and testing of the third proposed antenna which is a multi patch antenna with 2X2 format. Design of multi patch from single patch is discussed in this chapter. The proposed antenna provides multi band, high bandwidth and good gain.

Chapter-7: In this chapter, explanation is given about conclusions and comparision drawn from this research work and suggestion are given for future research work.

Appendix: It deals with the methods and producers followed to fabricate antenna using Printed Circuit Board technology and setup used with mathematical calculations to measure antenna return loss, voltage standing wave ratio, gain and radiation pattern.

1.5 SUMMARY:

This Chapter begins with introducing of Vehicular communications, one of the most prominent area in which lot of scope is available to design and implement. Various standards and applications of vehicular communications is discussed. Advancing Vehicular communications to the fifth generation wireless communications along with mm Wave were discussed. Different IEEE standards for vehicular communications were discussed in this chapter. Subsequently micro strip patch antenna with fractal geometry and defected ground is introduced for fulfilling the need for antenna for vehicular communications under 5G environment. Brief discussion is imputed on the research work carried out in the successive chapters.

CHAPTER-2

ANTENNA OVERVIEW

2.1 INTRODUCTION TO ANTENNAS:

In wireless communications one of the most important role is played by the antenna which is used to communicate between two nodes or points or distinct devices. In vehicular communications the complexity further increases as the devices will be travelling at appropriate speeds which cannot be predicted while laying the communication between those devices. Earlier in ancient times smoke signals were continuously used to provide the information, later telegraphs were introduced which evolved the communications and enhanced the use of the communication for various applications. The development was boosted up and their started the inception of using wireless communication using electro-magnetic signals which can travel at higher speeds and cover larger distances with less attenuations [23]. The device which was used to convert the electrical signal into electro-magnetic at the transmitter and vice versa at the receiver is provided the name as antenna. In wireless devices at both the ends antennas have an important role to play which are used to provide simple means to transferring signals where other modes of communications are not achievable. For long distance communication, in order to improve quality of information, authenticity and uncorrupted information transmission, various techniques are used and these are the main concern of researchers time to time. For vehicular communications it is very much important to provide a continuous and reliable communication between two autonomous mobile vehicles travelling at different speeds on the road. In this regard, antenna community have come forward to provide the antennas for fulfilling the various applications available for vehicular communications under 5G environment [24]. The designs are provided for single band, dual band, triple band, penta band, multi band and wide band applications to accomplish the demands of wireless communication applications such as vehicular communications. The antenna must possess the following attributes such as compact in size, low profile, conformal in nature and provide single or multi band or wide band depending on the applications [25].

Some of the antennas which can be used for vehicular communications are Helix antenna, GPS based strip antenna, J Slot antenna, parasitic and active patch antenna out of which one of the best suitable antenna is the active micro strip patch antenna [26]. Some of the important features of antenna are discussed in the next section before heading towards micro strip patch antenna.

2.2 ANTENNA PARAMETERS:

Antenna performance is inspected on the basis of the following parameters which are necessary while designing the antenna and to rate the performance of the antenna for various applications including vehicular communications.

2.2.1 REFLECTION COEFFICIENT (S11):

It is one of the major parameter to evaluate the performance of the antenna, which is also termed as return loss or S11. It is the function of power in the form of ration of power transmitted to the power reflected back, and is measure in dB where the magnitude of reflection coefficient is considered as the return loss. If power transmitted is considered as Pt and the reflected power is considered as Pr, then the ration between Pr and Pt is considered as the reflection coefficient or simply S11 [27]. If S11=0dB, then it is represented as no power is radiated by the antenna and entire power is reflected back. If S11=-10dB, it implies that 0.1 watt od energy is reflected back and 90% of energy is accepted power which is basically radiated.

$$\text{Reflection Coefficient, } \Gamma = 10 \log (Pr/Pt) \qquad \text{(Eq 2.1)}$$

In order to find the resonating points, the minimum reflection coefficient is considered and it is represented as resonating frequency (fr). Figure 2.1 provides a simple reflection coefficient of an antenna where the lowest peak is considered as fr.

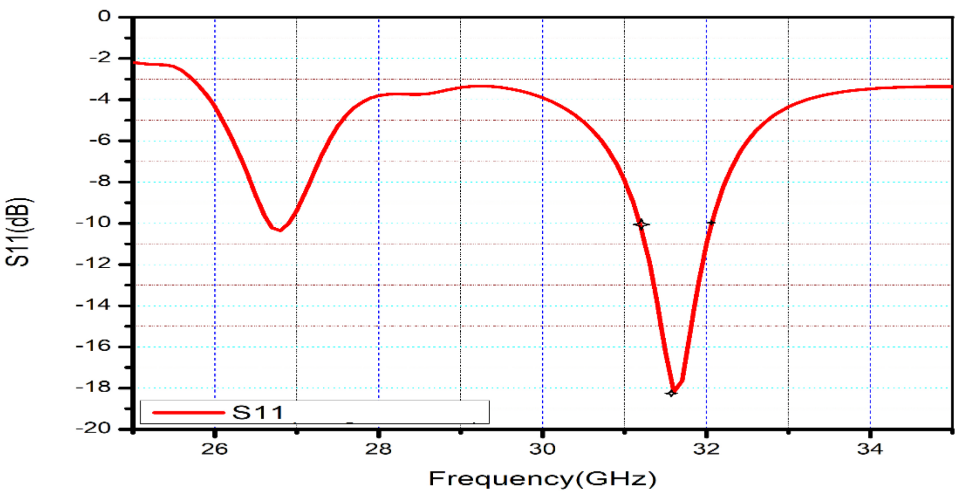


Fig 2.1 Reflection Coefficient of an antenna [27]

2.2.2 VOLTAGE STANDING WAVE RATION(VSWR):

In wireless communications, in order to deliver power to the antenna, antenna impedance must match with the line impedance. The matching of the impedance is described using the parameter called as voltage standing wave ratio (VSWR) [28].

It is the function of the reflection coefficient of the antenna and is provided with the formula as given in equation 2.2

$$VSWR = \frac{\mathbf{1+|\Gamma|}}{\mathbf{1-|\Gamma|}} \qquad \text{(Eq 2.2)}$$

The VSWR for practical antennas which are used in vehicular communication is between 1dB and 4dB as the value is minimum, better the performance of the antenna is rated. Figure 2.2 provides the idea of how the vswr is calculated with the help of voltages.

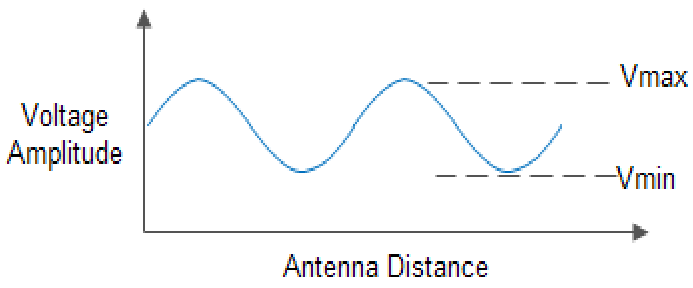


Fig 2.2 VSWR measurement along Transmission line [28]

2.2.3 ANTENNA GAIN:

The gain is one of the important parameter of the antenna which is defined as the energy radiated in one direction than Omni directional. Gain is the product of efficiency of the antenna as well as the directivity of the antenna [29].

$$G= \eta D \qquad \text{(Eq 2.3)}$$

The total gain is calculated in two ways, one is the Power gain and the second is the Directive Gain. In both the cases it is the radiated power of the antenna towards a specific direction depending on the average power introduced by the antenna. For any antenna to have significant gain is to provide at least 3dB or more which even includes in vehicular communication standards.

2.2.4 DIRECTIVITY:

It is the measure of the directivity of the radiation pattern generated by the antenna while radiating the signal and it is measure in decibels (dB). For any practical antenna the direction of radiation will be concentrated on one direction which makes the directivity greater than zero as Omnidirectional antenna radiates equally in all directions such that it consist 0 dB directivity [30].

$$D(\theta,\phi)=\frac{U(\theta,\phi)}{Ptot/4\pi} \qquad \text{(Eq 2.4)}$$

Where θ and ϕ are the zenith angle and azimuth angles respectively.

2.2.5 INPUT IMPEDANCE:

It is the factor which influence all other parameters of the antenna and it is “the impedance presented by an antenna at its terminals or the ratio of the voltage to the current at the pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point” [31].

$$Zin = Rin + jXin \qquad \text{(Eq 2.5)}$$

Where Zin is the input impedance of the antenna, and it is the summation of resistance and reactance of the antenna.

2.2.6 BAND WIDTH:

It is expressed as “the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard.” [32] The bandwidth is always calculated with reflection coefficient of -10dB or less than that. It is the amount of frequency which is between lower and upper cut off frequency ranging with less than -10dB of S11.

2.3 INTRODUCTION TO MICROSTRIP PATCH ANTENNA:

One of the revolutionary antenna is the microstrip patch antenna which came into existence from 1953, and as the time passes by, more and more advancements are seen in the antenna design and its key features. The antenna are widely used in many applications due to its low cost, low profile and very easy to fabricate and not only that the compact in nature which can be placed in any application without altering much about the size and the shape of it [33].

The basic blocks are considered as the patch and ground plane which acts as two terminals of the capacitor and a substrate material which provides the dielectric such that the voltage can be deposited which helps for radiation of energy.

The patch and ground plane are highly conductive in nature and typically made up of copper with a typical thickness of 0.0002mm. The patch is connected to the microstrip line which acts as a feeder to the patch antenna. The side view of the antenna is provided by figure 2.3 and the top view of the microstrip patch antenna is shown in figure 2.4

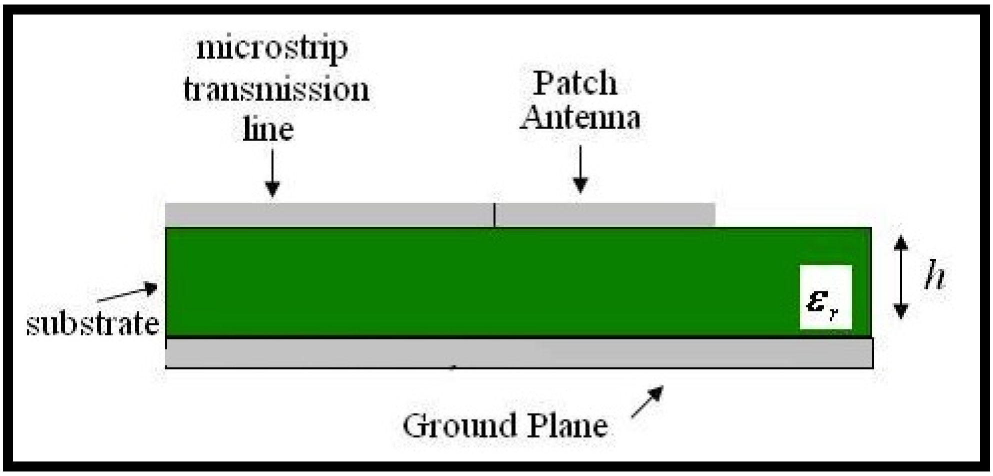


Fig 2.3 Side view of microstrip patch antenna [33]

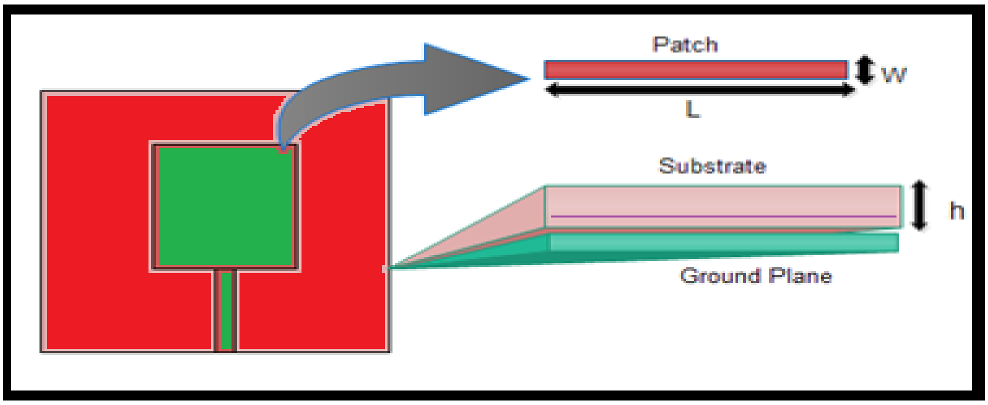


Fig 2.4 Top View of microstrip patch antenna [33]

The antenna is easy to fabricate as it uses PCB (Printed Circuit Board) technology and can be calibrated with any single sided CNC (Computer Numerical Control) machine with almost any type of substrate [34].

Microstrip patch antennas consist a simple radiating patch on top side of dielectric substrate and ground plan on bottom side as shown in Figure 2.4. The patch can be made up of any geometric design such as rectangular, triangular, square, circular and so on as shown in figure 2.5

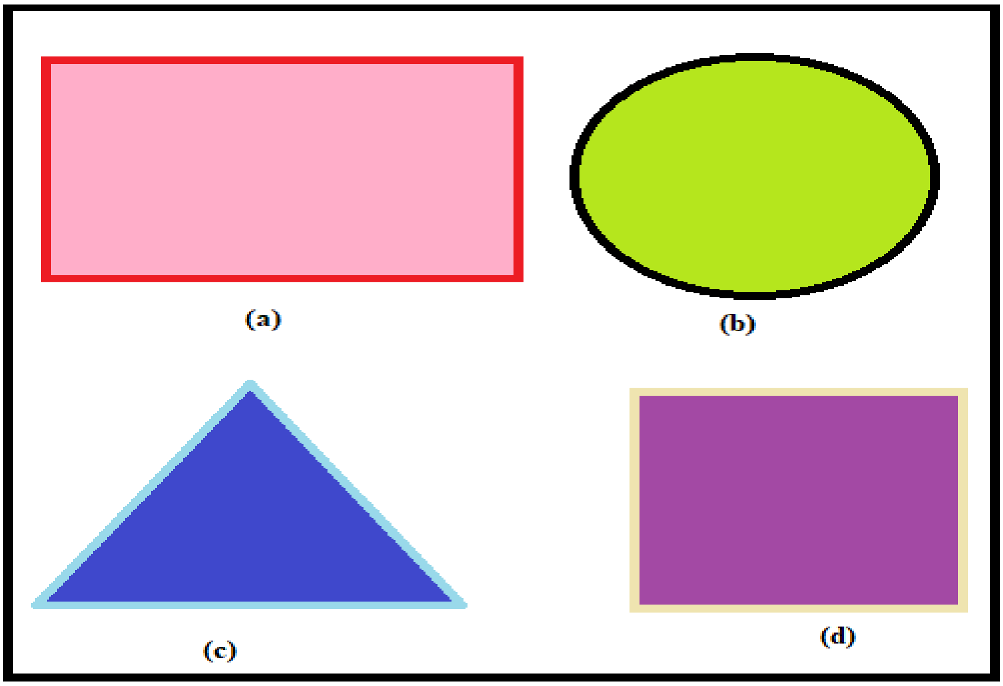


Fig 2.5: Different shapes of Patches used in microstrip antennas [34]

Some of the key elements of microstrip patch antenna are provided in Table 2.1a complete summary of the microstrip patch antenna which includes advantages, drawbacks and the area of applications.

Table 2.1 Microstrip patch antenna Summary [35-40]

Advantages	**Disadvantages**	**Area of Application**
Light weight, less space occupancy	Narrow Bandwidth	Vehicular Communications
Low Fabrication cost	Lower Gain	Bio medical
Compact in Size	Difficult Polarization	Mobile Communication
Multi-Frequency range operation	Excess Radiation at feed junction	Satellite Communications
Perfectly matched with solid state devices	Power Handling is low	Radar Systems
Easy to design and simulate	Poor End fire radiation	Global Positioning System (GPS)

2.4MICROSTRIP PATCH ANTENNA FEEDING TECHNIQUES:

Patch Antenna is excited with various feeding methods which provides with electrical signal at one end of the patch such that it radiates the energy fed to it. Some of the feeding techniques are discussed below [41].

(a) Line Feeding
(b) Probe Coupling
(c) Aperture Coupled Feed

2.4.1 LINE FEEDING:

It is a rectangular line which connects the patch to one end of the substrate such that the connection is provided between patch and ground. Most of the time, the transmission line is connected to the line feed such that the impedance is matched properly.

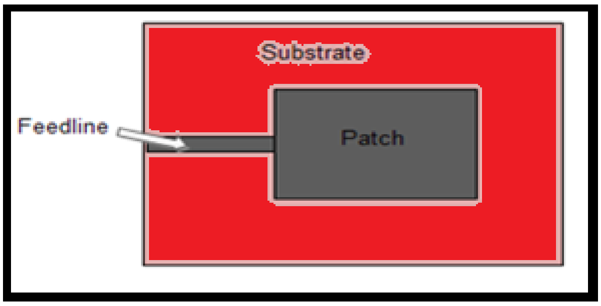


Fig 2.6: Line feeding for microstrip patch antenna [41]

2.4.2 PROBE COUPLING:

It is another common method in which instead of a line, coaxial cable is fed directly on the patch such that the area covered will be in compact compare to the line feeding. The only drawback with this type of feed is that the soldering the joins are a bit difficult compare to other type of feeds.

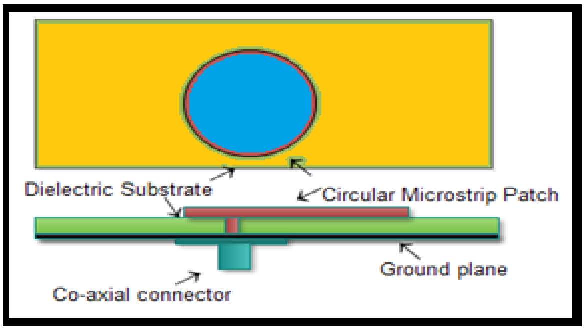


Fig 2.7: Probe coupling for microstrip patch antenna [41]

2.4.3 APERTURE COUPLED FEED:

This is way complicated method in which two substrates, the patch substrate and the feeding substrate are used along with a slot aperture on ground is used. This method is used in order to provide independent optimization of feed line and radiation such that the standing wave ratio is reduced and increase in radiation is carried out.

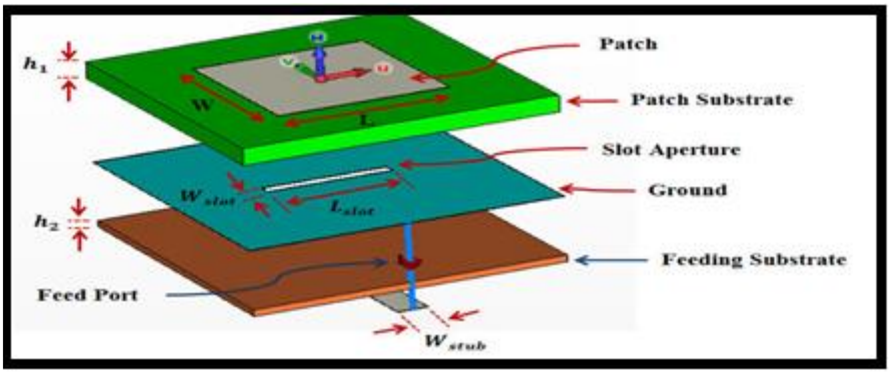


Fig 2.8: Aperture coupled feed for microstrip patch antenna [41]

2.5 FRACTAL GEOMETRY FOR PATCH:

Fractal geometry is implemented on the patch in order to boost up the efficiency and other parameters such as bandwidth and total gain of the antenna as the fractal geometry is a self-similar, filling the unused space and infinite iterations which are considered as the multi array without compromising on the dimensions of the antenna [42].

Fractal Geometry is one of the prominent structure which can be implemented on the patch such that the infinite iterations can directly impact the antenna parameters where multi band and wide band can be achieved [43].

Fig 2.9: Some of the fractal geometries available [43]

2.5.1 CLASSIFICATION OF FRACTAL STRUCTURES:

Deterministic Fractals and Non Deterministic Fractals are the two structures which are configured while designing the patch on a microstrip patch antenna. If the configuration uses algebra for calibrating the design, then the shape is considered as Deterministic shape and if the antenna is designed with randomness in nature then that antenna is considered as Non Deterministic Fractal shape [44].

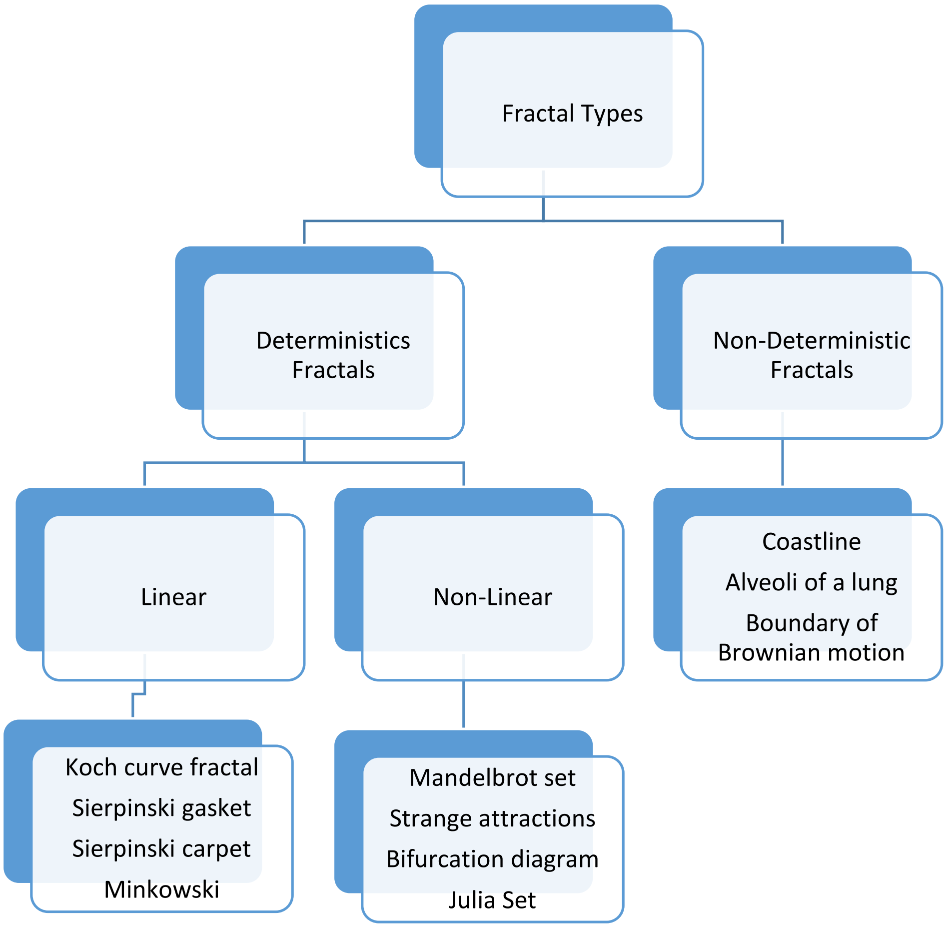


Fig 2.10: Classification of Fractal Structures on basis of classification [44].

Figure 2.10 provides the entire structures used for designing of the patch antenna with both deterministic and non-deterministic fractal structures.

2.5.2 COMMON DESIGNS FOR ANTENNA USING FRACTAL GEOMETRY:

1) SIERPINSKI GASKET: In 1916, Polish mathematician named 'Sierpinski' proposed geometry called Sierpinski. It is also known as Sierpinski Triangle which consist triangular shapes in nature with various iterations repeatedly without modifying the pattern [45].

