Journal of Engineering Design and Analysis
Volume 6, Issue 2 - 2023, Pg. No. 8-13
Peer Reviewed Journal

Review Article

Design of MIMO Antenna with Reflector-based Isolation Technique for mm-Wave Applications

E Kusuma Kumari[1], R Ramprasad[2]

[1,2]Department of Electronics and Communication Engineering Sri Vasavi Engineering College Tadepalligudem.

INFO

Corresponding Author:
R Ramprasad, Department of Electronics and Communication Engineering Sri Vasavi Engineering College Tadepalligudem.
E-mail Id:
hod_ece@srivasaviengg.ac.in
Orcid Id:
https://orcid.org/0000-0002-5798-6638
How to cite this article:
Kumari EK, Ramprasad R. *Design of MIMO Antenna with Reflector-based Isolation Technique for mm-Wave Applications. J Engr Desg Anal* 2023*;* 6(2): 8-13.

Date of Submission: 2023-11-13
Date of Acceptance: 2023-12-13

ABSTRACT

This work is focused on mutual coupling reduction among the antenna ports at mm-wave frequencies, which are frequencies of interest for 5G communication. Initially, the design and simulation of a single-port T-shaped wideband antenna resonating at 26 GHz with a frequency range of 24-28 GHz have been presented for possible Multiple Input and Multiple Output (MIMO) applications. The single-port wideband antenna has been extended to four-ports, and a reflector approach has been utilized to lessen mutual coupling. This isolation strategy reduces the mutual coupling by 5 dB, which is verified through software simulations. The isolation enhancement is also verified using surface current distributions.

Keywords: Antenna, Isolation Technique, MIMO antenna, Reflector

Introduction

A wireless technology named Multiple Input and Multiple Output (MIMO)can increase a communication system's channel capacity. Reducing the correlation coefficient of the signals received by different antennas and increasing the isolation among the antenna ports improves the MIMO working efficiency.[1] There is a considerable mutual coupling problem in MIMO technology as multiple antennas are closely packed. Consequently, most of the power provided to one port is coupled to the other port rather than radiating into space. As a result, channel capacity, radiation efficiency, and signal-to-noise ratio will be decreased. Therefore, lessening the mutual coupling degree of isolation possible between these antennas is necessary.

The spectrum bands that 5G will support are divided into low, mid, and high bands. For introducing 5G, many nations are concentrating on the mid-band (3.4-3.8 GHz) and mm-wave(24-28 GHz) bands.[2] High-speed communication is one of the key reasons why mm-wave is preferred over other frequencies. Massive MIMO is considered one of the key enablers for mm-wave 5G communication. As discussed in the above paragraph, the isolation parameter is very important incase of massive MIMO. The literature has several methods to improve the

isolation between the closely packed antennas. They are categorized into six types: decoupling networks[3],antenna placement and orientation[4], parasitic elements[5], defected ground plane structures[6], neutralization lines[7], and the use of metamaterials.[8] However, many of them work only at sub-6 GHz frequencies. Only a few isolation enhancement works are available in literature that focus on mm-wave frequencies[9],[10] and.[11]

The proposed work is a metal strip reflector- based isolation technique for the24-28 GHz band. The technique is explained using a four-port MIMO configuration. Isolation enhancement of 5 dB is achieved in the required band by using the proposed technique. Section II discusses the single-portT-shaped wideband antenna design. The single-port is replicated for four ports and the proposed isolation technique has been used to achieve the MIMO design; the same is explained in Section IV.

ProposedSingle-PortT-shapedWideband

Antenna Design

The proposed antenna element is printed on RT Duroid 5880 substrate with a relative permittivity of 2.3 and a thickness of 0.254 mm, making the design extremely thin. Fig. 1(a) and 1(b) illustrate the suggested design front and rear pictures respectively. The design has the following dimensions: X = 10, Y = 8, Z = 5.9, A = 0.9, B=6,C=3.15,D=3.15,E=2,F=2,GX-=1.4and

GY=1.4(all the units are in mm).

