RESEARCH ARTICLE OPEN ACCESS

Design of Dual-band Inverted Ladder shaped patch antenna for 5GmmWaveMobile, Satellite&RadarApplications

Mrs.G.Kalyani[1],P.Navya[2],P.Hyndavi[3],P.Supriya[4],P.TejoVyshnavi[5]
[1]*Assist.Professor,DeptofE.C.E,BapatlaWomen'sEngineeringCollege,Bapatla,AP,India.*
[2,3,4,5]*U.Gstudents,DeptofECE,BapatlaWomen'sEngineeringCollege,Bapatla,AP,India.*

ABSTRACT
In this paper, the design of compact microstrip patch antenna for the 5G mm Wavewireless communication is proposed. The 5 × 4.8 × 0.508 mm^3 sized antenna is made of RogersRT/duriod5880(tm)dielectricmaterialandisfedviaa50-Ωmicrostripfeedline.Tworectangular slots were etched beside the feed line and Inverted ladder shaped slots were placedon the radiating patch to create firstresonanceat28.2 GHz band from 27.5 - 28.5 GHzforMobileapplications(28/32.5/38GHz)andsecondresonanceat54.7GHzbandfrom52.78-56.85GHzforSatellite&Radarcommunications(40-75GHzforV-band). TheReturnloss(S11) for the first band & second bands are the -22dB and -14.5dB and VSWR of less than 2indicatesthatthedesignedbandshavestrongimpedancematchingcapabilities.Thepeakgainof 7.50dBi at 28.2 GHz and 8.0dBi at 54.7 GHz are attained and sustained omnidirectionalradiationcharactersareachieved. Theresultsdemonstratethattheproposed antennaisappropriatefornextgenerationwirelessapplications.
Key Words: Microstriplinefeed,Dualband,Fifth-generation,Mobile,Satellite&Radar

Date of Submission: 07-04-2023 Date of acceptance: 21-04-2023

I. INTRODUCTION

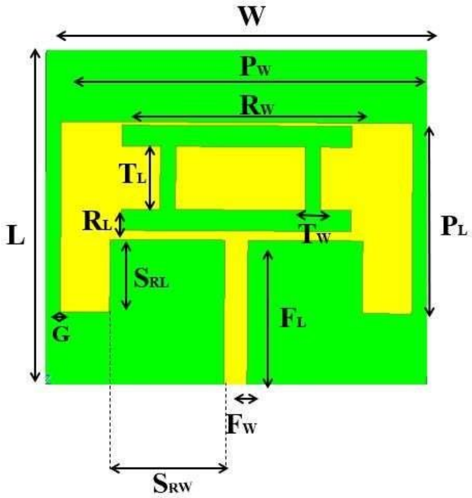
Overtheyears,theincrediblegrowthofwirelessdevices hasbroughtsignificantimprovements in putting forth advanced standards for communication networks. 4G LTE hascombined several commercial services efficiently within a currently deployed network capacitytomeetthedemandsofhigh-throughput,highdataratesandalsooffershigh-speedconnectivityattheuserend[1].Thecurrentmobile communicationspectrumatlowfrequency would be

able to keep up withthe rapidgrowth in the communication industrysoon [2].Sincethe upcoming Fifth Generation (5G) will be five times faster than the present Fourth Generation (4G).Itwillhaveextremelyhighdatarate,largebandwidth,highcapacity, high speedandLowlatency [3].5G technology is an incredible advancement in wireless connectivity that enables fasterandmoresecurenetworksforbillionsofconnected deviceswith"zero"latencyuserexperiences (delay less than 1ms) and introduces emerging services including e-Health, smarteducation, smart cities, smart homes, virtual reality (VR), smart factories, and the Internet ofVehicles (IoV), transforming our lives, society, and industries [4]. To enable the 5G, FCCdivided the key spectrum into low-band (up to 1 GHz), mid-band (sub-6 GHz), and high-band(mm Wave)[5].Onthe otherhand, the sub-6 GHz technology uses the power amplifiers,switches, filters, and discrete antennas separately. This leads to large space as the matchingcircuits between components are usually required to avoid the reflection. The insertion loss isalsohighbecausethe connectorsconsumeextralosses[6].