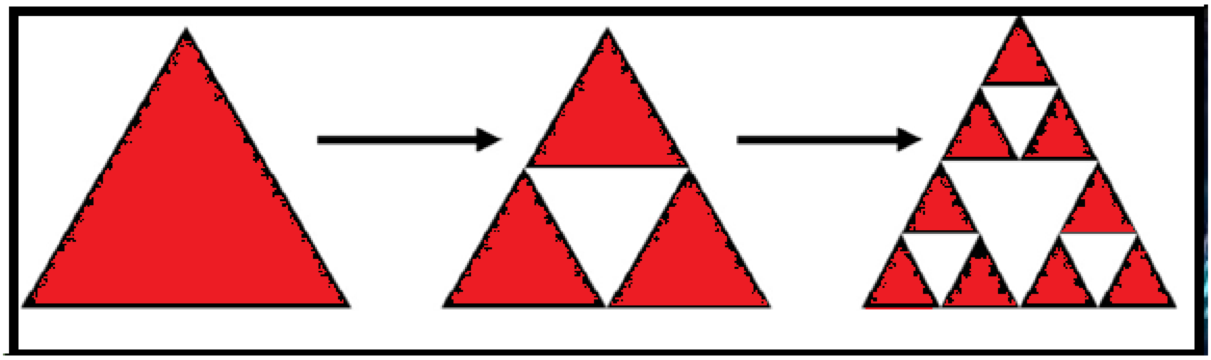


Fig 2.11: Sierpinski Gasket Fractal Geometry [45]

2) SIERPINSKI CARPET:

"The Sierpinski Carpet is developed by Waclaw Sierpinski in year 1916. It's a plane fractal and designed with help of rectangular patch. The first rectangle with dimensions of 1/3rd is extracted from the centre position of main rectangle. Square patch is used as initiator and scaled down from both x and y axis directions."[46]

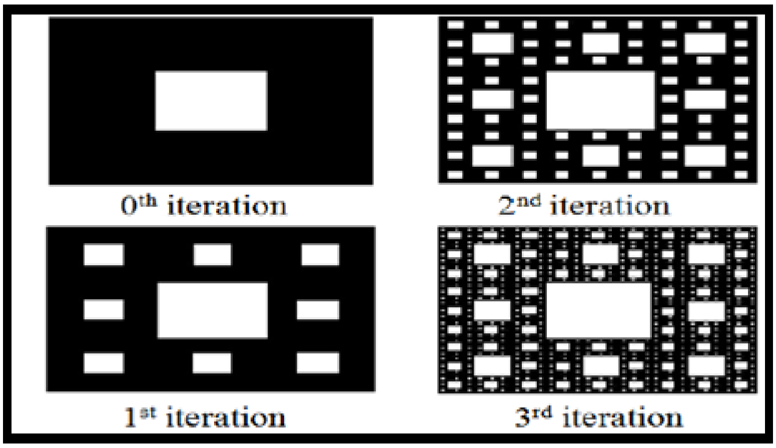


Fig 2.12: Sierpinski Carpet Fractal Structure [46]

3) HILBERT CURVE FRACTAL:

"Hilbert Curve geometry is developed by David Hilbert in 1891. In this structure each stage consists of four copies of previous design with one extra line segment as given in Figure 5.9 below. This structure is truly known for space filling property as it covers the entire area very effectively. Apart from tis, it has additional properties like self-avoidance and simplicity" [47].

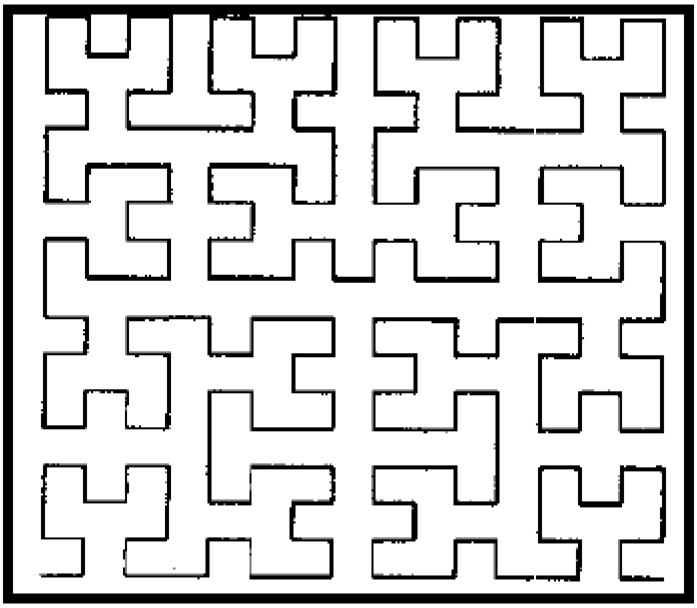


Fig 2.13: Hilbert curve Fractal Structures [47]

4) FRACTAL LOOP ANTENNA:

   These are the antennas which are designed in the form of loop which basically reduces the size of the antenna ten times less equivalent to traditional antenna. These are mostly squared shape and majorly used in outdoors [48].

5) MANDELBROT FRACTAL ANTENNA:

   These antennas are based on log-periodic concept where the antenna iterations are adopted using the log value of each antenna. These are the traditional antennas which were introduced way back in 1970's and majorly used in outdoor purpose to enhance the signal receiving capacity. These antennas are outdated as the heat dissipation is more [49].

6) NON-DETERMINISTIC FRACTALS:

   These are the antennas which are based on non-deterministic and the shapes are attracted from the nature or the imagination of the researches. The shapes such as sunflower, rhombus, hexagonal, butterfly, spider, fern and flame type of antennas are designed [50]. These are the non-coherent designs and have the liberty of usage by the researches.

2.5.3 FRACTALS ADVANTAGES AND DISADVANTAGES:

Any design has both advantages as well as drawbacks, in the similar way even fractal geometry had its own advantages and drawbacks.

The advantages are increase in bandwidth, good impedance matching, Multi band and wideband characteristics, Improved Voltage Standing Wave ratio, Component matching not needed and provides high directivity and reduces side lobes in antenna with improved gain [51-55].

The disadvantages are more complexity in design, heavy calculations for the model and difficult to fabricate when more number of iterations are available [56].

2.6 DEFECTED STRUCTURES:

In order to increase number of bands and to reduce the reflection coefficient (S11) one of the best technique is to use Defected Ground Structures (DGS). On top the antenna is designed using fractal geometry and on the bottom if the ground is defected then the antenna voltage deposits will be abrupt which in turn increases the efficiency of the antenna and better radiation pattern [57]. Slots and defects etched upon ground plane are called Defected Ground structures which provide imbalance on the structure. Both periodic and non-periodic configurations can be adopted while using DGS technique for the ground structure. Various defected structures have been discovered in the recent advancements of microstrip patch antenna such as rectangular cut, square cut , dumbbell cut, spiral cut, L-shaped, circular, U-shaped, hexagonal, V-shaped, concentric, arrow head etc. [58-65]. Current distribution and propagation through ground plane can be changed or can be controlled depending on the shapes selected which further able to controls electro-magnetic wave's generation and transmission through substrate material. Due to changes, there is direct impact on capacitive property of the entire structure which induce multi band and wide band in the outcome of the antenna parameters [66].

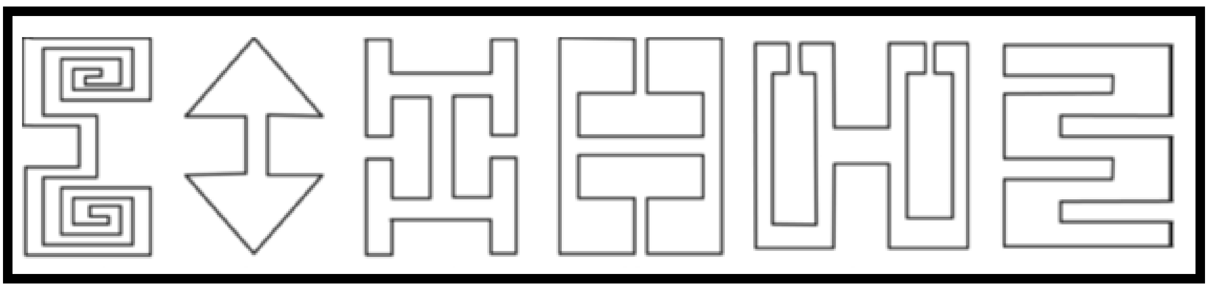


Fig 2.14: Different DGSs shapes used in ground plane of microstrip patch antenna[66]

2.7 SUMMARY:

This chapter provides absolute details of basic antenna, microstrip patch antenna and transmission line theory. It also explains about the fundamental parameters and their equations which are helpful to categorise and understand the antennas in a better way. Further, it explains the basic structure of patch antenna along with advantages, disadvantages and area of application of microstrip patch antenna. It also provides information regarding various types of feeds that can be provided to the microstrip patch antenna. Further, it provides the complete details on the fractal geometry and types of shapes that can be used to implement the patch. It finally explains about the defected ground structures that can be implemented on the ground structure of microstrip patch antenna.

CHAPTER-3

STATE OF THE ART

3.1 INTRODUCTION:

With the recent advancements in Vehicular communication applications, wireless communications under fifth generation and mm Wave applications, enhancement of microstrip patch antennas for various applications, which provides better safety, security, continuous connectivity, informative and radio access with intelligent transport system(ITS), their exist a lot of requirement in the present scenario[67] . To consummate all these requirements the proposed antenna must go through rigorous process to full fill these requirements. The major issues is to achieve a good bandwidth at futuristic frequencies with better performance of the microstrip patch antenna. The challenges are the type of vehicular application, type of frequency selection, shape of the antenna with selecting fractal geometry, selection of substrate and to select the structure of ground and finally to match the impedance selection of feed line. To overcome these challenges, various ideas, methods, designs and configurations are adapted from the various researchers and their work carried out in the form of literature survey.

3.2 LITERATURE SURVEY:

[68] "The antenna in this category is a conformal antenna which can be designed on the surface of a carrier, which is helpful for saving the space and there is no damage on the mechanical structure. The conformal antenna can be a Micro-strip, strip-line or crack antenna. The shape of this antenna is cylindrical, which is helpful to maintain a proper angle between main lobe and the plane of array. This antenna can be used for frequency of 35GHz and the results are suited for vehicular communications. With the addition of conformal antenna, bandwidth achieved was greater than 10%, and the gain was more than10dB, and the first side lobe level was reduced to−16dB. At very high frequencies the major problem that can be seen is the un-controlled radiation pattern. For vehicular communication, the pattern must be as directional as possible."

[69] "A well-controlled radiation patter is proposed switching of polarization among linear and orthogonal circularly polarized states using magneto-electric dipole antenna. This method can be used for the future antenna designs for the mm-wave communication. When this type of dipole antenna with a micro-strip line is used, there is a possibility of high mutual coupling".

[70] " To achieve a low mutual coupling the antenna is proposed with an insertion of rectangular slot along with the folded micro-strip line, by this way low mutual coupling can be achieved with the frequency ranging from 24GHz to 28GHz, and provides better reflection coefficient of -24dB at 26.3GHz and maximum gain of 6dB for the entire range of frequencies. A rectangular patch with non-dispersion structure is adapted with rectangular defected ground"

[71] "As the frequency is increased the bandwidth must be improved, in order to improve recessed ground plane is used in the design. For antenna arrays of 1X2, 2X2 with different impedance characteristics the author suggested an epsilon-near-zero impedance matching circuit for impedances of 50Ω, 100Ω, and 150Ω. Various techniques for impedance matching were discussed which is helpful for the research to be carried out."

[72] "As number of radiators are increased for arrays, there is a possibility of cross polarization current on the radiators and low port isolation, which can be eliminated using dual polarized antenna using vector synthetic mechanism, which has inherent advantages of high port isolation and low cross polarization, The structure consists of hexagonal split ring resonator (SRR) and a closed ring resonator (CRR). The antenna was modelled upon 0.254 mm thick Rogers's substrate and has a low profile of 6×8 mm2. It has a peak gain of 4.63 dBi with more than 80% radiation efficiency throughout its operating range. The proposed antenna has 2.83GHz bandwidth and 7.92 GHz at 38 GHz respectively."

[73] "discusses that microstrip antenna gain can be enhanced under some resonance conditions when antenna is covered with superstrate with proper distance in free space. Resonance conditions can be deduced by using proper transmission method and the cavity model to achieve the highest gain. Resonance effect can be changed by adjusting the spacing between antenna's superstrate and substrate and by varying thickness of the substrate. Depending upon these resonant lengths the permittivity, permeability and superstrate are determined and characteristics impedance can also be determined of the multilayer structure. Antenna performance is verified using simulation results and analytical methods also. From simulation results author concludes that proposed method enhances the antenna performance by 50% when compared to previous methods."

[74] "discussed about the issues regarding the unavoidable increase in the size of the antenna when number of radiators are increased. One of the remedies is to use an antenna with a stair case type to reduce the overall size and the author named it as Zeroth order resonance antenna. To increase more directivity, an antenna was proposed with eight

elements with very less envelope correlation coefficient which is helpful for isolation and to increase the bandwidth of the antenna in vehicular communications."

[75] "proposes use of electromagnetic band-gap (EBG) structures and artificial magnetic conductors (AMC) due to their advantages use to improve antenna performance like better efficiency, high gain, and low back lobe and less side lobe levels. He designed antenna using combination of EBG with patch antenna in single layer and combination of AMC with patch antenna in two different layers. Due to more compactness and robustness antenna is compatible with plane antenna fabrication technology because it not needs via holes. Proposed antenna works in RFID 2.48GHz frequency band, also it shows better radiation properties without increasing antenna size and thickness. Proposed antenna provided bandwidth of 34MHz with EGB and of 46MHz with AMC over 23MHz for simple antenna, as well as gain improved from 4.6dB to 5.576 dB over the operating frequency band."

[76] "Discussed about how the resources are allocated for vehicles with less latency and very high reliability. When the vehicles are under fast moving approach then it is very difficult to identify the channel information, due to which it is challenging to meet the necessities of acquiring good reliability and low latency. In order to achieve the challenges, steady state analysis is first performed by queuing analysis which uses available spectrum for Vehicle to Network and Vehicle to Vehicle links. Optimal power allocation algorithm is implemented for all available re use spectrum."

[77] "For content delivery in vehicular communication networks, an algorithm is proposed which uses same channel resource for multiple networks, to provide safe transmission of information, advanced Non Orthogonal Multiple Access Technique is implemented. Transmission analysis is carried out over Rician fading Channels and content chunk sizes with delay restrictions are derived to estimate information delivery efficiency. The obtained simulation results are compared with conventional OFDM and shown the improvement in content delivery."

[78] "The QoS improvement factors like maximum tolerance capacity and minimum Signal to Noise ratio at vehicular receivers were discussed along with the proposed transmit algorithm, where the simulation results are compared with other algorithms where the improvement in gain is noted. Also the Accountable Credential Management System which develops transparency ledger technologies for web public key infrastructures by addressing the resources specific to vehicular communication. By utilizing the enhanced data structure Accumulation Tree, the conventional transparency log can extend its services to deliver

secure and trusted authentication in a cost effective way without depending on revocation data."

[79] "For providing real time data services in the intelligent transport systems, a novel algorithm was proposed which was named as Adaptive Priority Data Servicing Schedule which works on fuzzy logic deadline estimation analysis and service arrangements. For guaranteed high speed data transmission under vehicular communication a new hybrid waveform is proposed to reduce the cost of optical wireless and optical camera based communications. Low and high data streams are used in the proposed technique where low data stream is to analyse and represent Region of Interest of light sources for establishing a communication path and high data stream is to provide high data speeds."

[80]" The accurate beam width and beam alignment are very much essential to transmit high directional mm waves under 5G frequency bands, for this an online learning scheme algorithm was proposed to predict beam alignment and directions with guarantee blockage free 5G millimetre wave vehicular network environment. To enhance the safety and secure aspects under fifth generation vehicular environments a direct current biased OFDM system was proposed which uses grouping of multiple LEDs for MIMO data transmission scheme to support LOS and its beyond."

[81] "Channel estimation plays a major role in data transmission where the noise elimination based discrete Fourier transform channel estimation for mm wave vehicular communication was proposed. Iterative cancellation method is considered first to estimate all the available path parameters later to enhance this estimation accuracy decision threshold limits are fixed for examining the authenticity of the path estimated.

[82] "discussed about the mm Wave technology based transmission system where the frequency of operation is 8 to 12 GHz for feasibility and effectiveness evaluation for vehicles on road and high ways. For fast and accurate handovers and for better quality of service two step timing advance approach is followed. To handle the access collisions and insufficient spectral efficiency the NOMA schemes were proposed, to reduce latency rates and also to achieve high data rates optimal scheduled algorithm and priority assignment schemes are initiated. This proposal provided better improvements in terms of performance analysis parameters like reducing bit error rates and improved signal to noise interference ratio which enhances the quality of service."

[83] "For security and privacy under Vehicular IoT networks a security system based on block chain technology was proposed for Software Defined Network enabled 5G vehicular

Ad-hoc Networks with scheduling procedures and comparison is made in terms of network performance under OFDM and MIMO technologies."

[84]" discussed an antenna which is used to maximise the wireless channel link in vehicular networks. The antenna design is a state of the art which has a combination of patch antenna with various PIN diodes which are used to provide multi band operations for the frequencies which ranges from 2GHz to 12GHz. Three different stages were implemented with a pair of diodes which are used to switch the frequencies and provide multi band applications. Eight antennas were designed such that the gain can be optimized for the said frequencies. FR4 substrate was used with each antenna unit set to a dimension of 30 X 30 mm. The gain was greater than 1.8dBi throughout the operational bandwidth and efficiency greater than 86% under Ultra wide band mode."

[85] "Proposed an antenna which is conformal in nature and can be placed on a windshield of a vehicle. The proposed frequency band is at 1.575GHz and can be used for Global Positioning System (G.P.S). Sputtering and electroplating is used as a substrate to achieve low VSWR and good reflection coefficient. Antenna was tested by placing at three different places on the vehicle, front, rear windshield and rear quarter respectively. An angle of 60 degrees conformal was achieved with good reflection coefficient of about -38dB."

[86] "proposed low-profile dual-band antenna with different polarization and radiation properties over two bands for vehicular communications. A fully functional prototype was designed and tested at the frequency ranging from 3.54GHz to 4.40GHz. Two circular patches are used along with a rectangular patch as two layer design which was implemented on a vehicle for communicating with another vehicle. The antenna possess a good gain with Uni-directional circular polarization and omnidirectional linear polarization."

[87] "proposes a regular hexagon broadband micro-strip antenna with a frequency band of 4.74GHz to 6.79GHz for the existing Vehicle to Vehicle communication. It acquires an Omni directional pattern whose out of roundness is less than 0.5dB. Three major V cuts and three minor V cuts were introduced on the patch to make the antenna work for broad band which incorporates WiFi, GPS and LTE on it. The substrate thickness was kept to 3mm as it was proposed to be placed on the roof of the vehicle. The antenna was tested on Agilent Technologies N5242A vector network analyser for the said frequencies and it possess a very good reflection coefficient and gain."

[88] "discuss about the vehicular technology and how in the real time scenario as number of vehicles with vehicular communication increases, their exist fading of the signal at the road side unit (RSU). Two models were proposed which are constant correlation (CC) and

exponential correlation (EC). The paper also discuss about how the cooperation takes place between the vehicles using single helper selection (SHS), multi-hop cooperative selection (MCS) and multiple helper selection (MHS). These techniques are used to transfer the information from one vehicle to the road side unit with the help of other vehicles.

The packet error probability was considered using the correlation of antenna gain at road side unit, which implies that if the gain of the antenna is around 3dB, the error probability will be less."

[89] "proposed a low cost, compact conformal antenna for vehicular communications applications with good gain and the material used to fabricate the antenna was poly vinyl chloride with a dimensions of 55mm X 40mmX 3mm. The antenna is used for various applications under 4G environment. The antenna was based on fractal geometry with various iterations made for calculating the antenna parameters. The maximum bend angle was up-to 120 degrees and tested for the frequency ranging from 1.8GHz to 6.4GHz."

[90] "proposed a dual band full duplex antenna design for vehicular communications with two ports of antenna, one for transmitting and one for receiving. Two duplex channels of 4.58-4.83GHz and 5.86-6.2GHz were used. Hairpin patch antenna was used with six resonators which were used to provide better characteristics of the antenna. A 2x2 full duplex mode was fabricated with two ports with a frequency ranging from 4.4GHz to 6.6GHz."

[91] "proposed a wide band 3D antenna for roof top vehicles with a unique design which can be used for LTE applications. The structure consists of folded metal sheets welded together building a geometry that allows covering two LTE bands. A U-cut and a V-cut antenna was fabricated for the frequency ranging from 850MHz to 2GHz. The antenna exhibits a very good return loss and coupling for the dual band."

[92] "proposed a 2X1 micro strip patch array antenna for vehicular communication with primary and secondary feeds with frequency ranging from 5.2GHz to 6.5GHz. The antenna is fabricated on a FR4 Epoxy substrate with a thickness of 1.6mm. The antenna performance was measured for a single patch, 1X2 and 2X1 array. A maximum gain of 9.6dB achieved using the multi array concept."

[93] "proposed a circularly polarised wide-beam width Fern Fractal shaped antenna for vehicular communications. The size of the patch was reduced by a 44 percent as the fractal geometry was introduced on the patch. The author proposed the antenna for eliminating blind spots form the vehicle, which was a drawback with the present available mirror

concept. A hexagonal patch was used which later converted to fern like structure which was used to increase the performance of the antenna.”

[94] “proposed an antenna with Rigorous Electromagnetic Channel Modeling for 5G applications. The frequency range was in ultra wide band up-to 5.9GHz. The antenna possess a better return loss and placed on the roof top of the vehicle. The coverage area reached was around 50mts. Left handed circularly polarized antenna array was proposed for vehicular communication with a resonating frequency of 5.9GHz. The antenna was designed using patch truncated corners and a square shaped radiator. The antenna was tested for single element and two element array for better performance. The efficiency was above 82% with very good return losses.”

[95] “proposed an integrated Wideband End-Fire 5G Beam Steerable Array antenna for mobile terminals in vehicular communication. An array consisting for four elements were used to provide good return losses and tested for frequency ranging from 22GHz to 30GHz.”

[96] “proposed a basic fractal model analysed for different applications, doesn’t shown much effect on the factors of improving bandwidth and gain so this model needs to be modified to achieve enhanced results. The design of modified Sierpinski fractal antenna is proposed for broadband antenna applications using HFSS simulator and achieved very good gain and bandwidth when the operating frequency is 2 to 8GHz but it is noticed that as frequency is beyond 10GHz then return loss are high.”

[97] “discussed about quadrilateral patch antenna with an overall size of 33mm x 40mm, and the resonance frequency is at 2.45GHz for a wideband harmonic rejection. The antenna has three iterations, each operating at harmonic resonances such as 5GHz, 8.4GHz, and 11.2GHz. A stub was introduced for understanding the impact on the design as well as results. The resonance frequency of the antenna got directly affected, and it shifted towards the higher bandwidth side. The author provided a remedy by adding two symmetric slots at the junction of the feed-line and the patch. The antenna possesses a moderate gain and broad harmonic suppression characteristics also.”

[98] “discussed about the Minkowski-like fractal geometry-based antenna working at 4.4GHz frequency with the dimensions of 20mm x 20mm. In this design, three iterations are used without modifying the size of the substrate. Dual-band resonance was obtained with high gain and desirable impedance bandwidth. The substrate is an FR4 with a dielectric constant of 4.4 and a thickness of 1.6mm.”

[99] "discussed about feed coupling with the ground layer, which is a combination of rectangular and circular iterations. The fractal ring is used in the design of the antenna dimensions were 40mm x 40mm. Finite element and time-domain method is used for simulating the antenna. The resonance frequency kept at 3GHz with a bandwidth of 1.8GHz. For every iteration, the gain is slightly increased a moderate bandwidth."

[100] "discussed about design which is based on hexagonal fractal geometry for super wideband applications. Three hexagonal iterations were used for satisfying the fractal geometry. The frequency at which this antenna operated is 0.2 to 11.5THz with dimensions of 600μm X 800μm. For such high frequencies, the ground plane defected with a random and irregular structure, which played a crucial role in making the antenna used for super wideband terahertz applications."

[101] "discussed about the bow-tie nano fractal geometry with a perfectly matched layer (PML) boundary conditions were used in order to prevent field reflections from 'Z' directions. SiO2 is used as a substrate, and four iterations are designed for enhancing the gain up to 6dB. Most of the fractal antennas are designed on a shape of hexagonal with multiple iterations such that the return losses can be further reduced. The size of the antenna proposed in the article is 44mm x 30mm with a three-axis patch. This design is used to achieve low VSWR for a range of frequencies upto12GHz. The three-axis antenna results are better than the traditional antenna, but it is challenging to fabricate the antenna.

[102] "proposed Koch-Minkowski and Koch-Koch Fractal geometry based microstrip patch antenna in addition with partial ground for wideband applications and achieved bandwidth of 2260MHz and gain of 6.1dB at 2.7 and 8.9 GHz for Koch-Minkowski and for Koch-Koch design achieved a bandwidth of 2440MHz and 5.6dB gain at same operating frequency. Through the simulation results it is noticed that the gain of the proposed design is reducing and return loss is high as the operating frequency is extended beyond 12GHz."

[103] "proposed a T shaped fractal patch antenna with three iterations with an operating frequency of 9GHz for improving return loss, gain and bandwidth and achieved return loss of -10dB under frequency range of 7.4 to 7.6GHz but achieved the return loss of -8dB at the specified frequency range i.e. 9GHz where improvement in gain is noticed in the frequency range of 7.8 to 8.6 GHz but VSWR is increasing as the frequency of operation is beyond 9GHz range."

[104] "proposed design for better impedance matching and persistent gain a new design under the frequency range of 3 to 10.8 GHz where the study is done in terms of group

delay, radiation Pattern and distribution of current and found satisfactory results but still there is a scope for further enhancement a compact low profile fractal antenna for wireless body area networks with Koch fractal structure operated at a centre frequency of 2.45GHz is proposed. The fabricated model shown good numerical as well as experimental results and the radiation efficiency is achieved as 75% under the specified frequency. But this efficiency is limited to specified frequency range, as the spectrum increases then it is noticed that there is a decrement in radiation efficiency."