The design's primary goal was to make the antenna resonate at the 26 GHz frequency, which was accomplished through several parametric simulations. The achieved reflection coefficient (S_{11}) response is shown in Fig. 2. The design procedure started with a simple T-shaped structure, which did not give the desired bandwidth. Introducing a square-shaped frame around a T-shape structure gives a significant dip at 26 GHz frequency with a 10 dB return loss bandwidth spanning roughly from 21 to 29 GHz, as illustrated in Fig. 2. The antenna gives a gain of more than 3 dBi, an efficiency of more than 80%, and a co- and cross-polarization difference of morethan30 dB, which tells the practical utilization of the proposed antenna.

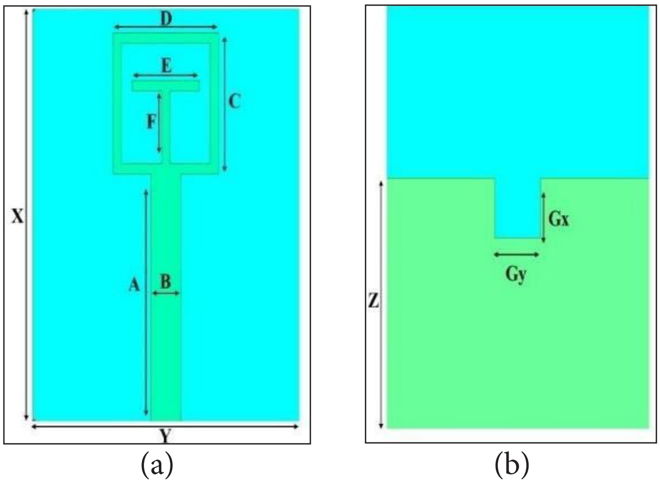


Figure 1.Single port antenna model. (a) front picture and (b) back picture

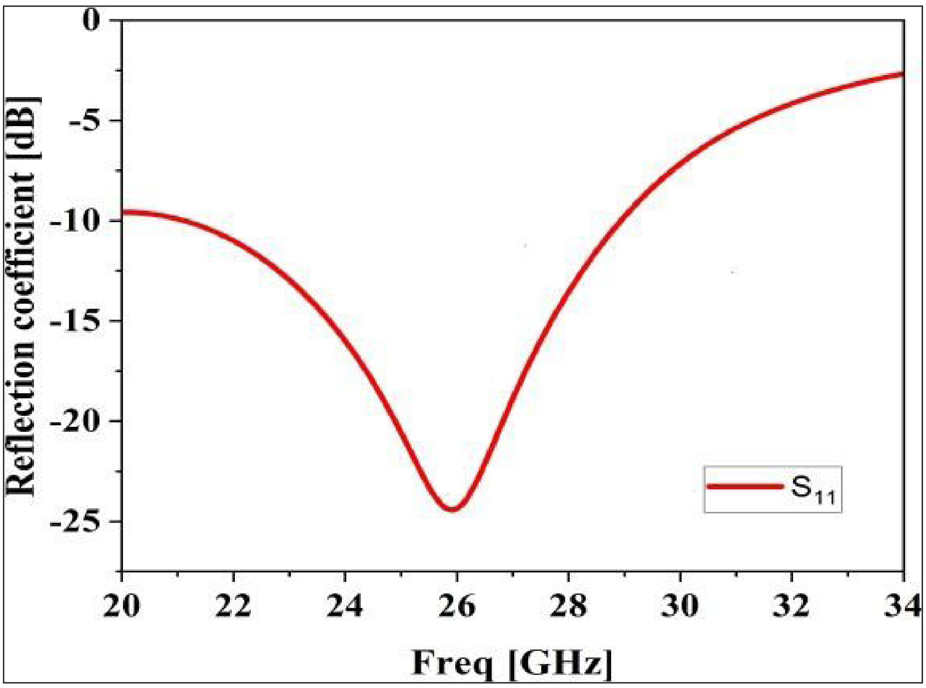


Figure 2.Reflection coefficient (simulated) of a single-port antenna

FourPortMIMOAntenna Design

Without Isolation Technique

As explained in Section II, a wideband single-port antenna was constructed before the four-port design. To utilize MIMO technology for 5Gsystems, a minimum of four antenna units must be employed.[12] Hence, the wideband antenna has been expanded to four ports, as shown in Fig. 3. Fig. 4 displays the results of the four- port antenna in the form of S- parameters that we obtained from the software simulations. There are two drawbacks to this four-port design, which are given below.