The5G NR radio standards such as n77 from 3.3GHz to 4.2GHz, n78 at 3.3GHz to3.8GHz, n79 from 4.4GHz to 5.0GHz and Millimeter wave (mm Wave) bands (>24GHz).Printed antennas (or) microstrip patch antennas are the most significant antennas due to its planarsurface. There arevariousmicrostrip antennatypesand themostlyused antennasaretherectangle and square microstrip patch antenna. Such antennatypesare used in a wide-rangingapplication i.e., airplane, satellite broadcasting, arms, mobile phones and in medical systems,because of some important features such as lightweight with low profile (conformal), easy tofabricate,simplefeeding(m-line),aperturecoupledfeedetc.,easytouseinanarrayconfigurationbyareasonabledirectivity(about6-8dBistypical)[7].Asfifthgeneration(5G)is developed and implemented, we believe the main differences compared to 4G will be the useofmuchgreaterspectrumallocationsatuntappedm m-wavefrequencybands,highlyomnidirectional antennas atboth the mobile device and base station [8].These scenariosbecome different at mm Wave frequencies can provide the basic ground for the new Generation(5G) contains unexploited spectrum (3GHz-300GHz) to fulfil the new generation needs [9].Anotherimportantpartofthe5Gmobilenetworkisto providemulti-gigabitcommunicationservices such as high-definition television (HDTV) and ultra-high-definition video (UHDV)[10]. MmWaveantennasarefindingapplicationsinawiderangeoffields,including5Gcellularnetworks wireless backhaul, radar and imaging systems with the growing demand for high-speedwirelesscommunication.MmWaveantennasareexpectedtopayanincreasinglyimportantroleinthedevelopmentofnext-generationwirelesssystems [11].

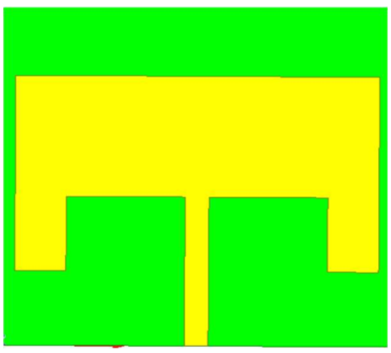
1. ANTENNADESIGNANDSTRUCTURE

Thefrontviewofthesuggestedantennadesignispresentedinthispaper.Thedimensions of the antenna shown in Fig1. consists of 5 × 4.8 × 0.508 mm^3 is designed onRogersRT/duroid5880(tm)substrateandtheground plane(L×Wmm^2)whichisfedbya50-Ω microstrip line (F_W × $F_L$$mm^2$). Many Substrates are available but the dielectric constants ofallsubstrates are below10GHz exceptRoger's substrate, therefore it is best for millimeterwave andit is mostsuitable for UHF because of low dielectric loss and low dispersion. Ithasthe characteristicsof low water absorption, lowest electricloss and low moisture absorption.The proposed antenna consists of an inverted ladder shaped slot which is etched on the radiatingpatch of size (P_L × P_W mm^2)and two slots were placed beside the feedline. An inverted laddershaped slot is formed by cutting the rectangular slot (R_L × R_W mm^2) and another slot of size(T_L × $T_W$$mm^2$). The dimensions of the slot (S_{RL} × $S_{RW}$$mm^2$) which is placed beside the feedline. The dual bands are achieved at the first resonance 28.2 GHz from band 27.5 - 28.5 GHzandthesecondresonanceat54.7GHzbandfrom52. 78 - 56.85GHz.



(a)

(b)



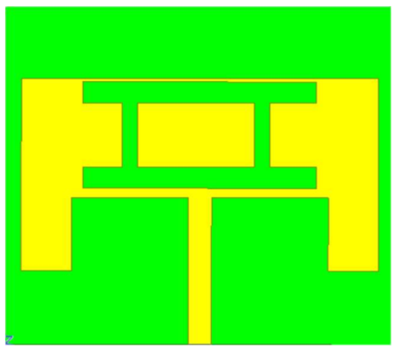


Fig1.(a)Optimizeddesignofproposedantenna,(b)Stage–1and(c)Stage-2

Table1. Optimizedparametersoftheproposedantenna.

Parameter	Value in(mm)
L	5.0
W	4.8
PL	4.59
PW	2.71
FW	0.3
HS	0.508
G	0.205
FL	2.07
RL	0.3
RW	3.0
SRL	1.5
SRW	1.035
TL	0.9
TW	0.3

3. RESULTSANDDISCUSSION

3.1 S-Parameter

The most significant feature in an antenna designing is the reflection coefficient (S11)which defines impedance matching and bandwidth. Scattering parameters describes the input-output relation between the ports in an electrical system. The 0dB S11 means that all the powerofsignalisreflectedand-10dBmeansthat3dBpoweristransmittedtotheantennaand-7dBof power is reflected, so the S11 should be less then -10dB for an antenna to perform effectively.This antenna has a return loss of-22dB and -14.5dB for 28.2 GHzand 54.7 GHz respectively as showninFig2.