[105] "proposed a multiband high gain Triangular shaped fractal antenna by reducing patch area and increasing the perimeter This design shown good polarization performance at 3.4,8.2,12.2,26 GHz frequencies and achieved gain of 6,8,9.3,9,7.4,9dB respectively, Under meta-material design a metallic e-shaped fractal based metamaterial absorber operating under k and ka bands. Transverse electric and transverse magnetic modes are considered to determine the robustness of the device proposed and got good results and it is noticed that PMA would be useful for limited frequency operation range in 5G environment."

[106] "proposed microstrip patch antenna with U-slot structure for 5G communication. Antenna design is simple in construction and more efficient to achieve compactness, multi band and broadband behaviour. It is observed that there is inverse relation between resonant frequency and U-slot length and feed point too. Also, frequency of operation increases by changing co-axial feed point radius and slot width. Moreover, U-slot structure is used to enhance bandwidth and help in achieving multi band behaviour in antenna. Antenna is designed using Rogers RO 4350(tm) with thickness (t) =1.57mm, εr value equals to 3.66, and loss tangent value 0.004. Overall antenna dimensions are 15.8 mm × 13.1 mm × 1.57 mm. This antenna resonates at 28 GHz with gain of 4.06 dBi and voltage standing wave ratio is 1.02. RL performance of the said antenna is -20 dB. Antenna is designed and simulation using HFSS simulator software.

[107] "design microstrip patch antenna using different parasitic patches with main patch to obtain an equicircural triangular structure. Different resonance effects are produced using these parasitic patches to widen the antenna bandwidth. Three antennas are designed to study the effect of each patch on bandwidth. Antenna is designed using FR4 substrate material with dielectric value εr= 4.4 and thickness 1.6mm. Coaxial feeding method is used with SMA connector. Also, two shorting vias are introduced in final design to reduce the input impedance to further enhance the bandwidth. From simulation results, bandwidth of

designed antenna obtained is 5.46 to 6.27GHz i.e. 13.8% without using vias and bandwidth of 17.4% is achieved from 5.5 to 6.55 GHz with introduction of vias with parasitic patches. Amer T. Abed et al., [106] proposed circularly polarized fractal microstrip patch antenna for Wi-Fi and WiMAX applications. Final structure is designed after following five steps. Antenna is designed using FR4 substrate with $\varepsilon r = 4.3$, $\tan \delta = 0.027$ with antenna size dimensions 18 × 18 × 0.8 mm3. In every antenna design, patch structure design is reduced by 1/8 of original size. From simulation results antenna operates at 2.4 to 2.48GHz and 5.15 to 5.825GHz and these bands are used for W-Fi and Wi-MAX applications with gain to 0 to 1.5 dB. Antenna size is compact and gives dual band of frequency operation. Also, antenna has circularly polarization and RHCP and LHCP can be achieved using switching action between inputs“

[108] “implemented concept of DGS in MIMO antenna for 5G wireless application to achieve compactness and high gain with less design complexity. Antenna patch design consists of T-shaped patch and to make antenna ground defected, five split ring slots each with width of 0.2mm are used in two iterations with proper distance from each other. Coplanar waveguide feeding method is used for 50ohm impedance matching with T-shaped patch. Antenna is fabricated on Rogers RT Duroid 5880 material with dielectric constant $\varepsilon r=2.2$, loss tangent=0.0009 and thickness (t)=0.8mm with overall dimensions 12mm x 12mm x 0.8mm of single design. Defected ground structures are mainly used to change the direction of currents in ground of antenna to generate multiple resonating modes for antenna. This concept is further implemented in MIMO with four elements with minimum spacing of $\lambda/2$ between each patch to avoid effect of coupling. Width of each antenna in array varies from 12 to 12.7mm because width of connector used Jyebao (K864N5-00AB) is 12.7mm. Proposed antenna structure provides gain of 10.6dBi for operating range 25.1 to 37.5GHz. Antenna is further used to introduce MIMO concept and shows good isolation between adjacent elements that makes it attractive for 5G MIMO application in cellular communication.”

[109] “presented a compact in size fractal antenna for wireless body area application in 2.4GHz ISM band. Patch shape used is triangular and proposed design is fabricated on vinyl polymer flexible substrate. To obtain final structure three concepts are integrated like Koch fractal geometry, DGS and meandering slits. Experimental and theoretical results are in good agreement with each other. Compared to already existing prototype, antenna is more compact in size of $0.318\lambda o \times 0.318\lambda o \times 0.004\lambda o$, with impedance bandwidth of

7.75% i.e. from 2.36-2.55GHz and peak gain of 2.06dBi with overall radiation efficiency of 75%."

[110] "design broadband microstrip patch antenna (MPA) for wireless communication applications. Antenna patch structure consists of a square patch in centre with two mushroom type arrays on opposite side of main radiating patch. Parasitic patch theory is used to widened bandwidth of antenna. Each array contains three mushroom units and all are identical in shape and size. Antenna is fabricated using RT/Rogers 5880 dielectric substrate with εr= 2.2, loss tangent 0.0009 and thickness (h)=1.52mm. Co-axial feeding method is used. Antenna size is 32 x 20 x 1.5mm3. Antenna results are simulated using HFSS software and it is depicted that antenna resonates between 11.9GHz to 18.2GHz with S11 below -10dB and gain value obtained over this range is from 10 to 10.5dBi. Proposed structure is suitable for satellite Ku band applications."

[111] "design microstrip patch antenna to obtain circular polarization using U shaped fractal geometry. Proposed antenna shows dual polarization characteristics, left antenna resonates in the Left-hand CP for transmitting and right antenna for receiving signals in RHCP mode. FDGS structures are used to improve antenna gain and efficiency by restoring radiation patterns. Antenna is fabricated using Taconic CER-10 substrate with dimensions 83mm x 45mm and thickness of 3.18mm, with dielectric constant εr=10. Antenna overall size is 100 x 100x 3.18mm. Three iterations of U-shaped structures are used. Results are calculated using HFSS software. Antenna resonates at 45MHz frequency band. Gain of antenna is calculated with and without using FDGS. Gain without DFGS is 2.56dBi and with using FDGS is 5.38dBic."

[112] "design microstrip patch antenna with high gain and wide-bandwidth microstrip antenna using concept of shorting pins. Antenna patch is rectangular in shape and shorted from opposite sides. Antenna mathematical analysis is done using cavity model method. Antenna is excited using co-axial feed which is placed at distance 2.2mm from one edge. Antenna is designed on substrate with εr=2.2 and thickness=2mm. Antenna structure with size 1.29λ0 × 0.73λ0 × 0.036λ0 is simulated and designed and it is clear from results that antenna has good harmony between simulation and measured results. From simulation results, antenna operates in 5.13 to 5.85 GHz with 13.1% bandwidth with gain variation 7.9 to 9.7dBi. Also, measured results reflect that antenna has S11 below -10dB from 5.17 to 5.9GHz with gain values changes between 8 dBi to 9.7dBi. Proposed antenna has advantages like wide bandwidth, small in size, high gain and lower level of cross polarization i.e. below -25dB."

[113] “proposed small sized microstrip patch antenna for wireless communication applications which resonates at 10GHz. To achieve antenna compactness, author uses defected ground structures below the radiating patch in the center of it. He uses Minkowski fractal shapes by adding high capacitive design for proposing the new miniaturized antenna. Overall antenna size is 0.200 × 0.150mm2, which is very small in dimensions. This antenna, provides gain of 3.2dBi and bandwidth of 270MHz over 10GHz resonating frequency. Using concept of DGS, antenna size reduction achieved is 68% with complete volume reduction of 85%. Proposed antenna structure is best suitable for movable X-band wireless sensor applications.”

[114] ”proposed about compact low profile fractal antenna for wireless body area networks with Koch fractal structure operated at a center frequency of 28.45GHz. The fabricated model shown good numerical as well as experimental results and the radiation efficiency is achieved as 75% under the specified frequency. But this efficiency is limited to specified frequency range, as the spectrum increases then it is noticed that there is a decrement in radiation efficiency”.

[115] “proposes printed wide slot line fed compact microstrip patch antenna with parasitic centre patch to further increase the bandwidth of conventional patch antenna. A 50ohm microstrip feed line is used to excite slot and rotated square slot resonator is considered as basic patch design. Resonator shows two frequencies i.e.f1 low resonant and f2 high resonant frequency. From simulation results author investigates that low resonance frequency deceases and high resonant frequency increases by placing parasitic patch in centre of rotated square slot. Simulation results show improvement in bandwidth more than 1GHz. Also proposed structure provides impedance bandwidth of 80% for 2.23 to 5.35 GHz bandwidth. Antenna covers WLAN 2.4, 5.2, 5.8 GHz bands and WiMax 2.5, 3.5, 5.5 GHz bands”.

[116] “proposed antenna with dimensions 37mm by 37mm, and fabricated using FR4 material with thickness of 1.6mm, relative permittivity of 4.4. To improve band, microstrip feed with 16 mm length and width 2.5 mm is used with a pair of semi-circular parasitic patches on both sides of it to provide additional resonance in the circuit. To provide strong coupling with feed line, gap of 0.5mm is maintained between patch and feed line. Antenna design is simple and easy in fabrication. Simulation results shows that bandwidth improvement is 136% for VSWR less than 2 for 2.1 to 11.1 GHz bandwidth. From simulation results the proposed antennas can be used for ultra-wideband modern wireless Communication applications”.

[117] “design and fabricate planer inverted F-antenna using two folded edges based on fractal geometry which shows multi band behaviours. From proposed antenna, two frequency bands are achieved at lower and higher frequencies i.e. 2.25 to 2.863GHz and 4.81to 6.21GHz respectively. Impedance bandwidth obtained is 613MHz i.e. 25% at lower band and 1400MHz which is 26.4% at high frequency band which shows wide bandwidth. At low frequency band with centre frequency 2,4GHz maximum gain achieved is 3.8dBi and 7.2dBi for cut off frequency of 5.3GHz for high frequency band. Antenna is compact in size with overall dimensions of 19.83 x 19.8 mm2. To achieve more compactness in design, antenna patch is folded under itself. The antenna structure is best suited for Wi-Fi, LTE, WiMAX, and WLAN applications for mobile phone device”.

[118]” proposed stacked low-profile antenna for UWB applications. Antenna contains three patches. One patch is angularly folded at 30 degrees also called bottom patch, middle patch with T-Shape and strip loaded patch as a top patch. The T-patch and angularly folded patch are combined together to achieve wide bandwidth. Author uses the shorting wall concept to minimize the antenna size further. Impedance bandwidth is improved using electromagnetic coupling between strip loaded patch antenna and T-shapes antenna. Considered dimensions of antenna are $0.12\lambda \times 0.14\lambda \times 0.08\lambda$, here λ is the lowest operating frequency wavelength. From simulation results author analyse that bandwidth of antenna is 107.46% for frequency band 3.1 to 10.3GHz. Antenna performs well in gain, radiation pattern and provides low delay variations in the designed frequency bands. Due to these entire advantage’s antenna is used for UWB applications”.

3.3 STATEMENT OF PROBLEM:

From Literature survey it is observed that various techniques are proposed for enhancing the bandwidth, gain and construction of antenna, fractal geometry on the patch and defected ground structure on ground plane is very much required. Antennas are constructed using rectangular, circular, triangular and elliptical structures and other geometry is imposed on the patch. Various substrates are configured in order to achieve the desire parameters which can be used for vehicular communications. Various feeding techniques are used for the antenna such as strip line, coaxial, aperture coupling or proximity coupling. The challenge is to fabricate an antenna which provides multi band or wide band for establishing various connections, compact in size such that it can be accommodated in vehicles, good radiation towards the direction of vehicle moments, single feed, better gain and low profile in nature.

3.4 SCOPE OF PRESENT WORK:

The present work is carried out in order to provide a better micro strip patch antenna with fractal geometry on the patch, defected ground structure on the ground plane, compact in nature, working at mm wave frequency range with better bandwidth. The antenna is designed and fabricated for achieving multi band such that it can be used for vehicular communication. The antenna parameters such as reflection coefficient (S11), voltage standing wave ration (VSWR), Total Gain of the antenna, Radiation pattern, current distribution, efficiency of the antenna are studied and compared. Simulation is carried out using HFSS simulation software, for fabrication dip trace software is used. To validate the simulated results, testing is done using Vector Network Analyser (VNA). Following are the objectives carried out in the present work

1. Operating frequency will be more than 10 GHz.

   The operating frequency is selected for 5G environment with the inclusion of lower channels of mm Wave with the range of 25GHz to 35GHz.

2. Design of antenna for High Bandwidth.

   The antenna is designed to achieve high bandwidth such that it can used for multiple applications in vehicular communications. The proposed bandwidth is around 2GHz to 3GHz in order to incorporate multiple applications to enhance the safety and comfort for vehicles on roads.

3. Design of antenna for High Gain.

   One of the important parameter is to provide good gain such that the power consumption and heat dissipation is reduced while using the antenna for higher frequencies. The proposed gain is around 10dBi for multi band applications.

4. Increasing Fractal Array Geometry

   Single patch is further increased to array of elements such as 1X2, 2X2 in order to achieve all the required specifications of the antenna and to provide better performance of the antenna for vehicular communication applications.

3.5 SUMMARY:

This chapter mainly deals with the literature survey of vehicular communication applications, 5G, mm Wave communication, microstrip patch antenna, fractal geometry, various substrates and defected ground structures. Chapter also explained about the parameters of antenna such as dimensions of antenna, reflection coefficient, Voltage standing wave ratio, total gain, bandwidth, radiation pattern and various other standards which can be implemented for vehicular applications.

From literature survey in order to handle high temperatures, either FR4 Epoxy material is used or Rogers RT Duroid material is suggested. Also for dimensions of patch under vehicular communications a maximum of 50mm X 50mm is used. The thickness of the substrate is configured for 0.55mm or 1.6mm. Various shapes are used for defected ground structure such that antenna parameters are improved. For multi element array antenna, a maximum of 2 X 2 antenna is used for vehicular communications. After extensive literature survey, this research work shows the progression in work as mentioned in state of art. Also, it provides motivation to design multi band microstrip patch antenna using fractal and defected geometry to further enhance antenna performance under 5G environment for vehicular communication applications.

CHAPTER-4

SINGLE BAND HIGH BANDWIDTH FRACTAL GEOMETRY WITH DEFECTED GROUND MICROSTRIP PATCH ANTENNA.

4.1 INTRODUCTION:

The proposed antenna is designed using single rectangular patch, and the dimensions of the antenna are calculated depending on the formulated equation which were discussed in the previous chapter. The frequency of operation is carried out at the lower proposed channels for 5G communication in the range of 25GHz to 35GHz with the resonating frequency is set to 30GHz as the centre frequency. The Substrate used for this proposed design is Rogers RO4003™ with the height of 0.55mm, and for providing the excitation, line feed is used with the impedance of 50Ω. Rectangular patch is selected with fractal geometry introduced in it with Non-Deterministic structure which combines the various geometrical structures in order to increase the complexity such that the antenna possesses good radiation. Defected Ground is used in this design and a nonlinear design is incorporated in it. The proposed antenna is simulated using Ansys HFSSv15 and the obtained antenna parameters are discussed in this chapter.

4.2 ANTENNA DESIGN:

The proposed antenna consist of a single rectangular patch with small rectangular cross section with the dimensions of 26×30mm and 8×30 mm as shown in figure 4.1. The antenna is designed using the non-deterministic fractal geometry as presented in literature review.The intention of the design is to generate the maximum voltage distribution towards the radiating direction.The substrate used for this design is Rogers RO4003™ and it has a relative permittivity of 3.55 with a dielectric loss tangent of 0.0027 and mass density of 1000 and the dimensions are as calculated $50 \times 38 \times 0.55$ mm^2, and the fractal geometry is introduced on the patch with 7 two iteration circles at distinct points such that the performance of the antenna can be better. The ground plane is first designed as a rectangular in shape with the dimensions of 50×38 mm and later defected ground is introduced in the proposed design. The patch and ground designs of proposed antenna are shown in figure 4.1 and the dimensions of the antenna are given in the table 4.1 and all the values are considered as milli meter in length. The Substrate is rectangular in structure and for the radiation, air is considered to be as the medium. Both patch and ground boundaries are considered as perfect E .

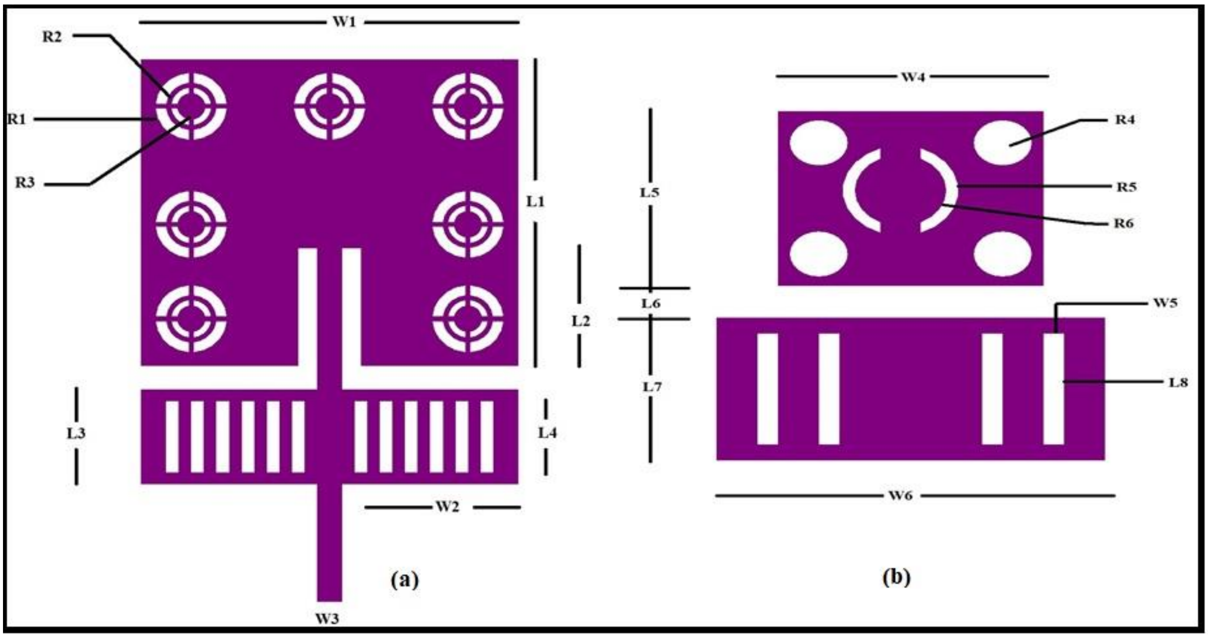


Fig 4.1 Proposed Antenna a) Patch with Fractal Geometry b)Ground with defected structure

Table 4.1 Dimensions of proposed Antenna

Parameters	Size(mm)	Parameters	Size(mm)
L1	26	L5	22
L2	10	L6	6
L3	8	L7	18
L4	6	L8	14
W1	30	W4	26
W2	14	W5	2
W3	2	W6	38
R1	2.82	R4	2.82
R2	2	R5	5
R3	1	R6	4

The length and width of the radiating patch is calculated using the equations stated below

$$W=\frac{1}{2fr\sqrt{\mu 0 \epsilon 0}}\sqrt{\frac{2}{\epsilon r+1}} \quad \text{.....................} \quad \text{(eq 4.1)}$$

$$L=\frac{1}{2fr\sqrt{\epsilon reff\sqrt{\mu 0\epsilon 0}}}-2\Delta L \ldots\ldots\ldots\ldots\ldots\ldots\text{(eq 4.2)}$$

The total fractal Area which is considered as Atotal is calculated using the equation as provided below

$$Atotal=Apatch-(12X\ Arect)-(7XAcircle)\ldots\text{(eq 4.3)}$$

As per the equations, the calculation of the dimensions of the antenna are obtained where the total area is calculated and distributed among the non-deterministic pattern of the antenna.

4.3 ANTENNA SIMULATION RESULTS:

Proposed antenna performance can be obtained in the form of simulation results and in this section, the simulated parameters are discussed which includes the reflection coefficient, VSWR, Total Gain, Current and voltage distribution, Radiation pattern with 2D and 3D patters. To analyse antenna performance, simulation is carried out using Ansys HFSS v15 simulator from 25GHz to 35GHz prior fabrication using PCB technology.

Figure 4.2 provides the reflection coefficient (S11) of the proposed antenna and the resonance occurred at frequency 31.34GHz with reflection coefficient of −32.31dB and the lower and upper cut off frequency as 29.35 GHz and 32.65GHz. It shows that the proposed antenna provides a single band for vehicular application with bandwidth of 3.3GHz.

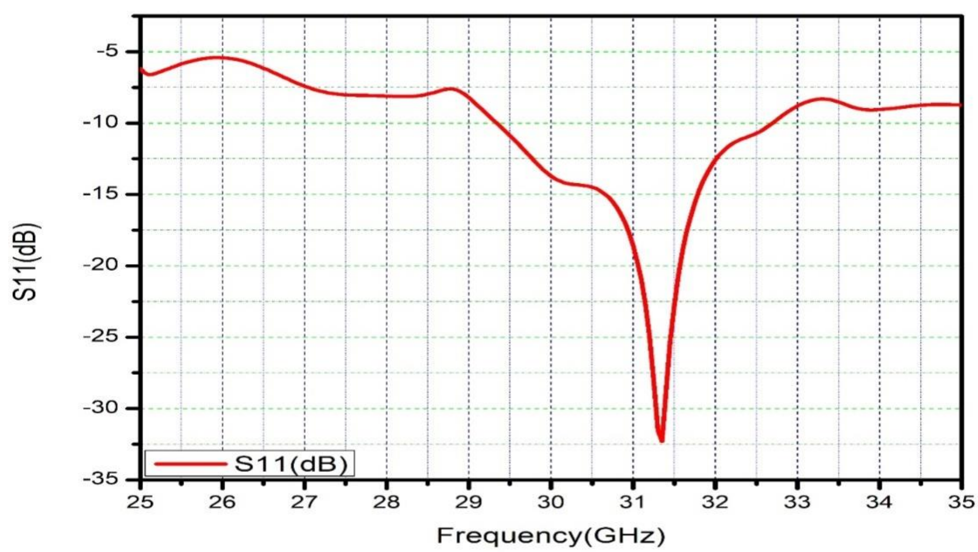


Fig 4.2 Reflection Coefficient of proposed antenna with resonating frequency at 31.34GHz

Figure 4.3 provides the voltage and current distribution of the antenna at the resonating frequency of 31.34GHz. Both voltage and current distribution is evenly distributed and more concentrated on the bottom rectangular plate.

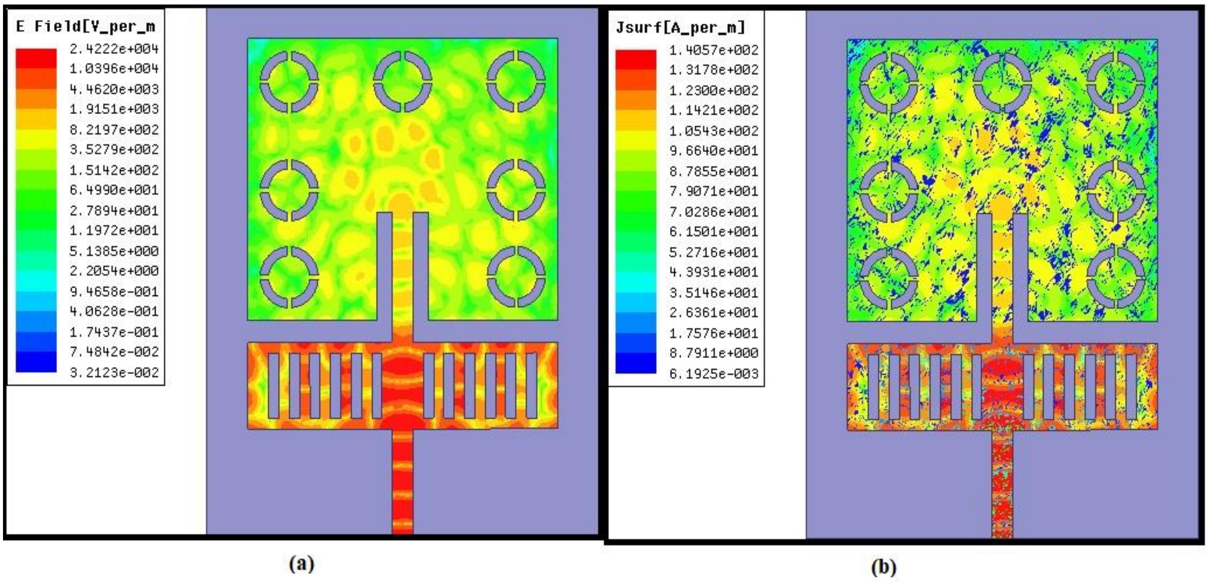


Fig 4.3: Voltage and Current distribution at resonating frequency 31.34GHz

Figure 4.4 provides the voltage standing wave ratio(VSWR) obtained from the simulation of proposed antenna. For any microstrip patch antenna the proposed VSWR limitation is up to 4, and for the reflection coefficient of −10dB, it is observed that the VSWR value is 2.and the range is between 1 and 4 in order to consider that the proposed antenna is better. It is observed that the proposed antenna VSWR is below 4 for the entire range of frequencies.