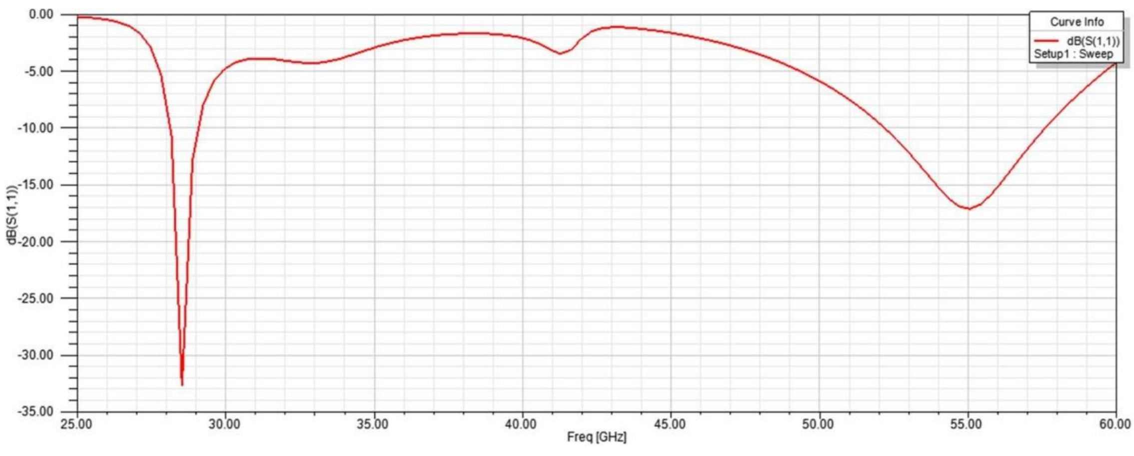


Fig2.S-Parameter

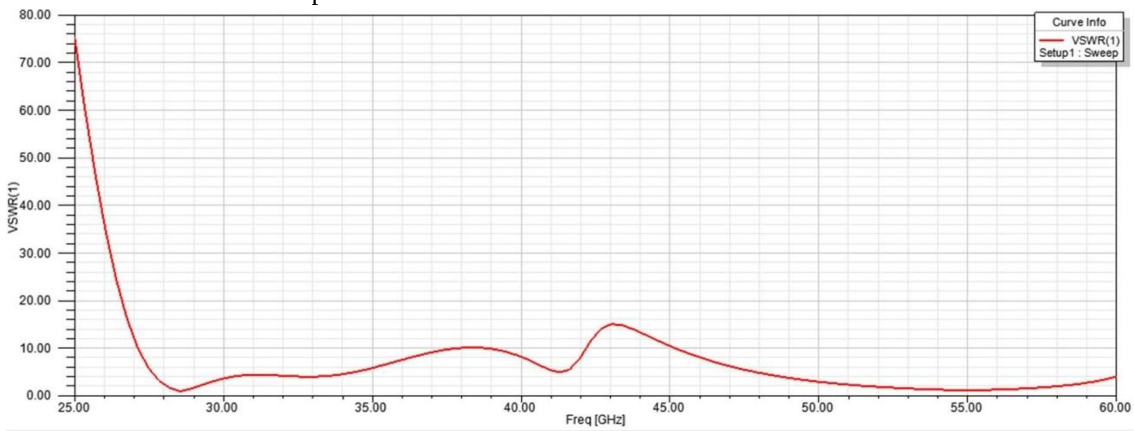
3.2 VSWR

VSWR (Voltage Standing Wave Ratio) is a measured of how the power of radio -frequency is transmitted efficiently from a power source, such as an antenna and a load, througha transmitter or receiver. VSWR is another parameter which indicates that the antenna can onlybe able to work where the optimum VSWR value is ≤ 2. Furthermore, if value of VSWR issmall, then the antennawillperform betterandvice versa. VSWR is a measure of the ratioofthe maximum voltage tothe minimum voltage and also define thematching of impedance tothe transmission line. This antenna hasa VSWR of 1.2 dB and 1.4 dB at 28.2GHz and 54.7GHzrespectivelywhichcanbeseeninFig3.

Fig3.VSWR

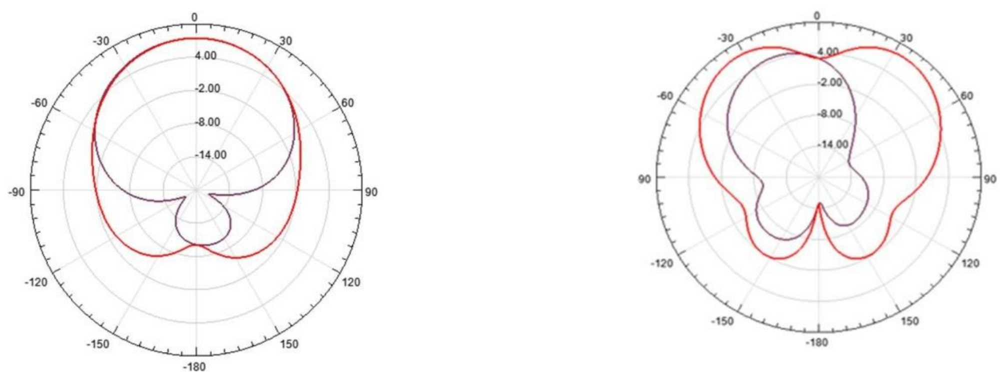
3.3 RadiationPattern

RadiationPatternof theAntennashowsthedistributionofenergyradiatedbytheantennain space. It is a graphical way of showcasing the radiation from the antenna as a function ofdirection, and also known as Field Strength Pattern. Radiation pattern in an antennas refers to



thedirectionaldependenceofthestrengthoftheelectromagneticwavesthatareradiatedorreceived by the antenna. The 2-D radiation patterns are such as E-plane and H-planeshown inFig 4. can be observed that the E-pattern is bidirectional and H- pattern is omnidirectionalwhichisrequiredforwirelessapplicationsandthe3-DradiationpatternsareshowninFig5.

GainPlotat28.2GHz **GainPlotat54.7GHz**

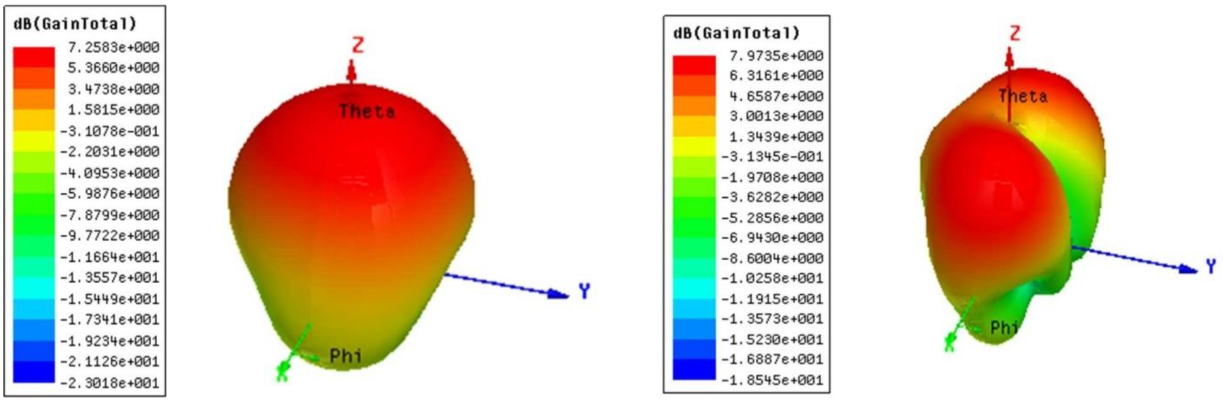


(a) (b)

Fig4. 2-DPatternsat(a) 28.2GHzand(b)54.7GHz.