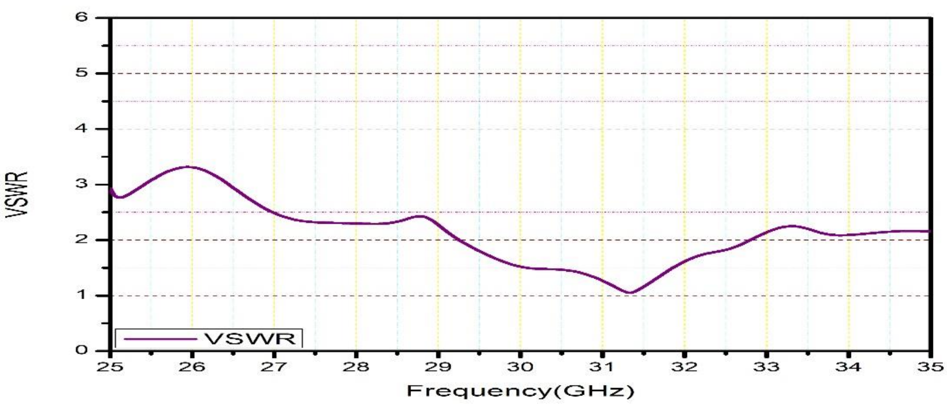


Fig 4.4 VSWR of the proposed antenna

Figure 4.5 provides the Total Gain with the primary sweep of frequency at theta and phi at zero degrees. The gain of the antenna reaches the maximum gain of 8.83dB, and for most of the frequency range the gain is greater than or equal to 3dB. The range starts from 25.5GHz and stays greater than 3dB till 35 GHz.

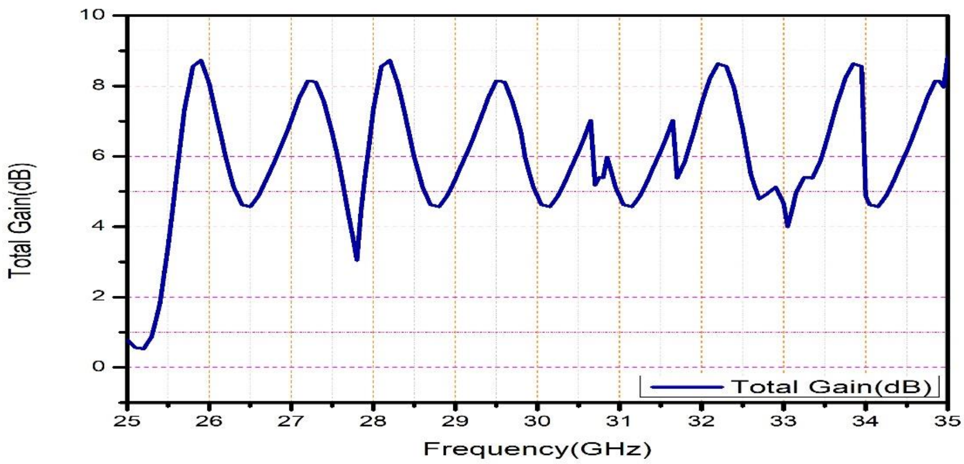


Fig 4.5: Total Gain of proposed antenna with theta and phi at zero degrees

Figure 4.6 provides the radiation pattern of the proposed antenna at the resonating frequency of 31.34GHz and it is observed that the pattern is generating the radiation with good gain towards the forward direction. As the antenna provides better radiation towards the forward direction, the antenna is very much suitable for vehicular communications as the antenna can be placed in front of the vehicle and the range is towards the forward direction. Radiation pattern is shown for both E-plane and H-plane.

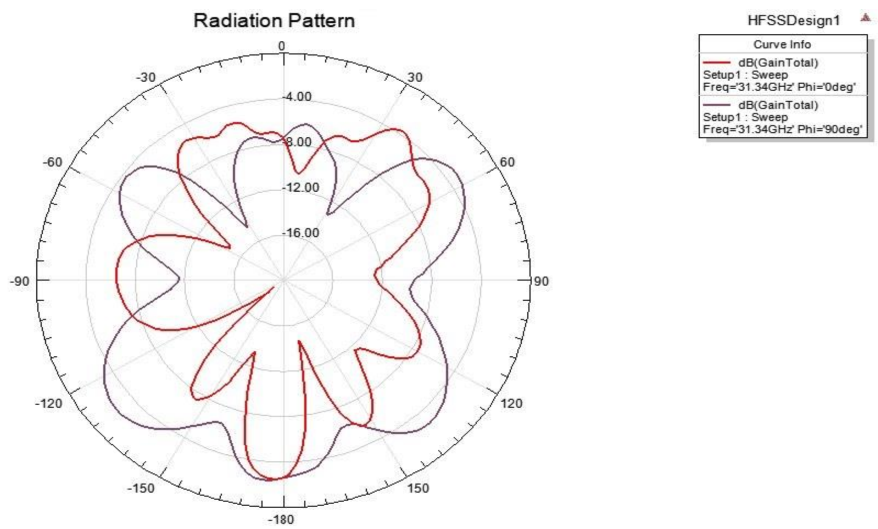


Fig 4.6: E-plane and H-plane radiation pattern of proposed antenna at 31.34GHz

Figure 4.7 provides the impedance of the antenna for both real and imaginary quantities as it provides the impedance tuning for the frequency ranging from 25GHz to 35 GHz, and it is observed that the antenna average real part impedance is near to 50Ω.

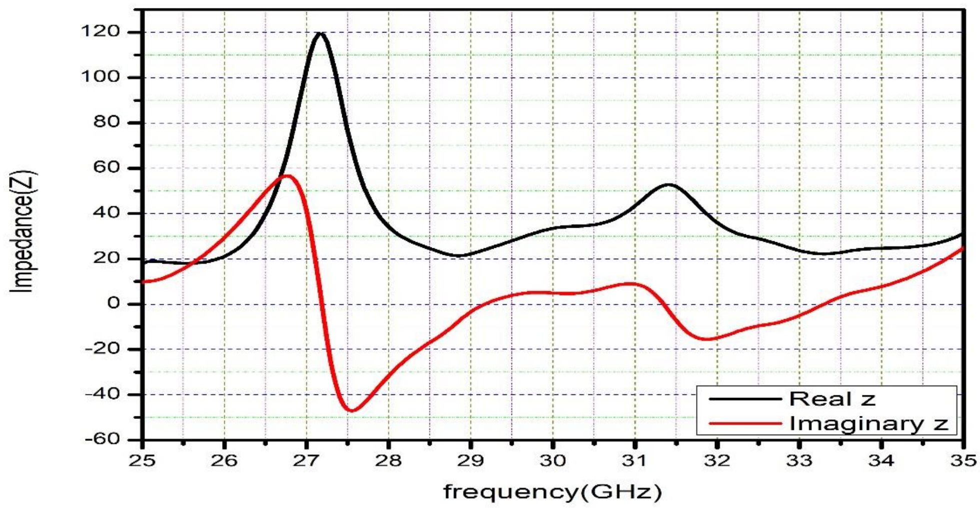


Fig 4.7: Real and Imaginary Impedance of proposed antenna

Figure 4.8 provides the 3-Dimensional polar plot for the resonating frequency of 31.34GHz and it is observed that the proposed antenna possesses a better gain all over the frequency range.

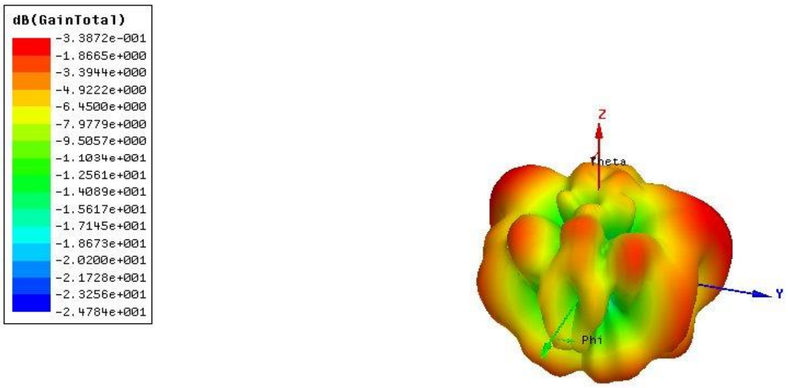


Fig 4.8: 3-D polar plot of proposed antenna at resonating frequency of 31.34GHz

Bandwidth is calculated depending on three factors, the first one is the reflection coefficient must be less than or equal to −10dB, the second is that the voltage standing wave ratio must be less than or equal to 4 and finally the gain of the antenna must be greater than or equal to 3dB. Table 4.2 provides the bandwidth of the proposed antenna with the factors as discussed.

Table 4.2: Proposed antenna simulated results in terms of S11, Gain, VSWR and Bandwidth

Frequency (GHz)	Cut off frequency	Reflection Coefficient (dB)	Bandwidth (MHz)	VSWR	Gain (dB)
29.35-32.65	31.34	−32.31	3300	1.04	8.83

The simulated bandwidth for the proposed antenna is 3300MHz and the range of frequencies are 29.35GHz to 32.65GHz with return loss of 32.31dB and VSWR of minimum 1.04 and maximum total gain of 8.83dB.

4.4 ANTENNA FABRICATION AND TESTING:

After design and simulation of the proposed antenna with Ansys HFSS, and the simulation results are well in the acceptance range, the next process is to fabricate the antenna. The proposed antenna is fabricated with Rogers RO4003™ and the height is 0.55mm and it is fabricated with double layer CNC machine and the outcome is shown in figure 4.9

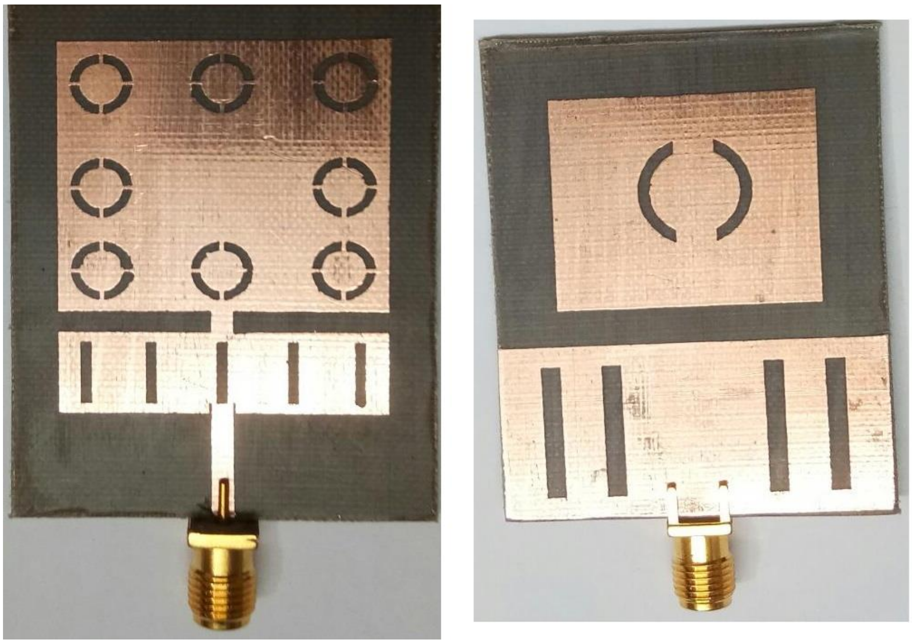


Fig 4.9: Fabrication of the proposed antenna front and back view.

Fabricated antenna reflection coefficient and VSWR is measured using Agilent Technologies N5247A Vector Network Analyzer. The fabrication cost of the antenna is around Rs 3,500/- which is cost effective compare to tradition antennas as the antenna is designed using fractal geometry, the size of the antenna is 23% less than the traditional antennas as per table 4.3.Figure 4.10 provides the simulated vs measured reflection coefficient of the proposed antenna.

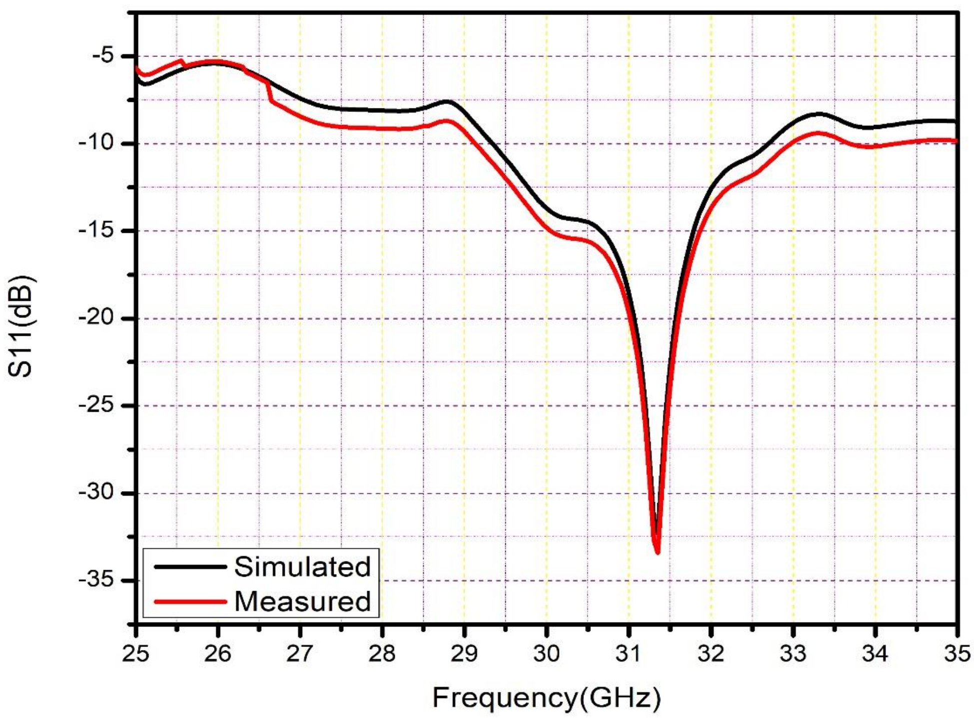


Fig 4.10: Simulated Vs Measured Reflection coefficient of proposed antenna

Figure 4.11 shows the voltage standing wave ration of simulated and measured values for the proposed antenna.

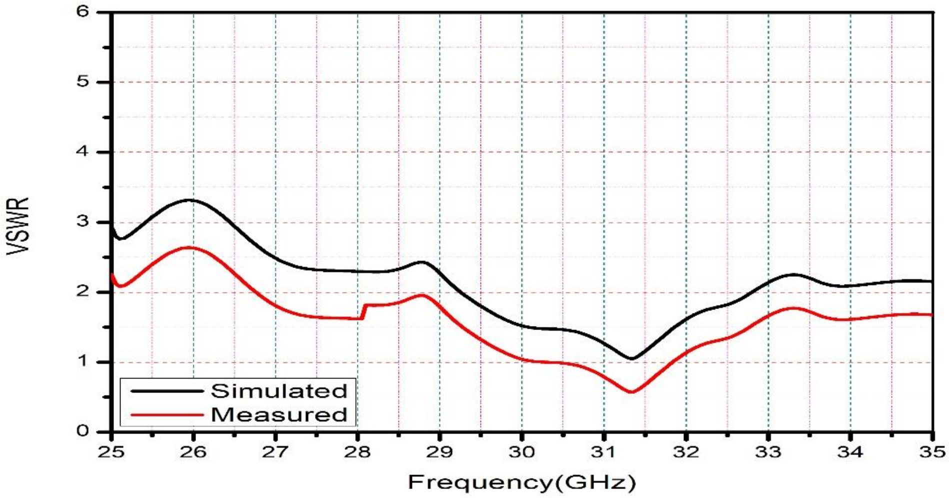


Fig 4.11 Simulated Vs Measured Voltage Standing Wave Ratio of Proposed Antenna

Proposed antenna shows good agreement between the simulated and measured values of both reflection coefficient and VSWR parameters. The comparative analysis is carried out and shown in the table 4.3

Ref.No.	**Ant. Dimensions (mm)**	**Substrate used**	**Operating Frequency (GHz)**	**Bandwidth (MHz)**	**Gain(dB)**	**Remarks**
[72]	60 x 60 x4.8	FR4 (two layers)	24.75–25.38,	630	5.85	Large in size and use two layers of substrate
[78]	138×90×6.79	Roger RT Duroid 5870	13.87-16.96	3090	5.62	Large dimensions, single band
[81]	100×100 x11	Rogers RT Duroid5880	14-16	2000	2.3	Very small bandwidth and large dimensions
[82]	96×73×14	RO4003C	25–27	3000	9.2	Large dimensions, small bandwidth
[84]	45x45x3.18	FR4	(15.58 - 15.88)	300	1.7	Less BW and gain, use large

						dielectric constant(ε=10)
[88]	55 x 48 x0.58	Rogers RT Duroid 4003	23.4–25.6	2200	2.36	Small, gain and bandwidth, large dimensions, single band
Proposed Antenna	50 x 38 x0.55	Rogers RO4003 ™	29.35-32.65	3300	8.83	Large Bandwidth, Compact in Size

4.5 SUMMARY:

In this chapter a single patch, single band fractal geometry based micro strip patch antenna with defected ground structure is presented. The antenna is Fabricated using the substrate material of Rogers RO4003™ . The antenna simulation and measured values are in a very good agreement and the key feature is the antenna is a single band with a very high bandwidth of 3300MHz, and can be used for specific application such as vehicle to Infrastructure where the amount of data transfer requires larger bandwidth. The frequency of operation is carried out under 5G lower Band channel ranging between 25GHz to 35GHz. The antenna possesses total gain of 8.83dB with the minimum reflection coefficient of −32.31dB.

CHAPTER-5

MULTI BAND COAXIAL FEED FRACTAL GEOMETRY WITH DEFECTED GROUND MICROSTRIP PATCH ANTENNA.

5.1 INTRODUCTION:

The proposed antenna is designed using single rectangular patch, and the dimensions of the antenna are calculated depending on the formulated equation which were discussed in the previous chapter. The frequency of operation is carried out at the lower proposed channels for 5G communication in the range of 25GHz to 35GHz with the resonating frequency is set to 30GHz as the centre frequency. The Substrate used for this proposed design is Rogers RO4003™ with the height of 0.55mm, and for providing the excitation, line feed is used with the impedance of 50Ω. Rectangular patch is selected with fractal geometry introduced in it with Non-Deterministic structure which combines the various geometrical structures in order to increase the complexity such that the antenna possesses good radiation. Defected Ground is used in this design and a nonlinear design is incorporated in it. The proposed antenna is simulated using Ansys HFSSv15 and the obtained antenna parameters are discussed in this chapter.

5.2 ANTENNA DESIGN:

The proposed antenna consist of a single rectangular patch with small rectangular cross section with the dimensions of 22 × 32mm and 11 × 31 mm as shown in figure 5.1. The antenna is designed using the non-deterministic fractal geometry as presented in literature review. The intention of the design is to generate the maximum voltage distribution towards the radiating direction. The substrate used for this design is Rogers RO4003™ and it has a relative permittivity of 3.55 with a dielectric loss tangent of 0.0027 and mass density of 1000 and the dimensions are as calculated 43 × 38 × 0.55 mm^2, and the fractal geometry is introduced on the patch with eight two iteration circles at distinct points such that the performance of the antenna can be better. The ground plane is first designed as a rectangular in shape with the dimensions of 50 × 38 mm and later defected ground is introduced in the proposed design. The patch and ground designs of proposed antenna are shown in figure 5.1 and the dimensions of the antenna are given in the table 6.1 and all the values are considered as milli meter in length. The Substrate is rectangular in structure and for the radiation, air is considered to be as the medium. Both patch and ground boundaries are considered as perfect E .

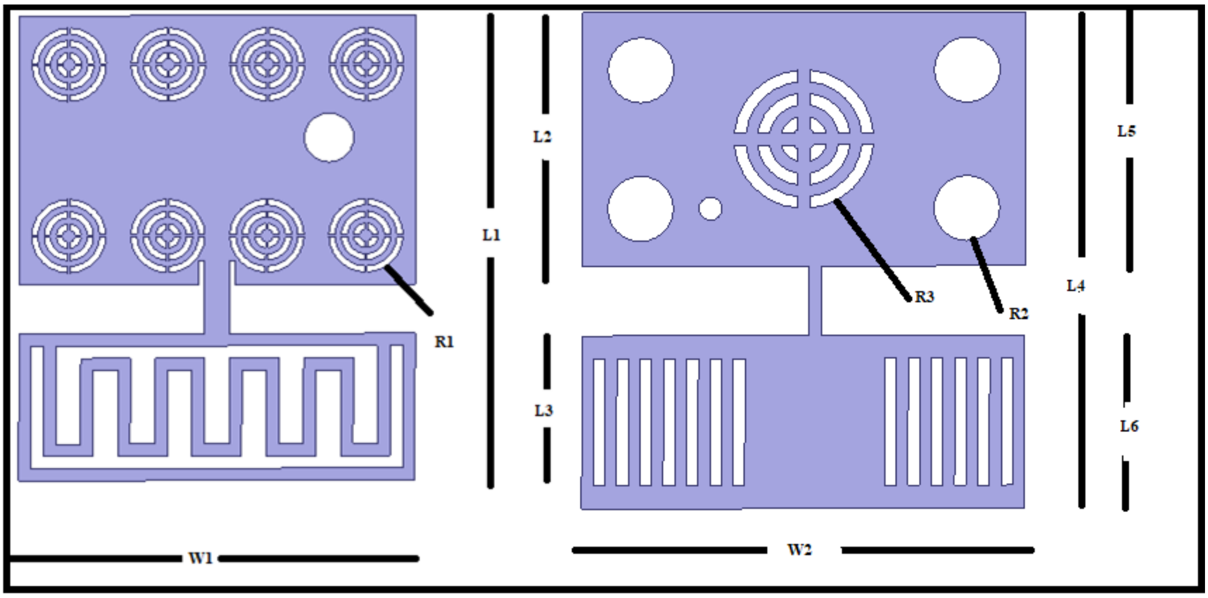


Fig 5.1 Proposed Antenna a) Patch with Fractal Geometry b) Ground with defected structure

Table 5.1 Dimensions of proposed Antenna

Parameters	Size(mm)	Parameters	Size(mm)
L1	38	L4	38
L2	22	L5	22
L3	12	L6	15
W1	32	W2	43
R1	3	R2	6
		R3	8

The length and width of the radiating patch is calculated using the equations stated below

$$W=\frac{1}{2fr\sqrt{\mu 0 \epsilon 0}}\sqrt{\frac{2}{\epsilon r+1}} \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(eq 5.1)}$$

$$L=\frac{1}{2fr\sqrt{\epsilon reff\sqrt{\mu 0 \epsilon 0}}}-2\Delta L\ldots\ldots\ldots\ldots\ldots\ldots\text{(eq 5.2)}$$

The total fractal Area which is considered as Atotal is calculated using the equation as provided below

Atotal=Apatch –(6X Arect)-(8XAcircle)…(eq 5.3)

5.3 ANTENNA SIMULATION RESULTS:

Proposed antenna performance can be obtained in the form of simulation results and in this section, the simulated parameters are discussed which includes the reflection coefficient, VSWR, Total Gain, Current and voltage distribution, Radiation pattern with 2D and 3D patters. To analyse antenna performance, simulation is carried out using Ansys HFSS v15 simulator from 25GHz to 35GHz prior fabrication using PCB technology.

Figure 5.2 provides the reflection coefficient (S11) of the proposed antenna and the resonance occurred at four different frequency locations which are 25.2GHz, 26.2GHz, 31.9GHz and 33.7GHz with reflection coefficients of −34.29dB, −15.29dB, −27.26dB and −22.46dB. It shows that the proposed antenna provides multiple band of operations such that it can be used for multiple applications in vehicular communications as stated.