3DPolarPlot

Gainat28.2GHz **Gainat54.7GHz**

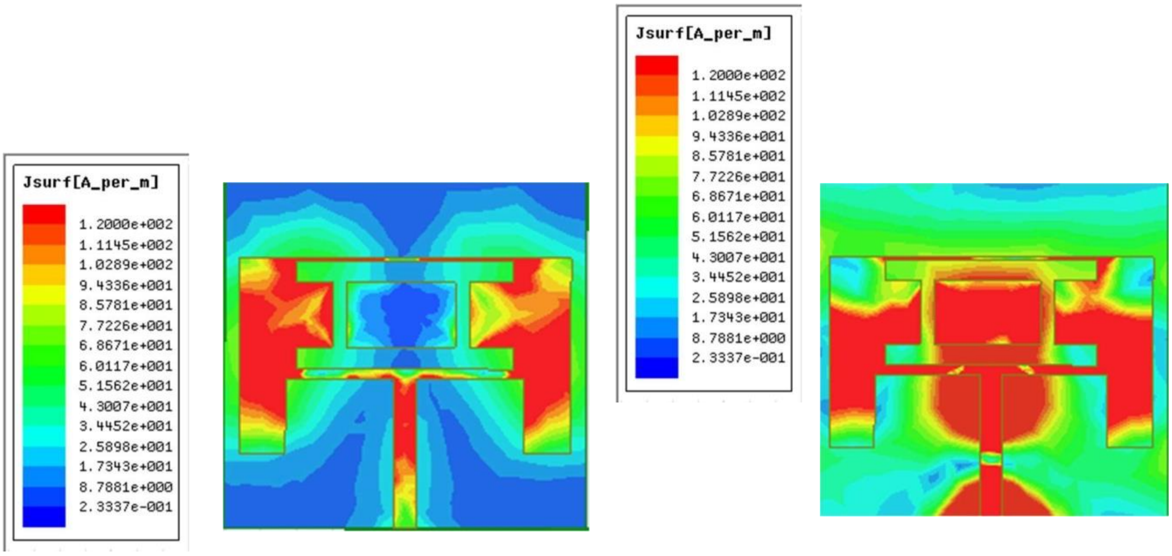


(a) (b)

Fig5. 3-DPolarPlotat(a) 28.2GHzand (b)54.7GHz.

3.4 SurfaceCurrentDistribution

Surface current distribution refers to the distribution of electric current over the surfaceof an antenna. When an antenna is excited by a signal, an alternating electric field is created inthe space around the antenna, which induces a flow of electric current on the surface of theantenna.Fig.6representsthesurfacecurrentsonthepatchantennaat28.2GGzand54.7GHz.It can be identified that the proposed design radiates wellat 28.2GHzand 54.7 GHz due togoodimpedancematching



(a) (b)

Fig6. SurfaceCurrent Distributionat (a) 28.2GHzand (b) 54.7 GHz

3.5 PeakGain

Peak gain refers to the maximum amplification that an electronic device or system canprovide to an input signal at a specific frequency. The Peak gain is commonly used to describetheperformanceofamplifiers,filters,andotherelectronicdevices.Itisanimportantspecification for engineers and technicians to consider when designing or evaluating electronicsystems,asitcanaffecttheaccuracy,stability,andoverallqualityofthesignalbeingprocessed.The peak gain plot of the inverted ladder shaped antenna is shown in Fig 7 and gain is morethan5dBiisachievedatthe28.2GHzand54.7GHzoperatingbandsoftheantenna.