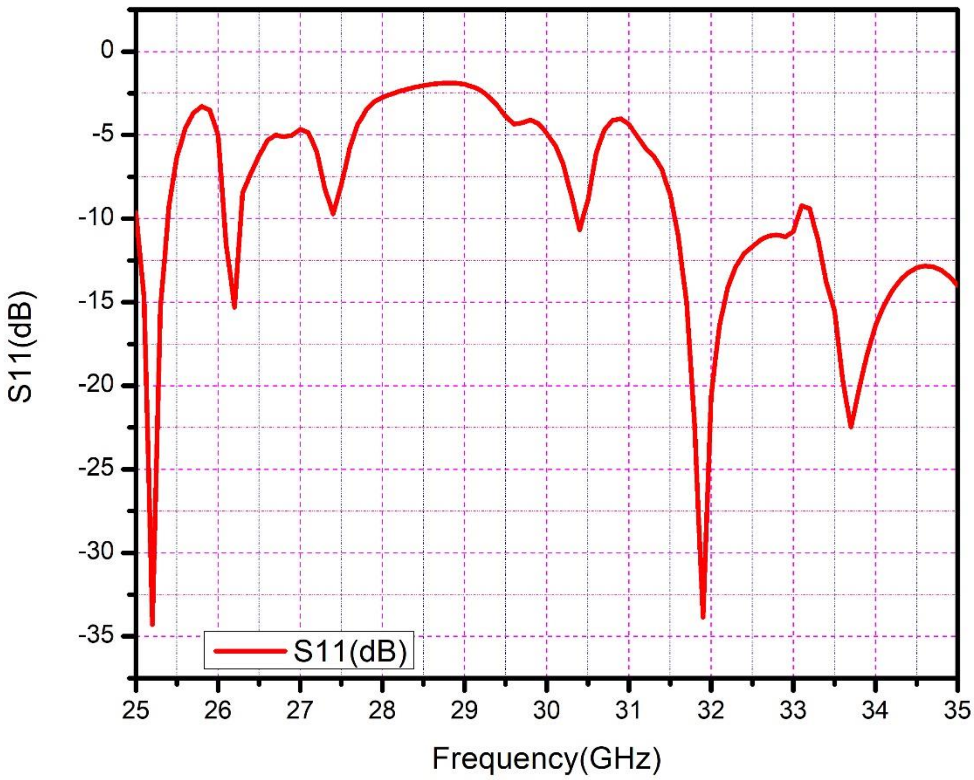


Fig 5.2 Reflection Coefficient of proposed antenna with four resonating frequencies.

Figure 5.3 provides the voltage and current distribution of the antenna at all the resonating frequencies. Both voltage and current distribution is evenly distributed and more concentrated on the centre of the rectangular plate.

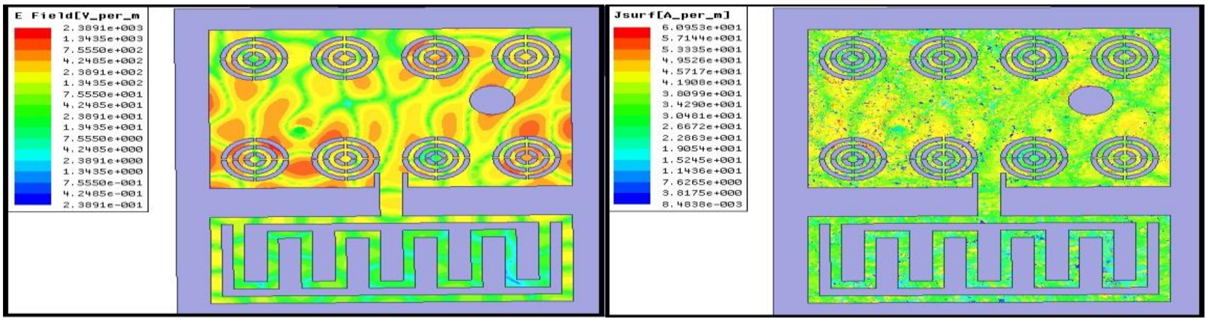


Fig 5.3(a): Voltage and Current distribution at resonating frequency 25.2GHz

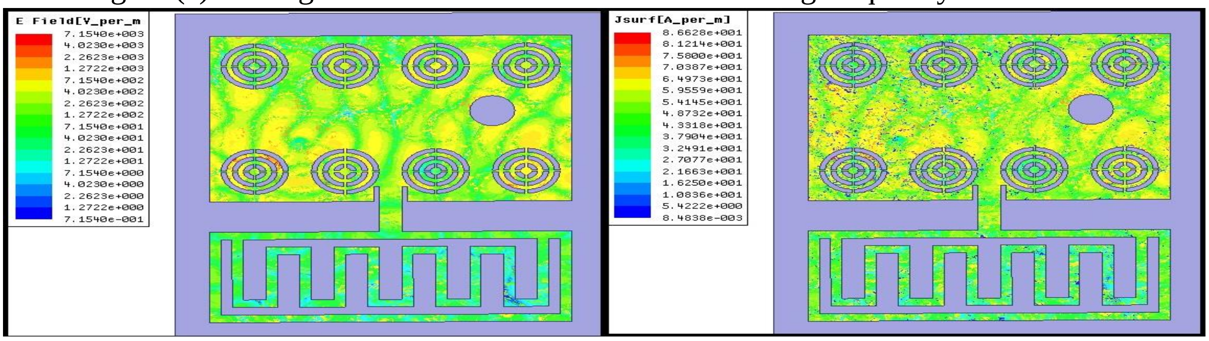


Fig 5.3(b): Voltage and Current distribution at resonating frequency 26.2GHz

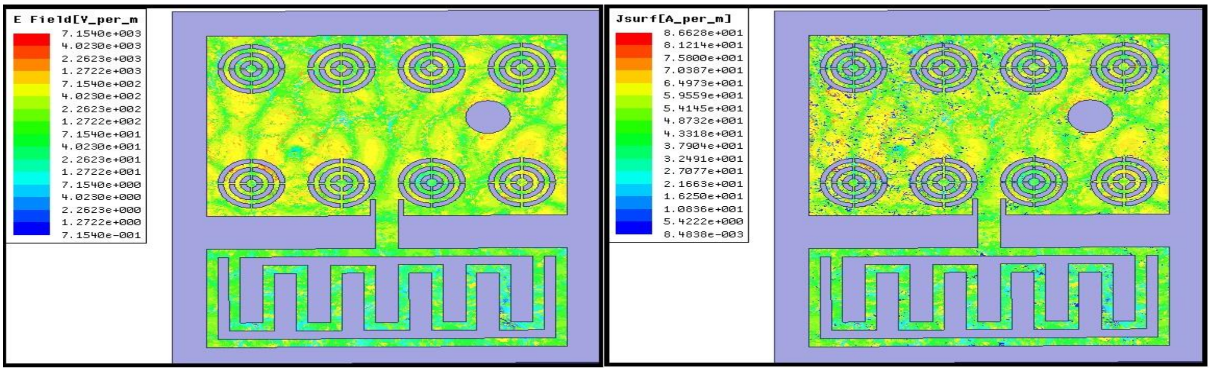


Fig 5.3(c): Voltage and Current distribution at resonating frequency 31.9GHz

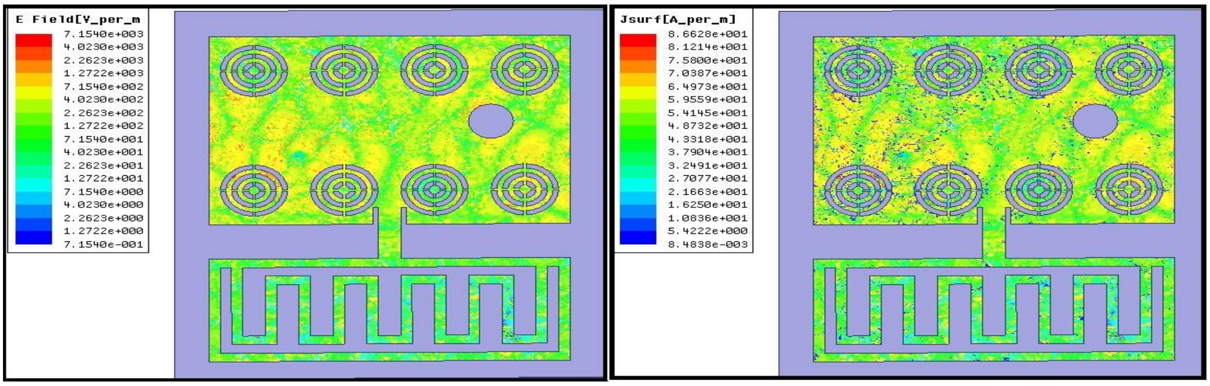


Fig 5.3(d): Voltage and Current distribution at resonating frequency 33.7GHz

Figure 5.4 provides the voltage standing wave ratio (VSWR) obtained from the simulation of proposed antenna. For any microstrip patch antenna the proposed VSWR limitation is up to 4, and for the reflection coefficient of −10dB, it is observed that the VSWR value is 2.and the range is between 1 and 4 in order to consider that the proposed antenna is better. It is observed that the proposed antenna VSWR is below 4 for the maximum range of frequencies.

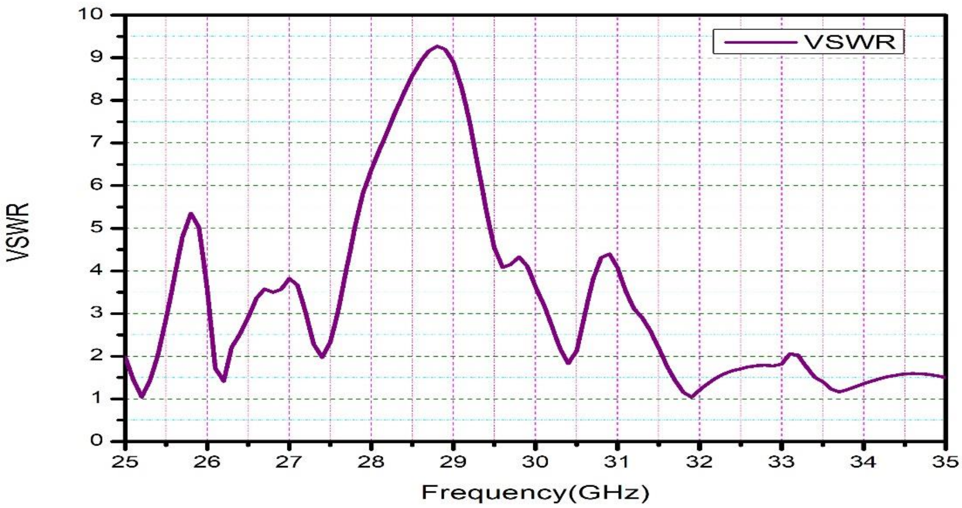


Fig 5.4 VSWR of the proposed antenna

Figure 5.5 provides the Total Gain with the primary sweep of frequency at theta and phi at zero degrees. The gain of the antenna reaches the maximum gain of 21.25dB, and for most of the frequency range the gain is greater than or equal to 3dB. The range starts from 25.45GHz and stays greater than 3dB till 35 GHz.

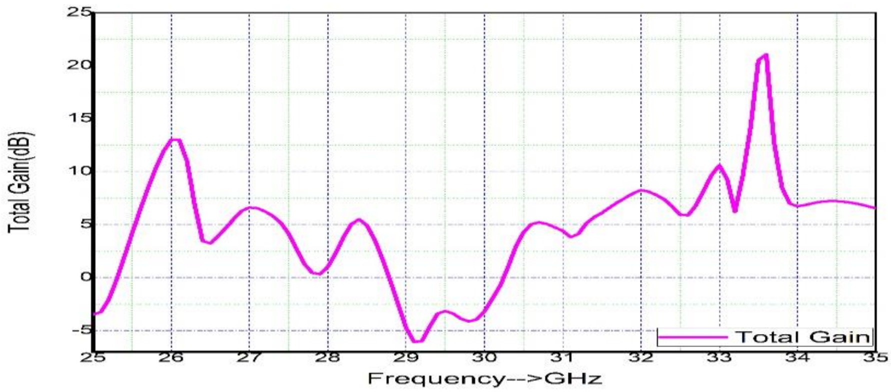
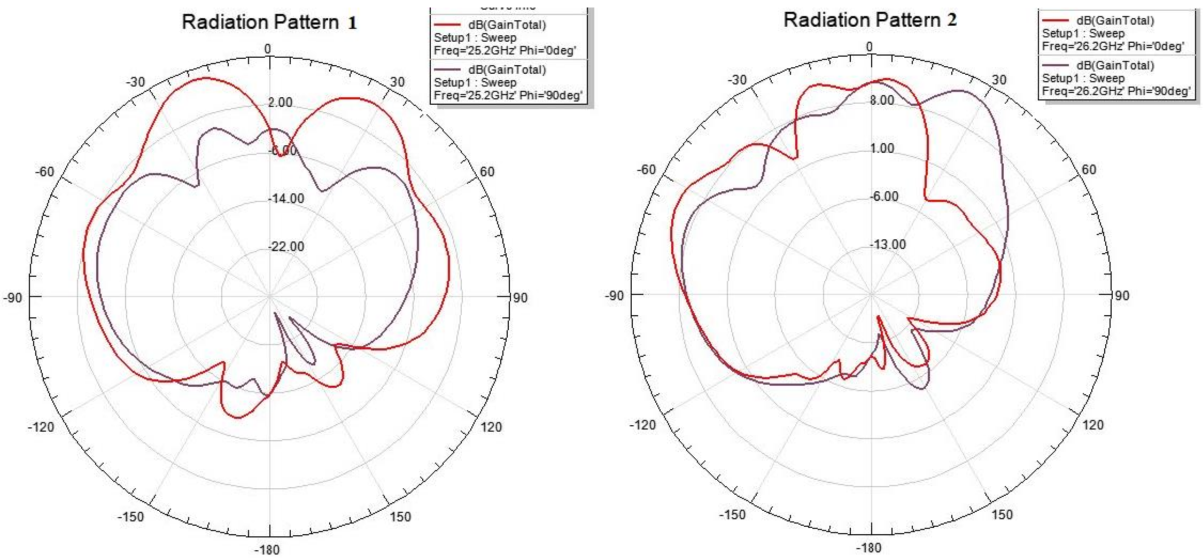


Fig 5.5: Total Gain of proposed antenna with theta and phi at zero degrees

Figure 5.6 provides the radiation pattern of the proposed antenna at all the resonating frequencies and it is observed that the pattern is generating the radiation with good gain towards the forward direction. As the antenna provides better radiation towards the forward direction, the antenna is very much suitable for vehicular communications as the antenna can be placed in front of the vehicle and the range is towards the forward direction. Radiation pattern is shown for both E-plane and H-plane.



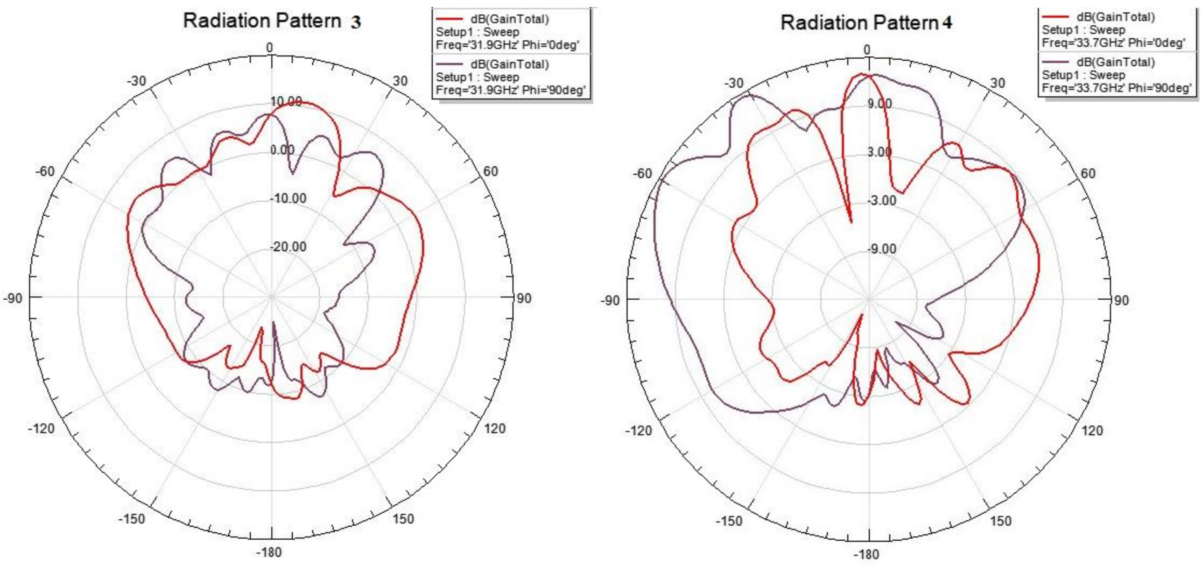


Fig 5.6: E-plane and H-plane radiation pattern of proposed antenna at 25.2GHz, 26.2GHz, 31.9GHz and 33.7GHz

Figure 5.7 provides the impedance of the antenna for both real and imaginary quantities as it provides the impedance tuning for the frequency ranging from 25GHz to 35 GHz, and it is observed that the antenna average real part impedance is near to 50Ω.

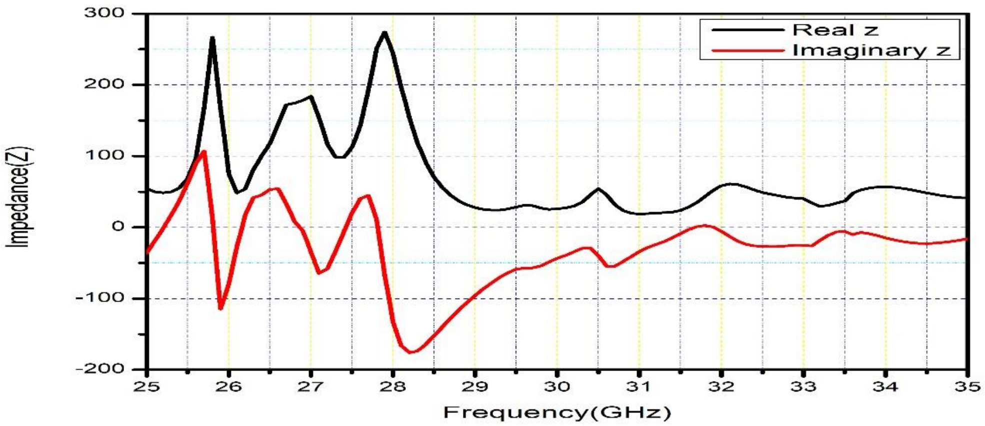


Fig 5.7: Real and Imaginary Impedance of proposed antenna

Figure 5.8 provides the 3-Dimensional polar plot for all the resonating frequencies and it is observed that the proposed antenna possesses a better gain all over the frequency range.

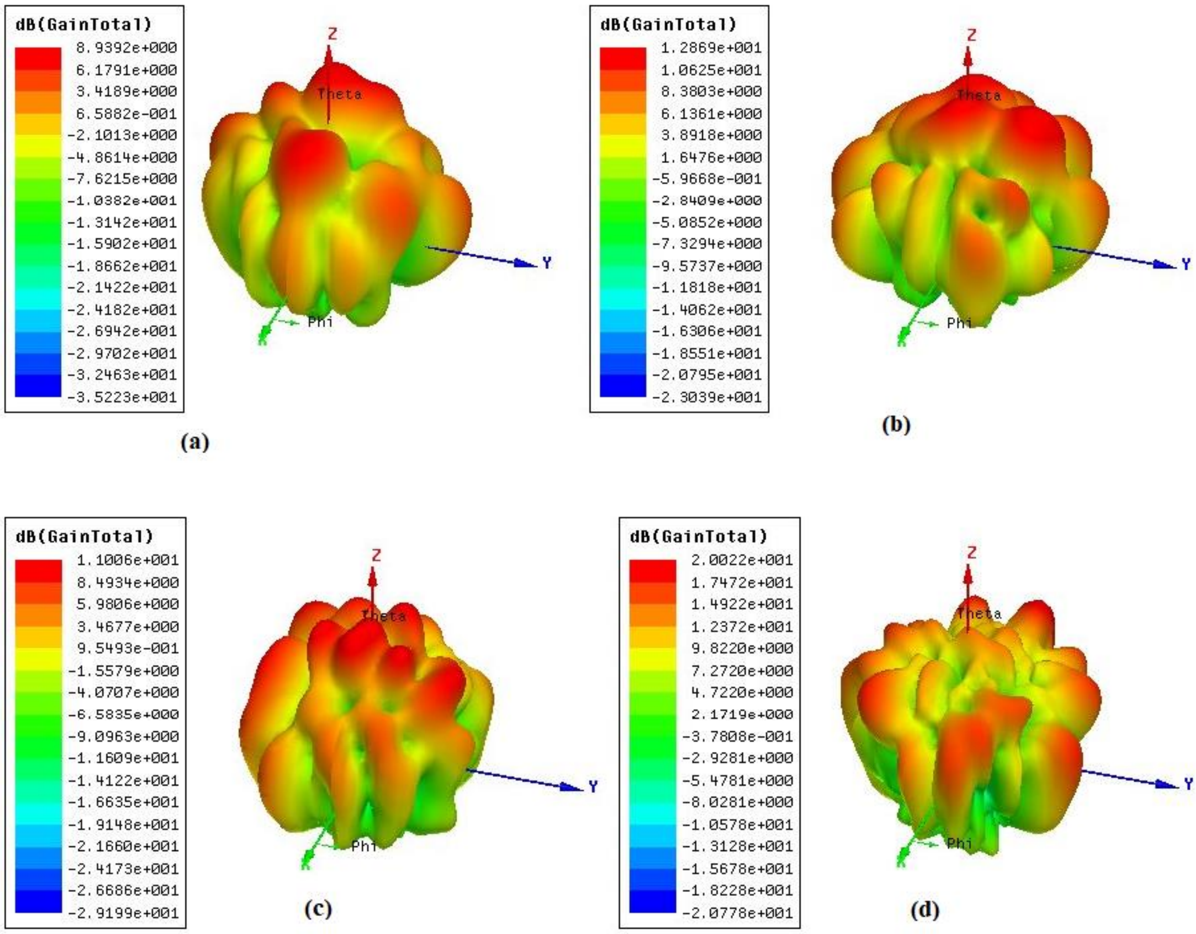


Fig 5.8: 3-D polar plot of proposed antenna at resonating frequencies a)25.2GHz b) 26.2GHz c)31.9GHz and d)33.7GHz

Bandwidth is calculated depending on three factors, the first one is the reflection coefficient must be less than or equal to −10dB, the second is that the voltage standing wave ratio must be less than or equal to 4 and finally the gain of the antenna must be greater than or equal to 3dB. Table 5.2 provides the bandwidth of the proposed antenna with the factors as discussed.

Table 5.2: Proposed antenna simulated results in terms of S11, Gain, VSWR and Bandwidth

Frequency (GHz)	Cut off frequency	Reflection Coefficient (dB)	Bandwidth (MHz)	VSWR	Gain (dB)
25.05 – 25.35	25.2	−34.29	300	1.03	12.31

26.1 – 26.25	26.2	– 15.29	150	1.41	3.86
31.6 – 33.05	31.9	– 33.8	1450	1.04	7.52
33.25 – 35	33.7	– 22.46	1750	1.16	21.25

The simulated bandwidth for the proposed antenna is 3650MHz and the range of frequencies are 25.05 GHz to 25.35GHz, 26.1GHz to 26.25GHz,31.6GHz to 33.05GHz and 33.25GHz to 35 GHz with return loss of 34.29dB,15.29dB,33.8dB and 22.46dB and VSWR of minimum 1.03, 1.41, 1.04 and 1.16 and maximum total gain of 12.31dB, 3.86dB, 7.52dB and 21.25dB. The results obtained provide a multi band, which can be used in vehicle to vehicle communications and instead of communicating with one to one vehicle, one to multiple vehicles can be used. Multiple vehicles can be communicated at the same instant of time without cross talk as the frequency bands are multiple with at least 100MHz of guard band.

5.4 ANTENNA FABRICATION AND TESTING:

After design and simulation of the proposed antenna with Ansys HFSS, and the simulation results are well in the acceptance range, the next process is to fabricate the antenna. The proposed antenna is fabricated with Rogers RO4003™ and the height is 0.55mm and it is fabricated with double layer CNC machine and the outcome is shown in figure 5.9

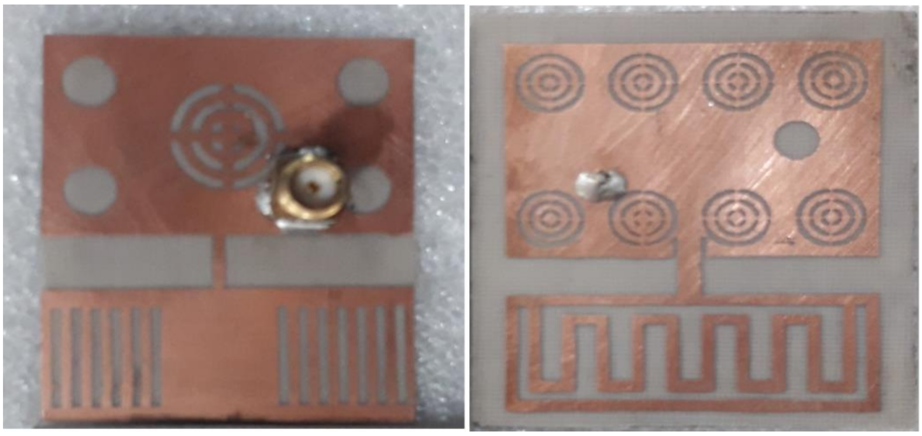


Fig 5.9: Fabrication of the proposed antenna front and back view.

Fabricated antenna reflection coefficient and VSWR is measured using Agilent Technologies N5247A Vector Network Analyzer. . The fabrication cost of the antenna is around Rs 3,500/- which is cost effective compare to tradition antennas as the antenna is designed using fractal geometry, the size of the antenna is 20% less than the traditional antennas as per table 5.3. Figure 5.10 provides the simulated vs measured reflection coefficient of the proposed antenna.

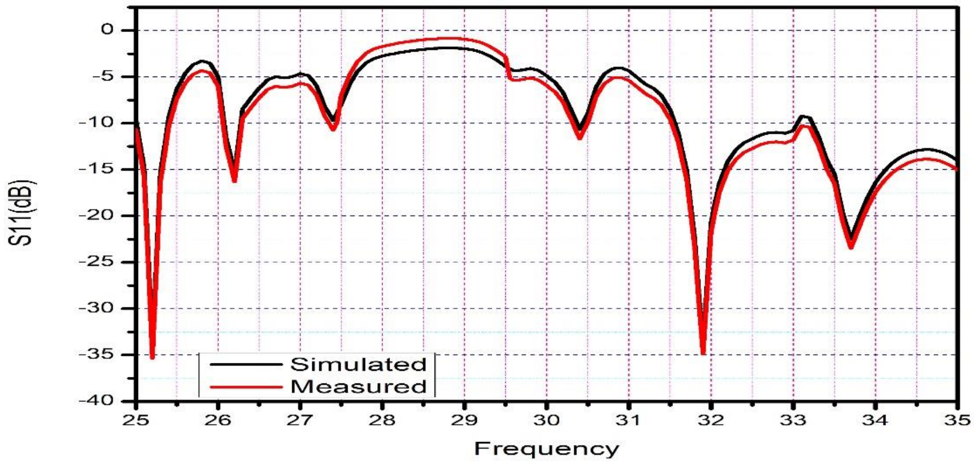


Fig 5.10: Simulated Vs Measured Reflection coefficient of proposed antenna

Figure 5.11 shows the voltage standing wave ration of simulated and measured values for the proposed antenna.

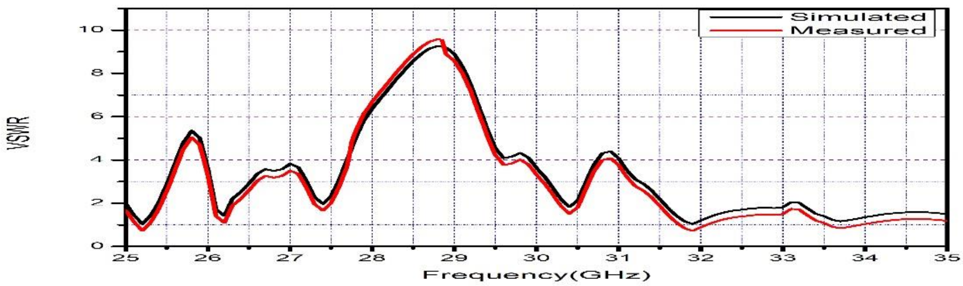


Fig 5.11 Simulated Vs Measured Voltage Standing Wave Ratio of Proposed Antenna

Proposed antenna shows good agreement between the simulated and measured values of both reflection coefficient and VSWR parameters. The comparative analysis is carried out and shown in the table 5.3

Table 5.3 Comparative analysis of various multi band antennas with proposed antenna

Ref.No.	**Ant. Dimensions (mm)**	**Substrate used**	**Operating Frequency (GHz)**	**Band width (MHz)**	**Gain(dB)**	**Remarks**
[66]	60 x 88 x4.8	FR4	3.62-4.75, 9.83-10.65	2230	3.4	Height is large
[67]	96×73×14	RO4003C	2.5–2.7, 3.4–3.6	30, 20	9.2, 7.0	Large dimensions, small bandwidth

[69]	95 x 60x0.8	FR4	0.74–0.965, 1.380-2.703	225, 323	0.76-4.5	Large dimension, less gain
[75]	96×73×14	RO4003C	25–26, 28-28.5, 29.38-29.95	1830	9.2	Large dimensions, small bandwidth
[76]	50.8x 62x0.8	Rogers RO4003 ™	13.85-14.15, 15.38-15.98, 18.36-19.21, 21.25-22.00	2400	8	Very complex structure, large dimensions and single wideband
[77]	59.5x59.9x3.7	Fabric	24.46-24.56, 28.36-28.66	400	3.8	Small bandwidth
Proposed Antenna	50 x 38 x0.55	Rogers RO4003 ™	25.05 – 25.35, 26.01 –26.25, 31.6 – 33.05, 33.25–35	3650	21.25	Multi Band, Good Bandwidth, High Gain

5.5 SUMMARY:

In this chapter a single patch, multi fractal geometry based micro strip patch antenna with defected ground structure is presented. The antenna is Fabricated using the substrate material of Rogers RO4003™ . The antenna simulation and measured values are in a very good agreement and the key feature is the antenna is a single band with a very high bandwidth of 3650MHz, and can be used for specific applications such as vehicle to vehicle, vehicle to infrastructure, vehicle to pedestrian and vehicle to road side unit where the amount of data transfer requires multiple band of frequencies. The frequency of operation is carried out under 5G lower Band channel ranging between 25GHz to 35GHz. The antenna possesses total gain of 21.25dB with the minimum reflection coefficient of −34.29dB.

CHAPTER-6

PENTA BAND FRACTAL GEOMETRY BASED MICROSTRIP ARRAY PATCH ANTENNA FOR VEHICULAR COMMUNICATION APPLICATIONS.

6.1 INTRODUCTION:

The proposed antenna is designed using single chakra shaped patch as well as 2×2 patch array such that the performance of the antenna can be carried out, and the dimensions of the antenna are calculated depending on the formulated equation which were discussed in the previous chapter. The frequency of operation is carried out at the lower proposed channels for 5G communication in the range of 25GHz to 36GHz with the resonating frequency is set to 30GHz as the centre frequency. The Substrate used for this proposed design is Rogers RT duroid 5880™ with the height of 1.6mm and for providing the excitation, line feed is used with the impedance of 50Ω. Rectangular patch is selected with fractal geometry introduced in it with Non-Deterministic structure which combines the various geometrical structures in order to increase the complexity such that the antenna possesses good radiation. The proposed antenna is simulated using Ansys HFSSv15 and tested using Agilent Technologies N5247A VNA. The obtained antenna parameters are discussed in this chapter.

6.2 ANTENNA DESIGN:

The proposed antenna configuration is carried out for single patch as well as multi patch with the dimensions of 39 × 48mm and 82 × 115 mm as shown in figure 6.1. The substrate used for this design is Rogers RT duroid 5880™ and it has a relative permittivity of 2.2 with a dielectric loss tangent of 0.0009 and mass density of 1100 and the dimensions for single chakra shape and 2×2 array patch are as calculated $39 \times 48 \times 1.6$ mm^2 and $82 \times 115 \times 1.6$ mm^2, and the fractal geometry is introduced on the patch with circular shape and internally made of seven iterations, with each iteration radius is reduced by 1mm as shown in Figure 6.1. The ground plane is a proper rectangular in shape with the dimensions same as the substrate for length and width. The patch and ground designs of proposed antenna are shown in figure 6.1 and the dimensions of the antenna are given in the table 6.1 and all the values are considered as milli meter in length. The Substrate is rectangular in structure and for the radiation, air is considered to be as the medium. Both patch and ground boundaries are considered as perfect E .

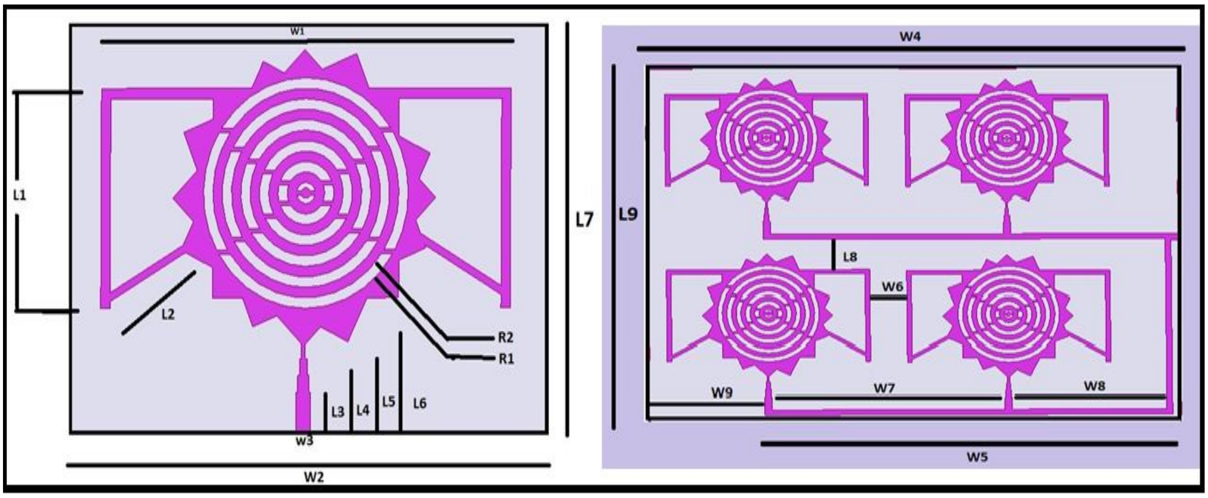


Fig 6.1 Proposed Antenna with single patch and multi patch (2×2 array)

The antenna dimensions are calculated as per the circular patch with radius of r, and the mathematical formulation is as follows:

$$\mathbf{R = Qr / \omega rC} \qquad \textbf{(Eq 6.1)}$$

$$\mathbf{L_1 = 1/\omega_r^2 C_1} \qquad \textbf{(Eq 6.2)}$$

$$\mathbf{C_1 = \frac{LW\mathcal{E}0\mathcal{E}e}{2h}\cos^2(\prod x_0/L)} \qquad \textbf{(Eq 6.3)}$$

in which L = Patch length, W = Patch width,x_0 = feed point location, h = substrate thickness.

$$\mathbf{Q_r = \frac{c\sqrt{\in e}}{fh}} \qquad \textbf{(Eq 6.4)}$$

where f = frequency of the designed antenna, c = light velocity, $\mathcal{E}_e$ = effective permittivity of medium.

$$\mathbf{\mathcal{E}_e = \frac{\in r+1}{2} + \frac{\in r-1}{2}(1+\frac{12h}{W})^{-1/2}} \qquad \textbf{(Eq 6.5)}$$

These equations are used for calibrating the dimensions of the proposed antennas, first the single paltch antenna dimensions are obtained and then using array elements concept the 1X2 and 2X2 antenna dimensions are obtained. The fractal geometry used is non-deterministc, due to which the total area of the patch is mateched with the obtained patch dimensions.

Table 6.1 Dimensions of proposed Antennas

Parameters	Size(mm)	Parameters	Size(mm)
L1	21	W1	44
L2	8	W2	52
L3	4	W3	1.6
L4	5.5	W4	115
L5	7	W5	90
L6	8.5	W6	8
L7	39	W7	50
L8	7	W8	33
L9	82	W9	25
R1	10	R2	9

The antenna from single circular patch to multi patch has evolved as shown in figure 6.2 which first designed as individual single patch, then followed by 1×2 patch, finally a 2×2.

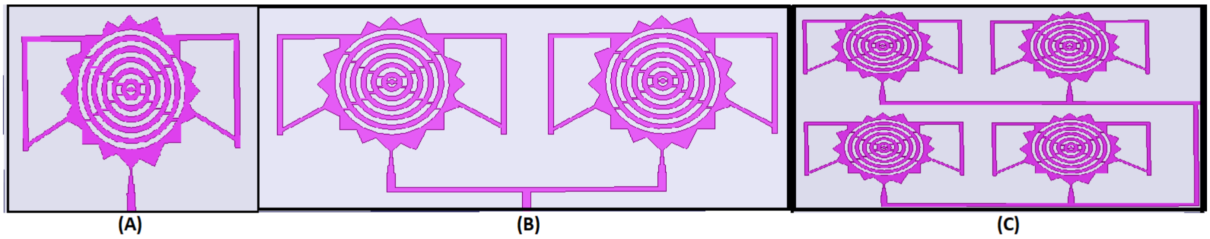


Fig 6.2: (A) Single patch antenna (B)1×2 patch antenna (C) 2×2 patch antenna

6.3 ANTENNA SIMULATION RESULTS:

Proposed antenna performance can be obtained in the form of simulation results and in this section, the simulated parameters are discussed which includes the reflection coefficient, VSWR, Total Gain, Current and voltage distribution, Radiation pattern with 2D and 3D patters. To analyse antenna performance, simulation is carried out using Ansys HFSS v15 simulator from 25GHz to 36GHz prior fabrication using PCB technology.

The parametric investigations are performed to observe the variations of reflection coefficients for different design evolution stages as discussed earlier. Figure 6.3 provides the parametric study of S11 for all the three designes which are single patch, 1×2 patch and 2×2 patch configurations. As the number of elements are increased, the reflection coefficient of the proposed antenan drastically reduced and the number of resonating points have been increased. So, with the suggested 2×2 patch array configuration, the antenna resonates at multiple bands with enhanced operating bandwidths.

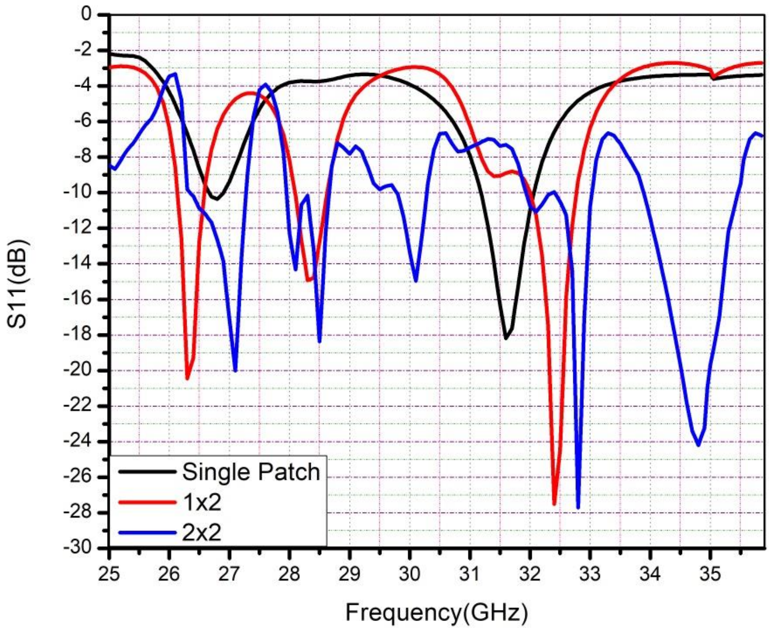


Fig 6.3: Parametric study of S_{11} for single patch antenna, 1×2 patch antenna and 2×2 patch antenna

Figure 6.4(a) provides the reflection coefficient (S11) of the single circular patch antenna and the resonance occurred at two different frequency locations which are 26.8GHz and 31.6GHz with reflection coefficients of −10.96dB and −18.19dB. Figure 6.4(b) provides the reflection coefficient of 2 × 2 with five operating bands of 27.1GHz, 28.5GHz, 30.1GHz, 32.8GHz and 34.8GHz with the reflection coefficients of – 20.01, −18.36, −14.96, −27.71 and −24.19 respectively . It shows that the proposed single patch antenna provides two bands of operations whereas the 2× 2 provides penta band of operations such that it can be used for multiple applications in vehicular communications as stated.

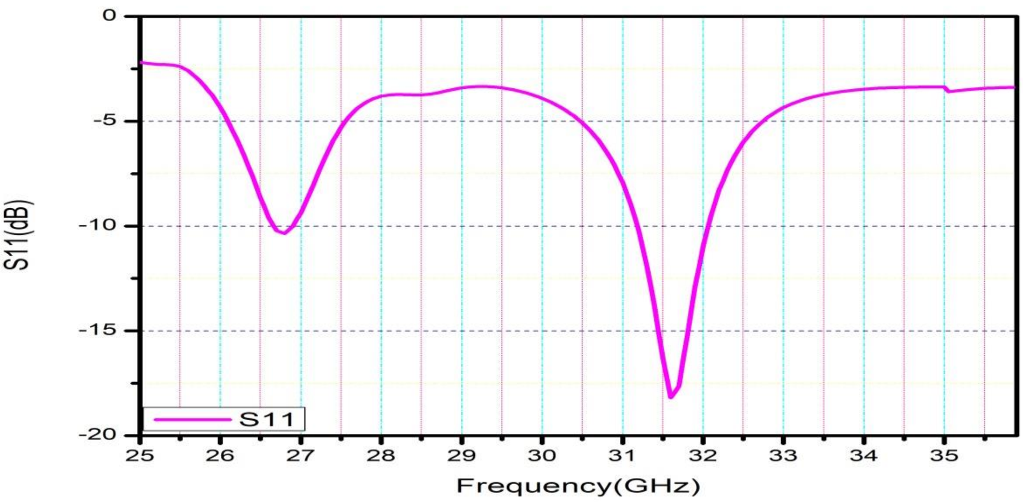


Fig 6.4(a) Reflection Coefficient of proposed single patch antenna

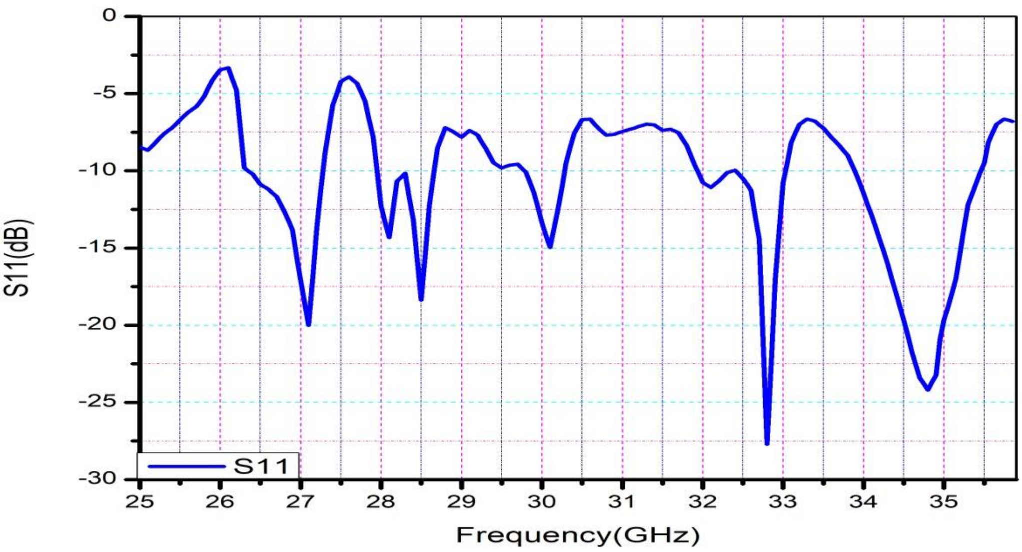


Fig 6.4(b) Reflection Coefficient of proposed antenna 2× 2 patch antenna.

Figure 6.5 provides the surface current distribution of both single patch and 2× 2 patch antennas. For both the antennas the current distribution is evenly distributed and more concentrated on the structure.

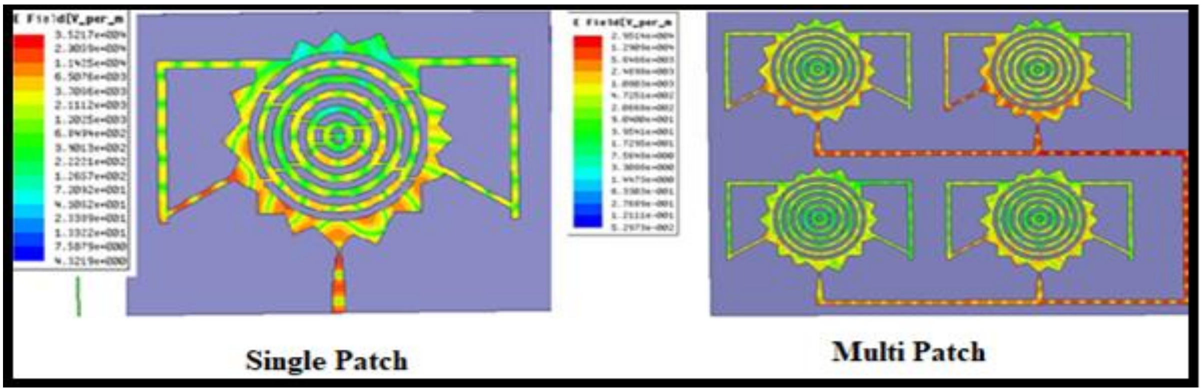


Fig 6.5: Surface Current on a single patch antenna at 31.35GHz and multi-patch antenna at 32.8GHz

Figure 6.6 provides the voltage standing wave ratio (VSWR) obtained from the simulation of both the proposed antennas. For any microstrip patch antenna the proposed VSWR limitation is up to 4, and for the reflection coefficient of −10dB, it is observed that the VSWR value is 2.and the range is between 1 and 4 in order to consider that the proposed antenna is better. It is observed that the proposed antenna with 2× 2 patch has better VSWR compare to the single patch and it is below 4 for the resonating points and band of frequencies.

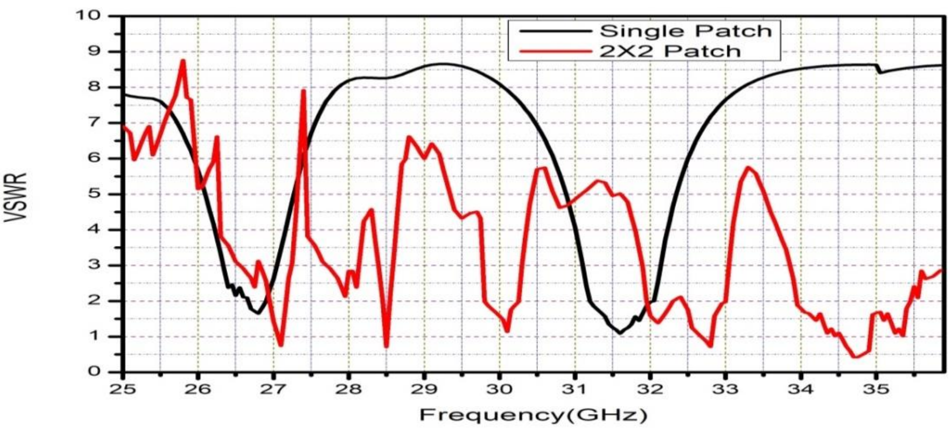


Fig 6.6 VSWR of the proposed single patch antenna and 2×2 patch antenna

Figure 6.7 provides the details about total gain of both the proposed antennas with the primary sweep of frequency at theta and phi at zero degrees. The gain of the single patch antenna reaches the maximum gain of 8.2dB which is better than multi patch, and for most of the frequency range, the gain is greater than or equal to 3dB. The gain of the multi-patch antenna reaches the maximum gain of 10.64dB at resonating frequency of 32.8GHz and 6.69dB at 28.5GHz respectively and compare to single patch the gain is little bit compromise but it is greater than 3dB for all the resonating points.

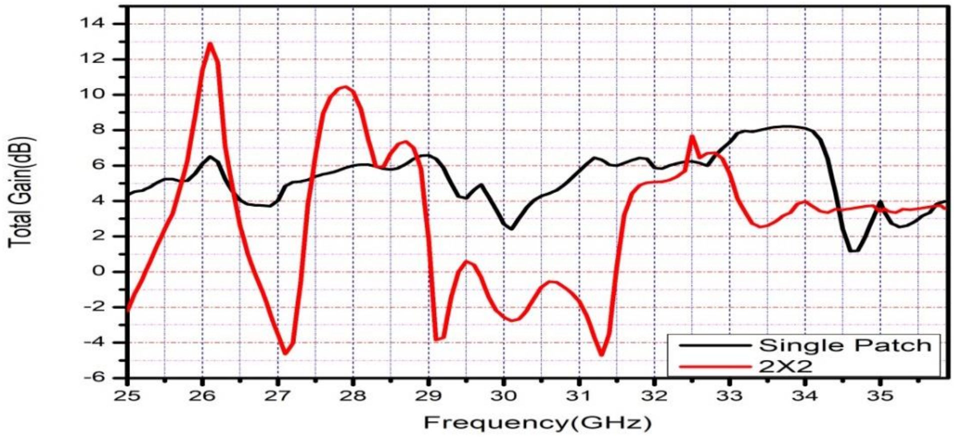
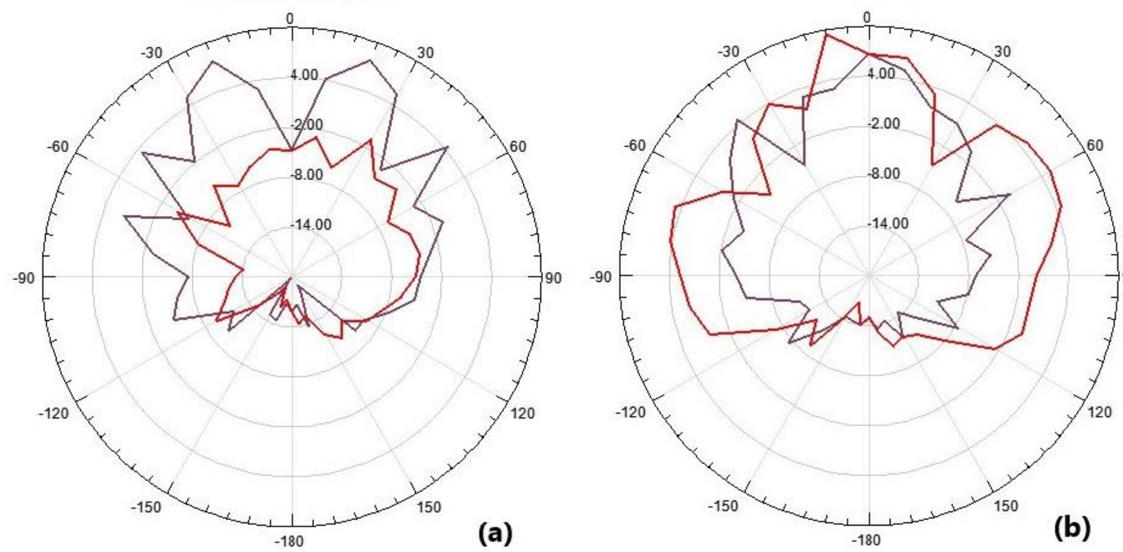


Fig 6.7: Total Gain of single patch and 2×2 proposed antennas

Figure 6.8 provides the radiation pattern of the proposed antennas at all the resonating frequencies and it is observed that the pattern can be used for vehicular communication applications as it is radiating toward the forward direction. Radiation pattern is shown for both E-plane and H-plane.