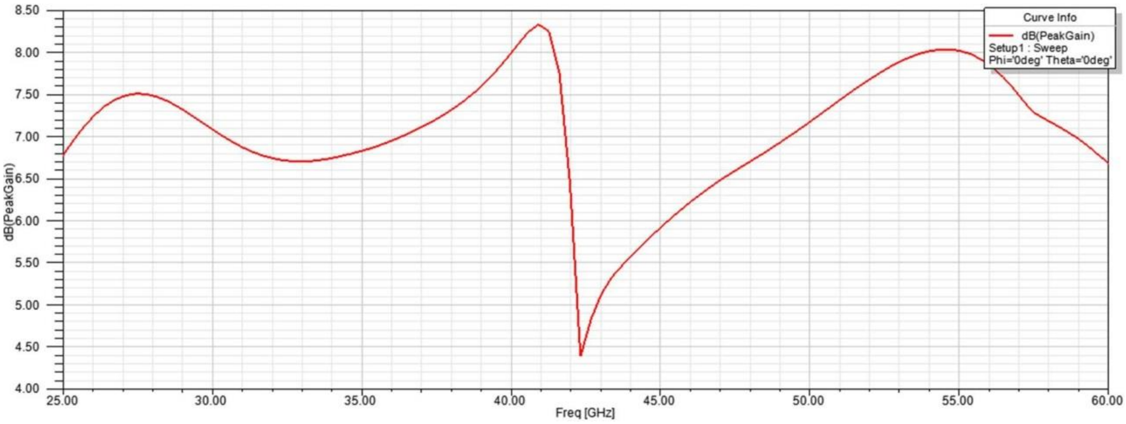


Fig7. PeakGainat28.2GHzand54.7GHz

4. CONCLUSION

A compactdual-band microstripantennafor 5Gmm Wavewirelessdevice applicationispresented in this work. The antenna with dimensions 5 × 4.8 × 0.508 mm^3, is fed by a 50-Ωmicrostrip line and is constructed on Rogers RT/duroid 5880(tm) dielectric material. On theradiating patch, arectangularslot was used toinduce aresonanceatthe28.2GHzbandbetween27.5 GHz and 28.5 GHz and asecond resonance at 54.7GHz between 52.78 GHz and 56.85GHz. Due to Strong impedance matching abilities are demonstrated at the designed bands withS11 of -10dB and VSWR of below 2. The antenna also offers the peak gain of 7.50 dBi at 28.2GHz and 8.0dBi at 54.7 GHz. The results show that the presented design is appropriate for 5GmmWavewireless applications.

5. References

[1] Syeda Fizzah Jilani 1, Akram Alomain2,” Millimeter-wave T-shapedMIMO antenna withdefected ground structures for 5G cellular networks”, Queen Mary University of London,Vol.12Iss.5,pp.672-677,January2018.

[2] J.ChandrasekharRao1,U.SrinivasaRao2,M. VinodKumar3,D.SreenivasaRao,”ADual-bandU-shapedmicrostripantennafor5GmmWaveapplications”,BapatlaEngineeringcollege,A.P.-522101,India

[3] D.Imran1,M.M.Farooqi2,M.I.Khattak3,Z.Ullah4,M.I.Khan5,M.A.Khattak6,MillimeterWaveMicrostripPatchAntennafor5GMobileCommunication”,UniversityofEngineeringand Technology,Peshawar,Pakistan.

[4] Md. MhediHasan1, Mohammad Tariqul Islam 2, Md Samsuzzaman 3Mohd Hafz Baharud-Din 4, Mohamed S. Soliman 5, AhmedAlzamil 6, “Gain and isolation enhancement of a wide ban MIMO antenna using Meta surface for 5G sub-6GHz communication system”, University Kembangan Malaysia, (2022)12:9433.

[5] RezaulAzim1,AKMMoinulH.Meaze2,AdnanAffandi3,MdMottahirAlam4,Mdwirelesscommunicationapplications”,UniversityofChittagong,InternationalJournalofSamsuzzaman5,MohammadT.Islam6,”Amulti-slottedantennaforLTE/5GSub-6GHzMicrowaveandWirelessTechnologies,Aug2020.

[6] M.Idrees Magray 1, Saou-Weinsu 2, Jenn-Hwan Tarng 3,”Differntail-fed,Dual-Aperture b-Sed, Quasi-end-fire 5G mm wave Antenna-in-package design”,National Yang Ming ChainoTung University,vol.10,pp.89091-89100,Aug2022.

[7] OwaisKhan1,MuhammadAnab2,AamirSultan3,SyedMaqsoodShah4,AliRaza.”Millimeter-WaveRectangularMicrostripPatchAntennaDesignFor5GApplications”,CECOSUniversityofIT&EmergingSciences,Peshawar,Pakistan,Vol.19,pp.6782-6792,no:22022.

[8] Theodors.Rappaport1,Shusun2,Rimmamayzus3,HangZhao4,Yanivazar5,KevinWang6,“MillimeterWaveMobileCommunicationsfor5GCellular:It WillWork”,Polyt-echincInstituteofNewYorkUniversity,NewYork,NY11201,USA,IEEEAccess,vol.1,pp.335-349,May2013.

[9] Oras Ahmed sharef 1,Ahmed Mohammed Ahmed Sabaawi 2, Karrar Shakir Muttair 3, MAhmood Farhan 4,"Design of multi-band millimeter wave antenna for 5G smart phones",MiddleTechnicalUniversity,Vol.25,No.1,pp.382-387,Jan2022.

[10] AdamuMohammedJajer1,"MillimeterWavePatchAntennaDesignAntennaforFuture5gApplications",TianjinUniversityofTechnologyandEducationTianjin,P.R.China,InternationalJournalofEngineeringResearch&Technology(IJERT),Vol.6Issue02, pp.289-291,February 2017.

NiuY,LiY,JinD,SuL,VasilakosAV."Asurveyofmillimeterwavecommunications (mmWave)",for5G:opportunitiesandchallenges.Wirelessnetworks.vol;21(8):2657-2660,Nov21,2015.