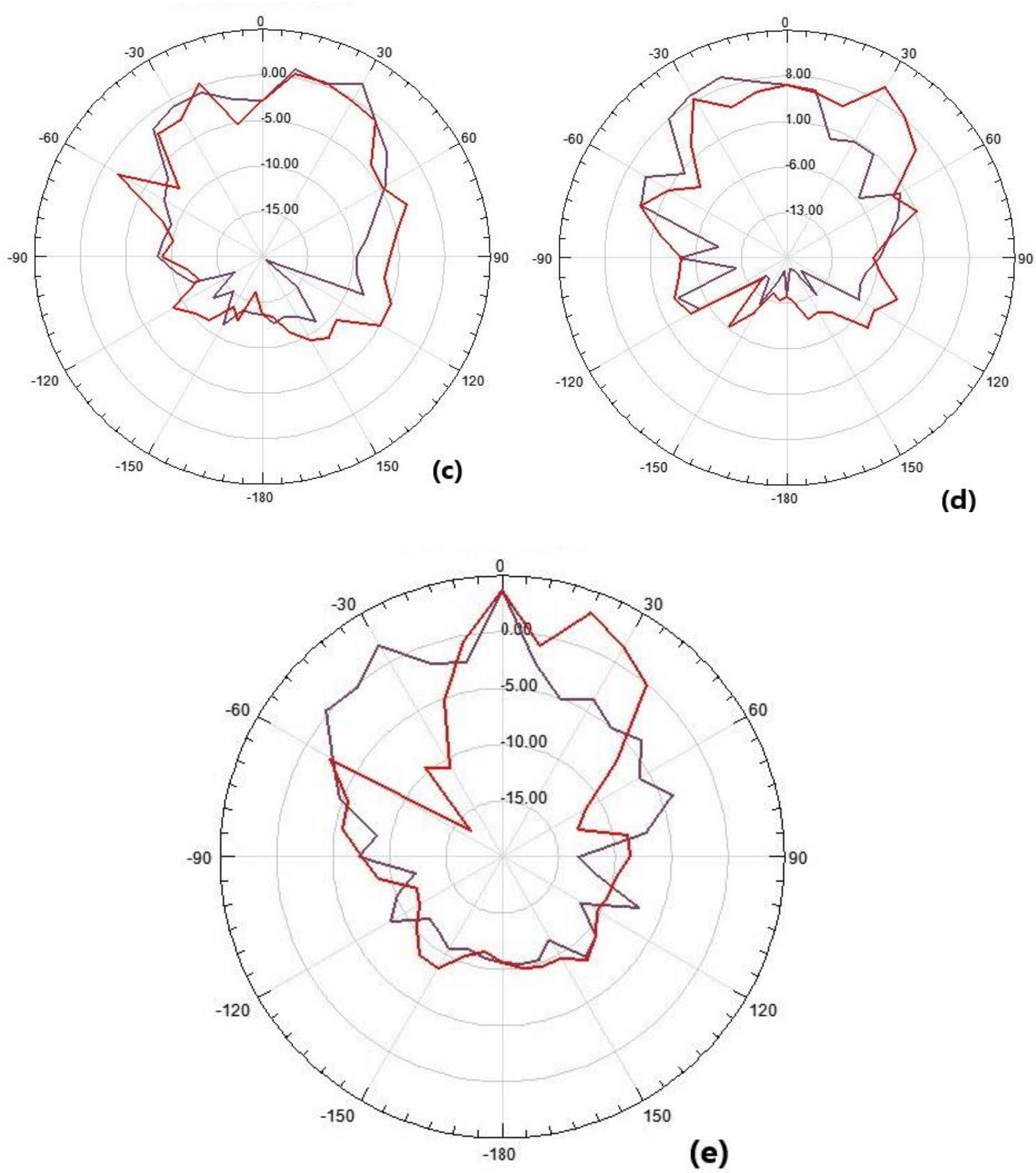


Fig 6.8: Radiation Patterns for E-plane represented in black and H-plane represented in red color of multi-patch antenna at a) 27.1GHz b) 28.5GHz c)30.1GHz d)32.8GHz e) 34.8GHz

Figure 6.9 provides the impedance of the proposed antenna for both real and imaginary quantities as it provides the impedance tuning for the frequency ranging from 25GHz to 36 GHz, and it is observed that the antenna average real part impedance is near to 50Ω.

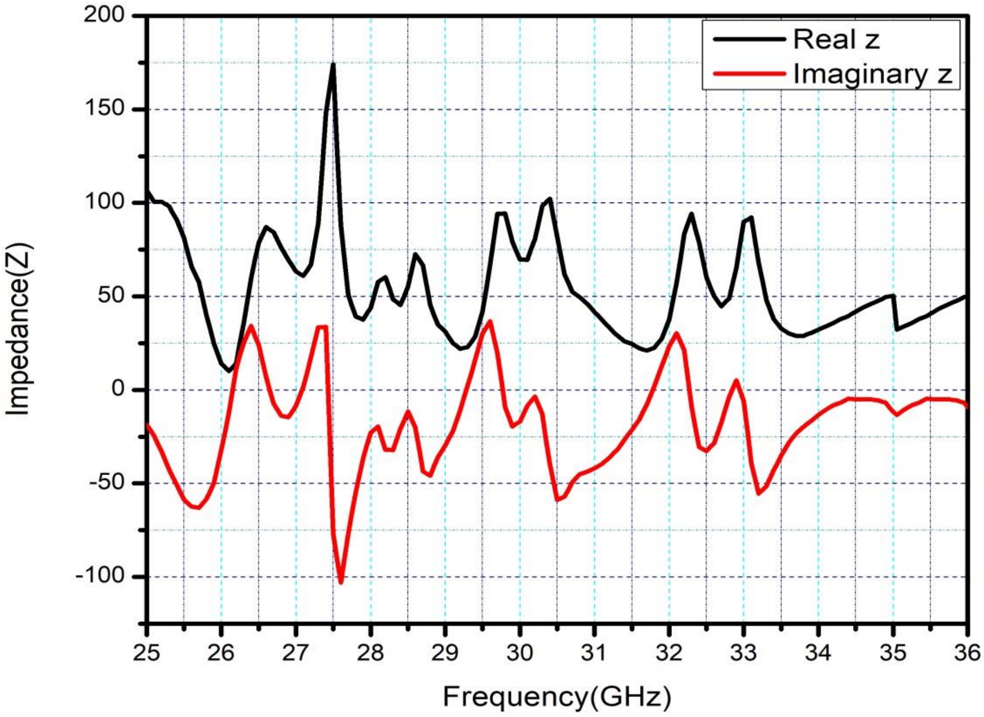
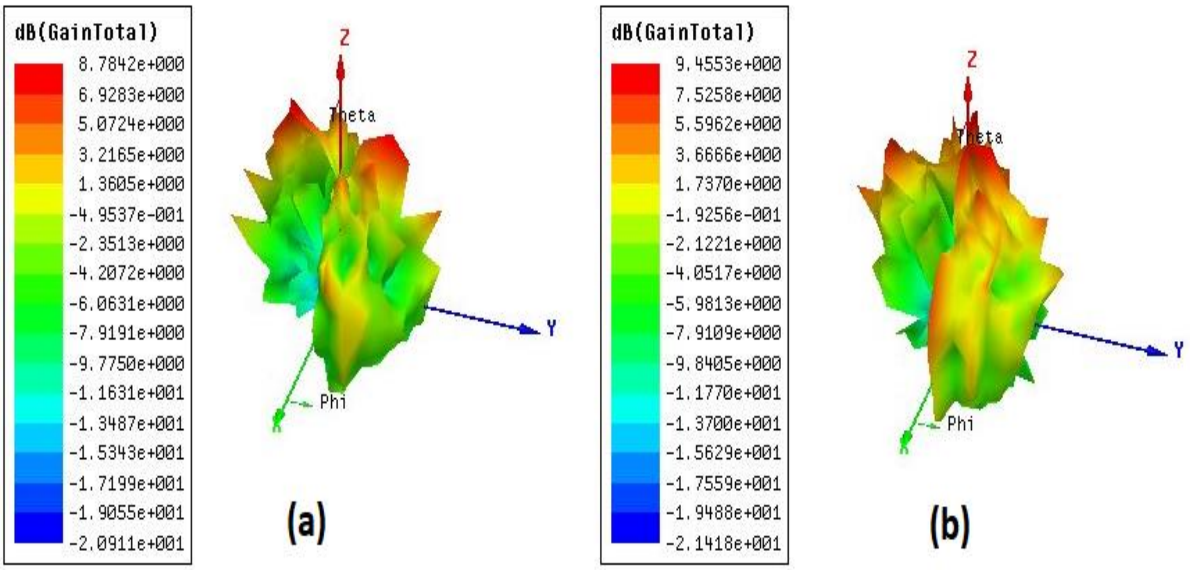


Fig 6.9: Real and Imaginary Impedance of proposed antenna

Figure 6.10 provides the 3-Dimensional polar plot for all the resonating frequencies and it is observed that the proposed antenna possesses a better gain all over the frequency range.



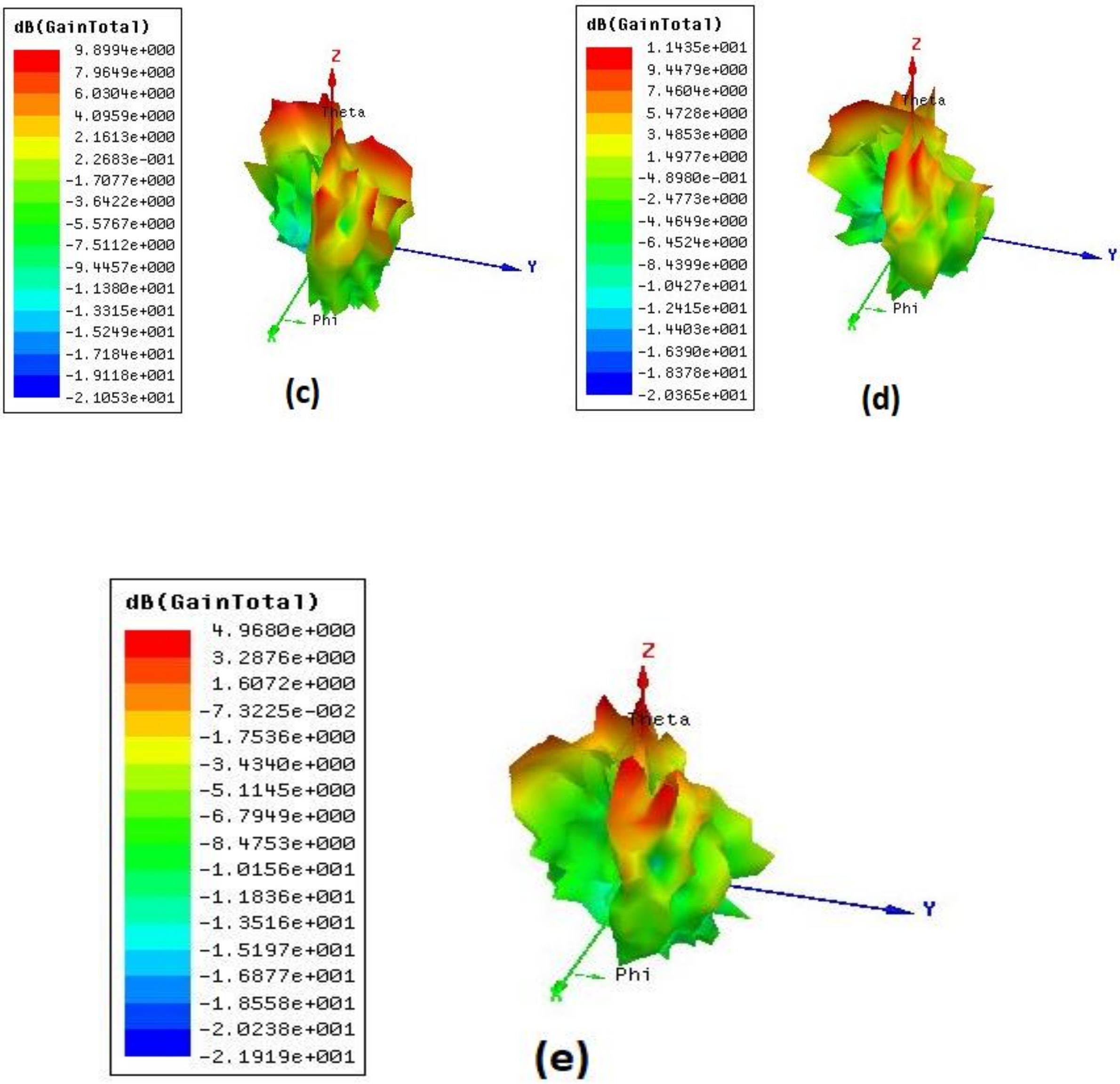


Fig 6.10: 3-D polar plot of proposed antenna at resonating frequencies a)27.1GHz b) 28.5GHz c)30.1GHz d)32.8GHz and e) 34.8Ghz

Bandwidth is calculated depending on three factors, the first one is the reflection coefficient must be less than or equal to −10dB, the second is that the voltage standing wave ratio must be less than or equal to 4 and finally the gain of the antenna must be greater than or equal to 3dB. Table 6.2 provides the bandwidth of both the proposed antenna with the factors are discussed.

Table 6.2: Proposed antenna simulated results in terms of S11, Gain, VSWR and Bandwidth for single patch and 2X2 array.

Frequency (GHz)	Cut off frequency	Reflection Coefficient (dB)	Bandwidth (MHz)	VSWR	Gain (dB)
Single Patch					
26.7 – 26.9	26.8	– 10.35	200	1.06	6.51
31.2 – 32.05	31.5	−18.19	850	1.02	5.99
2×2 proposed antenna					
26.35 – 27.25	27.1	– 20.01	900	1.31	7.11
27.95 – 28.65	28.5	– 18.38	700	1.02	10.64
29.8 – 30.25	30.1	– 14.96	450	1.04	5.81
31.95 – 33	32.8	–27.71	1050	1.03	6.72
33.9 – 35.45	34.8	–24.19	1550	1.02	3.91

The simulated bandwidth for the proposed single patch antenna is 1050MHz and the range of frequencies are 26.7 GHz to 26.9GHz and 31.2 to 32.05GHz with VSWR of minimum 1.06 and 1.02 and maximum gain of 6.51dB and 5.99dB. The simulated bandwidth of 4.65GHz and the range of frequencies are 26.35GHz to 27.25GHz,29.8GHz to 30.25GHz,31.9GHz to 33GHz and 33.9GHz to 35.45GHz and VSWR of minimum 1.31, 1.02, 1.04, 1.03 and 1.02 and maximum total gain of 7.11dB, 10.64dB,5.81dB,6.72dB and 3.91dB respectively.

6.4 ANTENNA FABRICATION AND TESTING:

After design and simulation of the proposed antenna with Ansys HFSS, and the simulation results are well in the acceptance range, the next process is to fabricate the antenna. The proposed antenna is fabricated with Rogers RT duroid 5880™ and the height is 1.6mm and it is fabricated with double layer CNC machine and the outcome is shown in figure 6.11

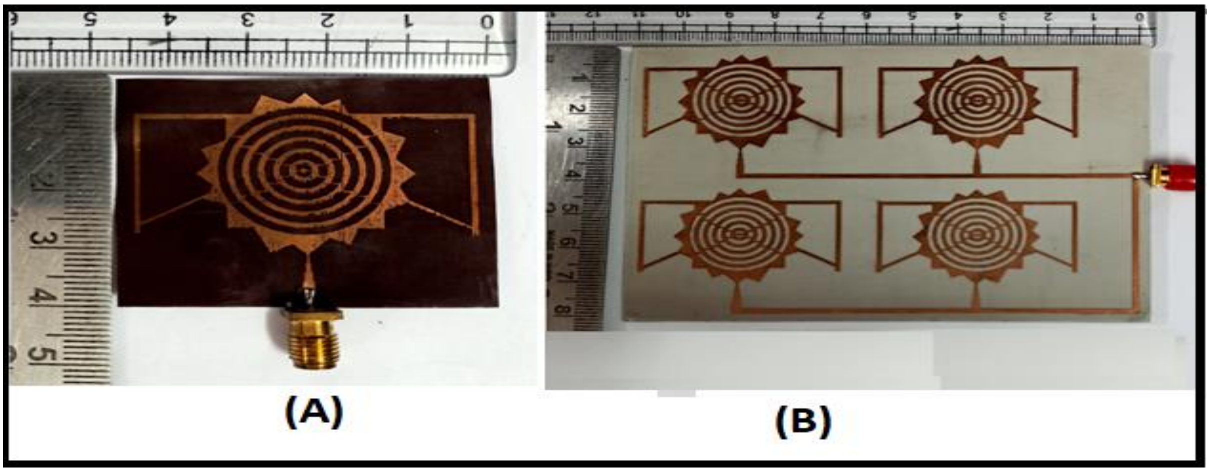


Fig 6.11: Fabrication of the proposed antenna front and back view.

Fabricated antenna reflection coefficient and VSWR is measured using Agilent Technologies N5247A Vector Network Analyzer. . The fabrication cost of the antenna is around Rs 4,500/- which is cost effective compare to tradition antennas as the antenna is designed using fractal geometry, the size of the antenna is 15% less than the traditional antennas as per table 6.3. Figure 6.12 provides the testing of both the proposed antennas.

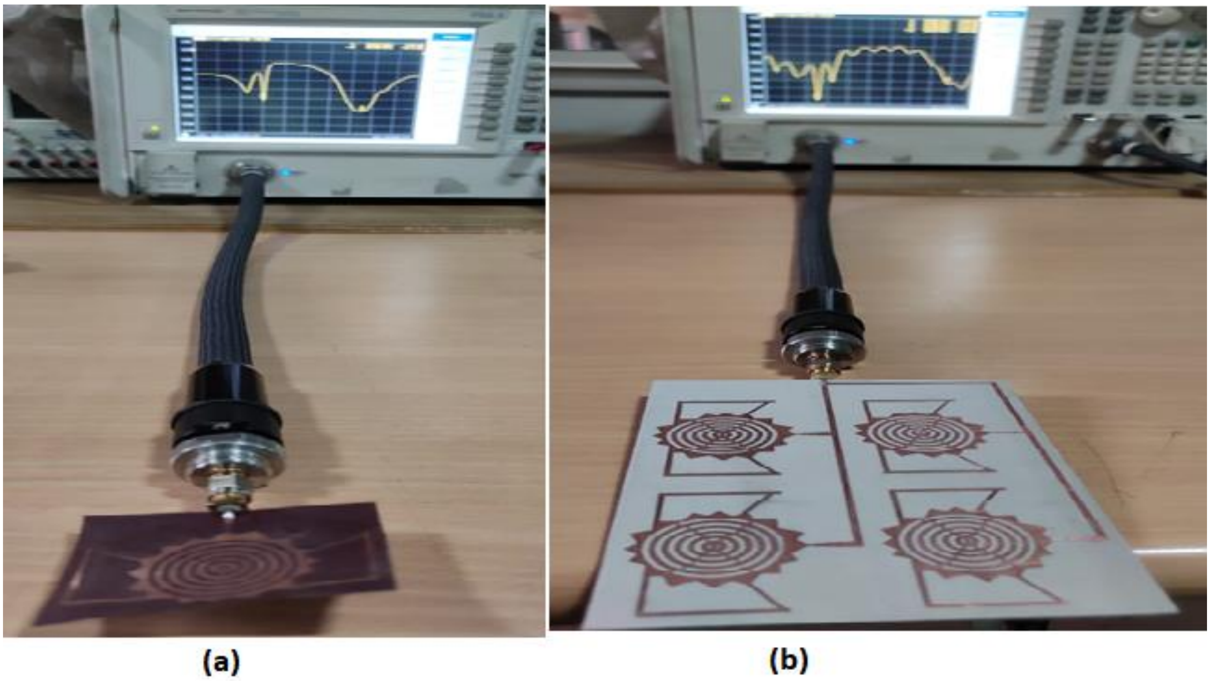


Fig 6.12 Testing of fabricated proposed antennas using VNA

Figure 6.13 provides the simulated vs measured reflection coefficient of single patch proposed antenna .

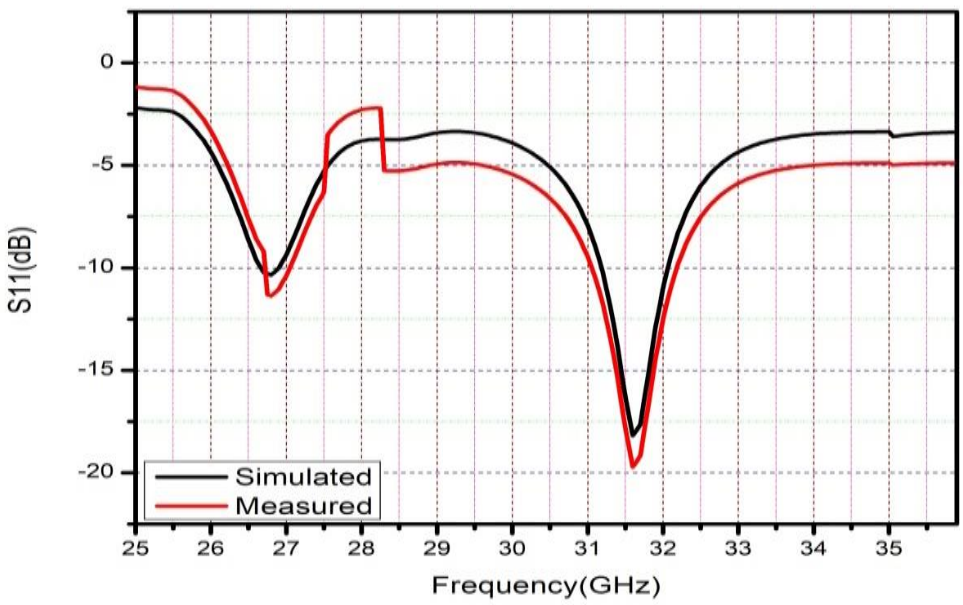


Fig 6.13: Simulated Vs Measured Reflection coefficient of proposed single patch antenna

Figure 6.14 provides the simulated vs measured reflection coefficient of 2×2 proposed antenna

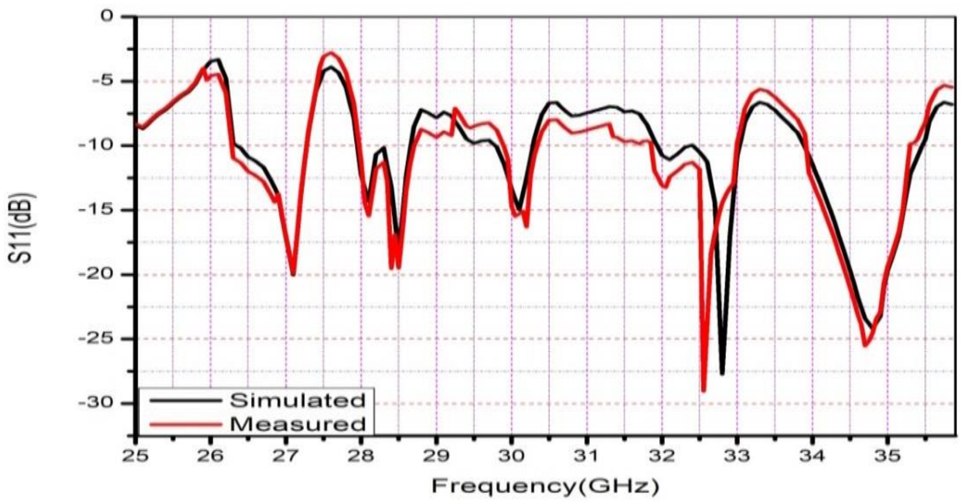


Fig 6.14 Simulated Vs Measured Reflection coefficient of proposed array antenna

Proposed antenna shows good agreement between the simulated and measured values of reflection coefficient parameters. The comparative analysis is carried out and shown in the table 6.3

Table 6.3 Comparative analysis of various multi band antennas with proposed antenna

Ref.No.	**Ant. Dimensions (mm)**	**Substrate used**	**Operating Frequency (GHz)**	**Bandwidth (MHz)**	**Gain(dB)**	**Remarks**
[66]	140 × 88 ×3.3	Rogers RT/duroid 5880tm	0.5GHz-1.1GHz, 3.6GHz-3.95GHz, 5.25GHz-5.85GHz, 7.35GHz-8.1GHz, 9.65GHz-10.25GHz 11.03GHz-12GHz	2400 MHz	6.9dB	Height is large
[67]	32 × 36 ×1.6	Rogers RT/duroid 5880tm	4.0GHz-4.65GHz, 5.67GHz-6.1GHz, 10.35GHz-11.0GHz	1200 MHz	7.32dB	small bandwidth
[69]	26 × 30 × 1.53	FR4_Epoxy	3GHz-8GHz, 8.92GHz-10.65GHz, 18GHz-22GHz, 28.5GHz-30GHz	1600 MHz	9.56dB	Large dimension, less gain
[75]	120 ×120 × 4.3	Rogers RT/duroid 5880tm	2.36GHz-2.50GHz	130 MHz	10.68dB	Large dimensions, small bandwidth
[76]	150 × 150 × 4	Rogers RT/duroid 5880tm	9.8GHz-10.36GHz 13.6GHz-15GHz	2360 MHz	8.35dB	Very complex structure, large dimensions and single wideband
Proposed Design-single patch	39 × 48 × 0.52	Rogers RT/duroid 5880tm	26.7GHz-6.9GHz 31.2 GHz-32.05GHz	1050 MHz	6.51dB	Dual Band, Good Bandwidth
Proposed Design: multi-patch antenna	82 × 115 × 0.52	Rogers RT/duroid 5880tm	26.35GHz-27.25GHz, 27.95GHz-28.65GHz, 29.8GHz-30.25GHz, 31.95GHz-33GHz, 33.9GHz-35GHz.	4650 MHz	10.64dB	Multi Band, Good Bandwidth

6.5 SUMMARY:

In this chapter a single patch and multi patch with 2×2 array are proposed which are based on chakra shape fractal geometry based micro strip patch antenna is presented. The antenna is Fabricated using the substrate material of Rogers RT/duroid 5880™. The antenna simulation and measured values are in a very good agreement and the key feature is the multi patch antenna has a penta band with a very high bandwidth of 4650MHz, and can be used for multiple applications such as vehicle to vehicle, vehicle to infrastructure, vehicle to infrastructure, vehicle to pedestrian and vehicle to road side unit where the amount of data transfer requires multiple band of frequencies. The frequency of operation is carried out under 5G lower Band channel ranging between 25GHz to 36GHz. The multi patch antenna possesses total gain of 10.64dB with the minimum reflection coefficient of −27.71dB.

CHAPTER-7

CONCLUSION ANF FUTURESCOPE

7.1 INTRODUCTION:

As the Vehicular communication applications are advancing towards the fifth generation and milli meter wave communications, the automobile industry is influenced with the concept of safety, security and comfort travel and to avoid road accidents, it is undeniable that there is a need of technology improvement such that it can support the autonomous and intelligent automobile units on roads. Research carried out in the past decade on vehicular communications came with various possible applications in the field of vehicular communications such as Vehicle-to- Vehicle Interface (V2V), Vehicle-to-Road side unit Interface (V2R), Vehicle-to-Pedestrian Interface(V2P), Vehicle- to-Infrastructure Interface(V2I) and Vehicle-to-Network Interface (V2N) which are designated as Vehicle-to-Everything Interface(V2X). To keep up the pace with the automobile industry and upcoming technology, it is inevitable to be a part of it and to contribute towards the next big thing. The idea of the research work carried out is to design and fabricate a Microstrip patch antenna which overcomes the drawbacks and withstand the various needs of vehicular communications, three designs are proposed in this thesis report and mainly concentrated on designing using fractal geometry for achieving high bandwidth, good gain and wideband and multi band at futuristic frequency of 5G. The proposed antennas are designed and simulated using Ansys HFSS v15 software tool, and later with the help of computer numeric control (CNC) are fabricated. The testing of the proposed antennas is carried out using Agilent Technologies N5247A Vector Network Analyzer.

The first proposed antenna is based on single rectangular patch with Rogers RO4003™ as substrate material with the dimensions of $50 \times 38 \times 0.55$ mm^2 and fractal geometry is introduced on the patch with 7 two iteration circles at distinct points, with defected ground structure. The frequency of operation is carried out from 25GHz to 35GHz in 5G lower band and the proposed antenna resonated at 31.34GHz with reflection coefficient of -32.31dB, with lower and upper cut off frequency as 29.35 GHz and 32.65GHz. Single band with bandwidth of 3300MHz is achieved with maximum gain of 8.83dB. With one single band it is suggested that the proposed antenna can be used for specific application such as vehicle to Infrastructure where the amount of data transfer requires larger bandwidth.

The second proposed antenna is based on single rectangular patch with small rectangular cross section with the dimensions of 22×32mm and 11×31 mm with the substrate of Rogers RO4003™ with the dimensions of $43 \times 38 \times 0.55$ mm^2. Coaxial feed line is provided with defected ground structure with frequency of operation between 25GHz and 35GHz in 5G lower band and the proposed antenna resonated at four different frequency locations which are 25.2GHz, 26.2GHz, 31.9GHz and 33.7GHz with reflection coefficients of −34.29dB, −15.29dB, −27.26dB and −22.46dB. The bandwidth achieved is 3650MHz with maximum gain of 21.25dB and the proposed antenna can be used for specific applications such as vehicle to vehicle, vehicle to infrastructure, vehicle to pedestrian and vehicle to road side unit where the amount of data transfer requires multiple band of frequencies.

The third and final proposed design is 2×2 patch array with chakra shape which is progressed from single patch to 2×2 multi patch with substrate as Rogers RT duroid 5880™ and the frequency of operation is carried out from 25GHz to 36GHz with substrate dimensions as $82 \times 115 \times 1.6$ mm^2 .The proposed array antenna resonated at five different places 27.1GHz, 28.5GHz, 30.1GHz, 32.8GHz and 34.8GHz with the reflection coefficients of − 20.01, −18.36, −14.96, −27.71 and −24.19 respectively and the maximum gain achieved is 10.64dB.The proposed multi patch antenna has a penta band with a very high bandwidth of 4650MHz, and can be used for multiple applications such as vehicle to vehicle, vehicle to infrastructure, vehicle to infrastructure, vehicle to pedestrian and vehicle to road side unit where the amount of data transfer requires multiple band of frequencies.

The proposed antennas are operated at the frequency ranging from 25GHz to 36GHz which covers all the lower bands of 5G frequency spectrum and testing is carried out at the said frequencies. For vehicular communications, especially for V2V communication, the bandwidth required was around 2GHz to 3GHz. The proposed antennas provide bandwidth in the required range and stable for almost for the entire frequency range in which the antennas are operated. The proposed antennas provide total gain around 10dB which converted to realized gain of around 14dBi which provides a better antenna strength while operating at 5G frequencies under vehicular communication applications. These objectives are achieved by both single patch and multi elements forming an array of 2X2 and the dimensions are perfectly fits in vehicular communication application standards.

These three proposed designs can be used for single and multiple band of applications in vehicular communication domain as the antennas are compact size, cost effective, accommodate multiple application interfaces with very high bandwidth and good gain and satisfactory other parameters which can be contributed for vehicular communication domain.

7.2 FUTURE SCOPE:

The microstrip patch antenna suffers with narrow band and when frequency of operation is increased, the performance of antenna is degraded and the gain is limited, and the research work carried out and presented in this this provided answers to some of the parameters but as the research work is focused mainly on bandwidth improvment, better gain and making the antenna to work in multi band, there are other areas in which the work can be carried out. This part explains the work that can be extended for future research work.

1. As the vehicular communication domain is related with different vehicles which are manufactured in different shapes and sizes, one of the parameter is to design the antenna with conformal in nature. The challenge is to design conformal antenna with substrate materials that can withstand very high temperatures as they will be mounted on the structure it-self.
2. In the research work carried out, only the lower 5G band and milli meter wave band were concentrated, in future the antennas can be designed and simulated for higher band of frequencies. The challenge is to design the antenna at futuristic frequencies with compromising on the basic parameters required for vehicular communications
3. In the research work carried out, the extent of multi patch antenna is only up to 2×2 patch array , which can be extended to 4×4 and 8 ×8 patch arrays. The challenge is to design the antenna with multiple patch arrays without compromising on the size of the antenna which is a key parameter in vehicular communication applications.

APPENDIX A

A.1 ANTENNA FABRICATION

Antenna designing process is carried out in Antenna design and simulation software HFSS. After converting the HFSS file into Gerber files antenna fabrication process starts. For Microstrip patch antenna, PCB fabrication technology is used. With the increase in fabrication demands of electronics components on smaller boards, boost-up the need of PCB fabrication technology. PCB is a board that provides the mechanical strength to components and provides connectivity between them through copper tracks. PCB can be single layer, double layer or multi-layer boards. Main components of PCB are substrate, copper layers and solder mask. Dielectric material should have low value of dielectric constant and dielectric loss to achieve good radiation performance of antenna. Selection of dielectric constant material depends on applications. Dielectric materials with thick substrate and low dielectric constant provide high bandwidth and better antenna efficiency but leads to large size structures. On contrary, material with high dielectric constant give rise to more surface waves and less bandwidth is achieved due to this. For proposed antenna designing dielectric substrate selected is Rogers RT Duroid with dielectric constant 2.2 and thickness of 0.8mm to get better antenna efficiency. RT Duroid material is also available in 0.5, 1.6, 2.4 and 3.2mm thickness. Most commonly used material is FR-4 Epoxy but it is highly lossy material, so Rogers RT Duroid material is selected for antenna fabrication. PCB board used is Double layer with copper layers of 0.35micrometer thickness on both sides.

For PCB fabrication some steps and followed. Initially, design is prepared on software than Gerber files are created. For creating Gerber files, software used is Dip Trace. It provides the complete information related to copper layers, solder mask and component notation etc. Next step is to print the PCB design using special printers called plotters. It creates a film of design also called photo negative. After preparing the blueprint of design, it is printed on the PCB using where wanted copper is kept and unwanted is removed. This process is called etching and in PCB designing Ferric chloride material is used for etching process. After removing the unwanted copper, PCB is washed with alkaline solution to further remove any leftover copper and dried. The complete PCB designing process is shown in Figure A.1 below.

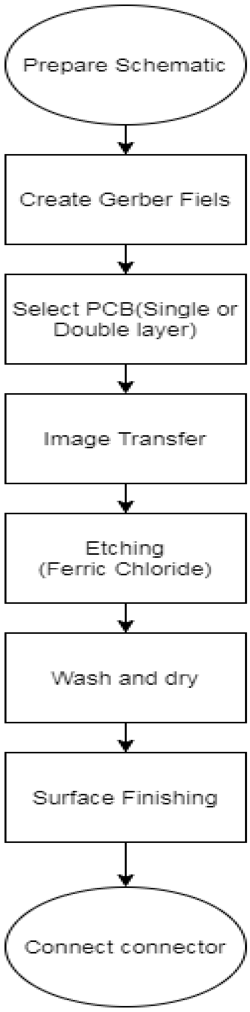


Figure A.1: PCB Fabrication process

A.2 ANTENNA TEST PROCEDURE

In practical antenna testing, after fabricating antenna using PCB fabricated technology, fabricated antenna performance is analysed in terms of Return loss, VSWR, Gain and Radiation patterns. Antenna Return loss and VSWR measurement can be done using VNA. For measurement of far field parameters like gain and Radiation Pattern Spectrum analyzer and signal generator is needed as given in Table A.1.

Table A.1: Apparatus used for Antenna parameter measurement

Antenna Parameters	Apparatus used
Return loss (S11)	VNA

VSWR	VNA
Gain	Spectrum Analyzer/ Signal Generator
Radiation pattern	Spectrum analyzer

For testing proposed antenna prototype, instruments used are given in following Table A.2 with specification.

Table A.2: Antenna testing devices used for proposed antenna performance measurement

S. No.	**Instrument_Name**	**Company_Name**	**Model No**	**Spec.**
1	Network Analyzer	HP	8720A	130MHz-20GHz
2	Signal Generator	Wiltron	68147B	10MHz-30GHz
3	Spectrum Analyzer	HP	8593E	9KHz-26.5GHz

A.2.1 Return loss/VSWR measurement using VNA (8720A)

VNA used for antenna return loss and VSWR measurement is HP8720A as shown in Figure A.2. It is high performance microwave network analyzer that covers frequency range of 130MHz to 20GHz with 100kHz frequency resolution for measurement of reflection and transmission parameters. VNA can have two ports or four ports for connection of DUT (Device under test). Before antenna measurement, VNA should be calibrated properly using calibration kit. Following steps are taken to measure VSWR for proposed antenna.

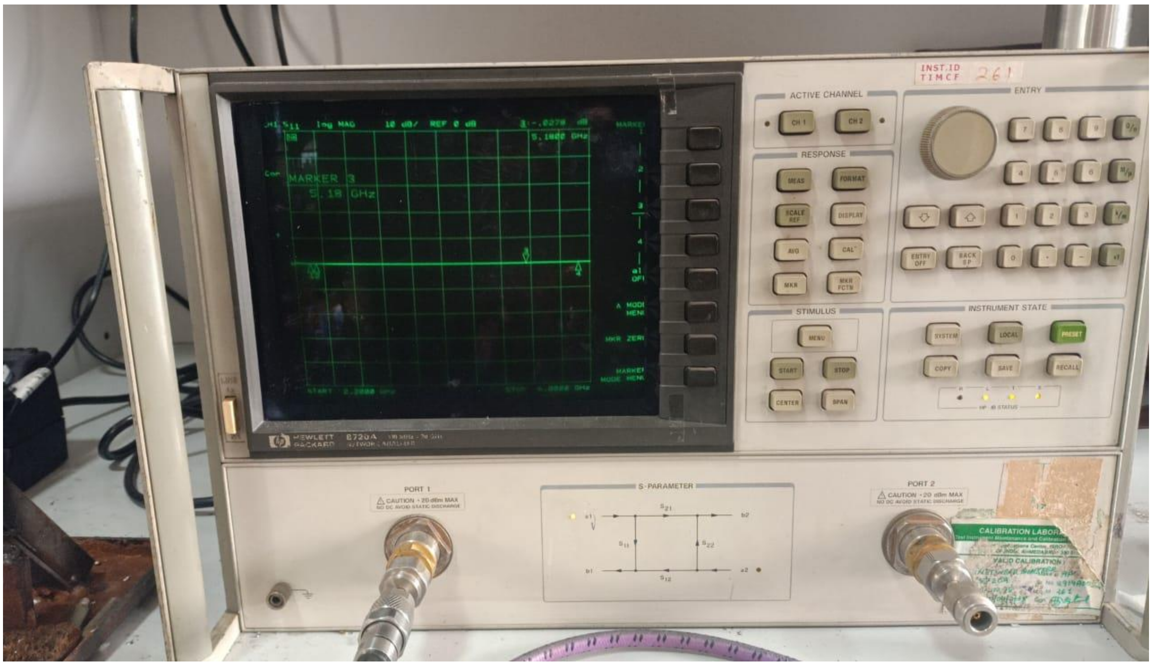


Figure A.2: VNA equipment used for proposed antenna return loss and VSWR measurement

A.2.1.1 Return loss Test procedure

1. Connect the test equipment as shown in the Figure A.3 below.
2. Switch on the Vector Network Analyzer and set the desired band of frequency means set the start frequency i.e. 1GHz and Stop frequency that is 15GHz.
3. Select S11 parameter for VSWR. Calibrate the Network Analyzer by connecting calibration module. Set the network analyzer for S11/ VSWR.
4. Connect the other end of the feeder cable to the Antenna under test (AUT)
5. Read the response in VNA over the band, which is the VSWR of the antenna
6. Note the Value of S11/VSWR.

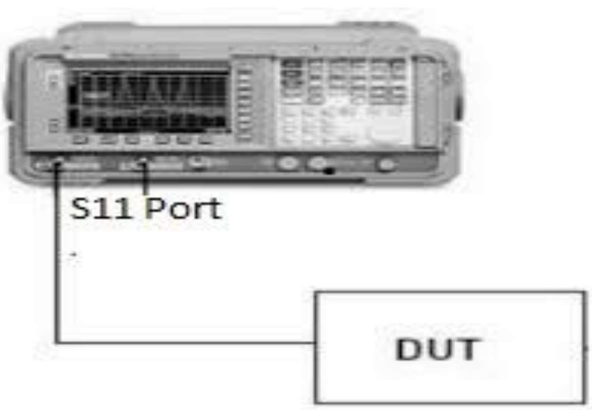


Figure A.3: Test setup for VSWR measurement

VNA port calibration can be done for frequency range between 1GHz to 15GHz using different methods like standard open, short and match load. Calibration means offset line after switching ON VNA should be aligned with Zero. After, this calibrated VNA has to connect with AUT (Antenna Under Test) with cable on VNA S11 port. Here cable used for making AUT device with VNA is LMR-400/ RG316 (Loss less cable) of length 10 meters. Fabricated antenna Return loss (S11) characteristics can be obtained by making connection of antenna with any one port of calibrated network analyzer and operating VNA in S11 or S22 mode. The graph which is display on VNA display, is observed and the frequency for which S11 value is lowest means a sharp dip is achieved on the S11 graph is called resonant frequency of cut of frequency. Return loss graph also provides information about antenna bandwidth of operation, range of frequencies for which return loss value is less than -10dB is mainly considered as antenna bandwidth. Antenna bandwidth is the range of high frequency cut off frequency and low cut off frequency below-10dB and calculated using following formula in percentage.

$$\text{Bandwidth (\%age)} = \frac{f_h - f_l}{f_c} \times 100 \qquad \text{(A.1)}$$

Where, $f_h$represents the higher -10dB point on graph, f_l denotes the lowest -10dB point on graph and fc is the cut of frequency with minimum return loss value,

` ` **A.2.2 Antenna Gain measurement**

Antenna gain is the measurement of antenna power transmitted by antenna under test in a given direction. Antenna gain in given direction is expressed as the ratio of radiation intensity in given direction to the total input power. Antenna gain represents the antenna directivity and antenna electrical efficiency as expressed by expression (A.2).

$$\text{Gain} = 4\pi \frac{Radiation\ Intensity}{Total\ Input\ Power} \qquad \text{(A.2)}$$

Antenna gain measurement cab be done using (1) two antenna method (2) Reference antenna method. Proposed antenna gain measurement is done using reference antenna method. Reference antenna considered is LPDA (Long Periodic Dipole Array) wideband antenna. The AUT is placed in far field range of the reference antenna considered. Far field distance is calculated using far field formula given in expression (A.3). Antenna gain measurement is done in free space. Gain of AUT is measured with reference to the power signal received or detected by reference antenna.

$$\text{Far field} \geq \frac{2D^2}{\lambda}$$

$$\lambda = \frac{speed\ of\ light}{frequency} \qquad (A.3)$$

Here, D=Antenna length or Diameter and f= operating frequency

Both Reference antenna and AUT antenna are mounted on tunable and proper distance is maintained between them for gain measurement. Before antenna gain measurement, insertion losses are measured. Test Procedure for Insertion Loss Measurement is as follows:

1. Connect the test equipment as shown in Figure A.4
2. Switch on VNA and set the desired band of frequency
3. Select the S21 parameters for Insertion Loss (dB). Calibrate the network analyzer by connecting to Calibration module.
4. Connect both the end of connector as shown in Figure A.4.
5. Read the response in network analyzer over the band which is Insertion Loss
6. Note the Value of Insertion Loss

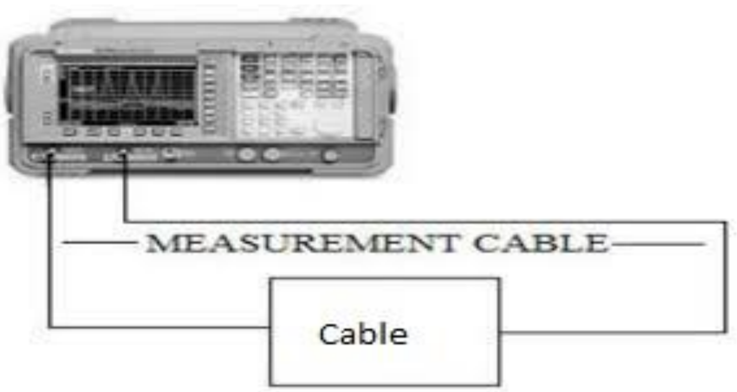


Figure A.4: Test setup for Insertion Loss measurement

A.2.2.1 Test setup for Gain Measurement

i. Distance 'D' between TX (Reference/Transmitting Antenna) and Rx (Antenna under test/receiving antenna) is 8M.
ii. Cable used is LMR-400/ RG316 (Loss less cable) of length 10 meters.

Formula:

a) Free Space Path Loss (FSPL)=92.5+20log(Freqin GHz)+20log(Distance Din KM)
b) Total Loss (TL) = FSPL+Measured Cable Loss
c) Gain:

G=((FSPL-RSL)/2) or G = Tx Power + FSPL- RSL- G(ref) (A.4)

Where G(ref)= Reference Antenna Gain in dB and RSL is Received Signal Level in dB

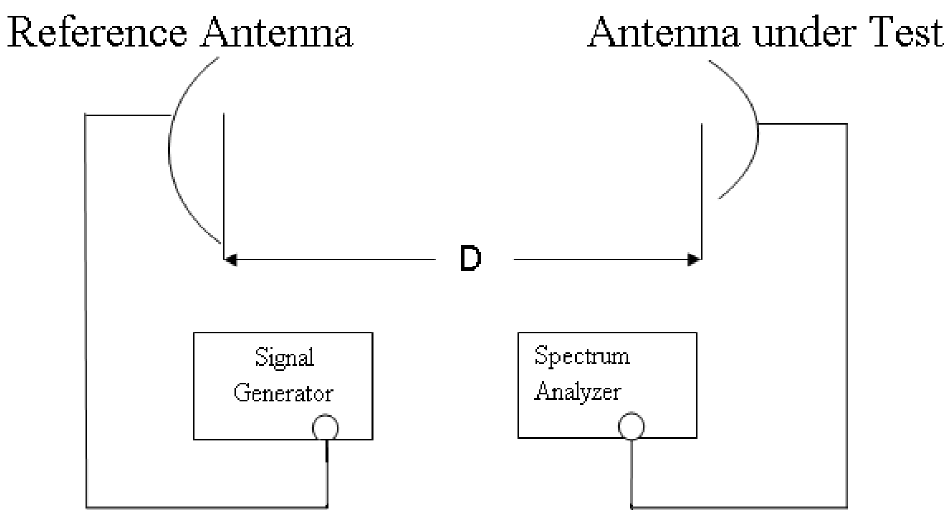


Figure A.5: Test setup for gain measurement

A.2.2.2 Test Procedure for Gain:

1) Measure the cable loss and calculate the FSPL and TL by using formula A and B
2) Connect the test setup as shown in Figure A.5.
3) Measure the RSL level from S12 Port and note the values.
4) Calculate the Gain using formula

Gain expression from Friis transmission formula is give in equation (A.5)

$$(G_t + G_r)\text{dB} = 20\log_{10}\left(\frac{4\pi R}{\lambda} + 10log_{10}\left(\frac{P_r}{P_t}\right)\right) \quad \text{(A.5)}$$

Where, $(G_t)_{dB}$= gain of the Tx antenna (dB)

$(G_r)_{dB}$ = gain of Rx antennas (dB)

Pr = received power (watts)

Pt = transmitted power (watts)

R = Distance between antenna (m)

λ = signal wavelength (m)

A.2.3 RADIATION PATTERN MEASUREMENT

Antenna measurement setup used for Gain and Radiation pattern measurement is same. Radiation pattern of antenna represents the measurement of antenna power density transmitted in particular direction. Antenna radiation pattern measurement is carried out to analyse fabricated antenna radiation in far field region and comparison is done between simulated and measured patterns to validate antenna performance for specific application. For radiation pattern measurement, antenna under test is placed in far field region with respect to reference antenna used.

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