1. The isolation between the adjacent antenna elements is near 10 dB at 24 GHz.
2. There is a discontinuity in the ground plate of the antenna units.

A value of -10 dB for mutual coupling is considered to be high. Because of mutual coupling, the input power supplied to the port gets wasted by coupling with the other ports instead of radiating. This problem becomes critical if there are more adjacent antenna elements, which massively affects the antenna's overall efficiency. Because of high mutual coupling, the surface currents are flowing to the other ports even if we excite

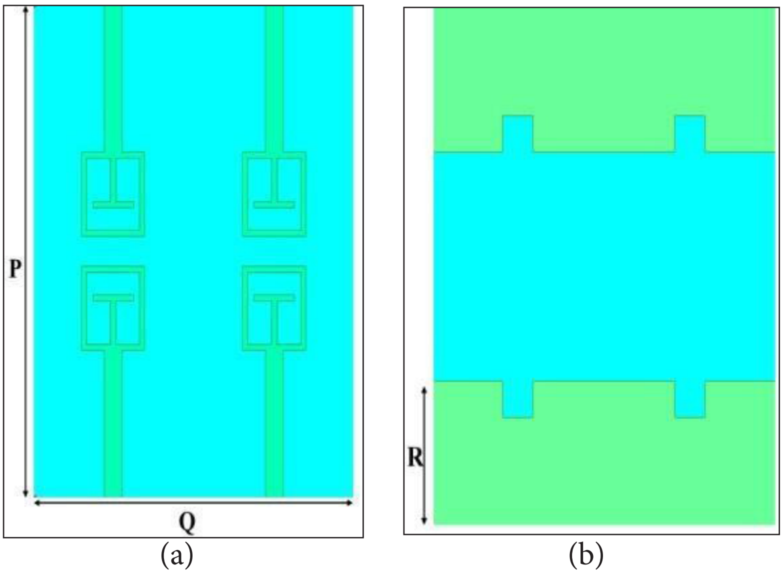


Figure 3.Four port antenna model without isolation: (a) front picture and (b) back picture.(P=20mm,Q= 16mmandR= 5.6mm)

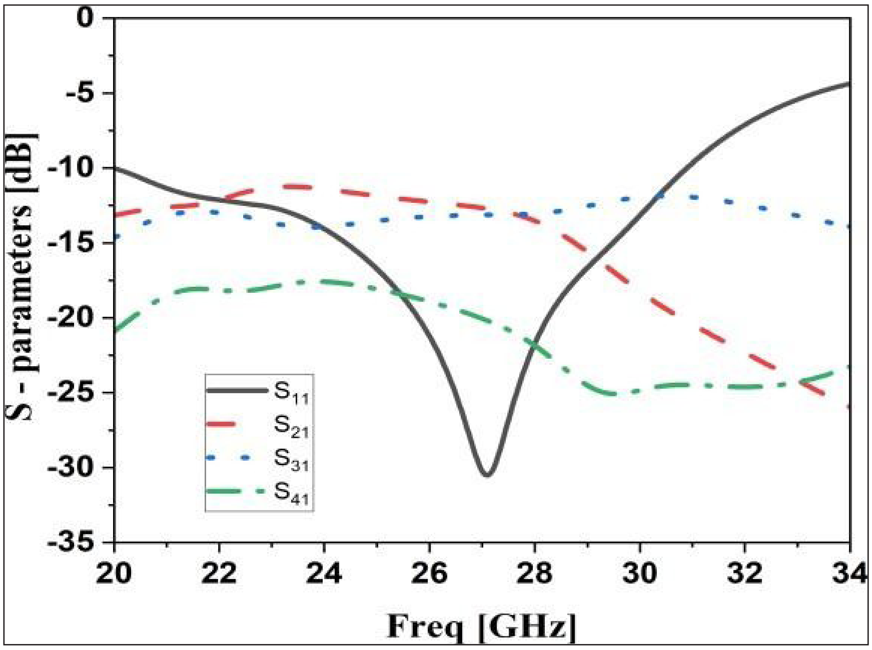


Figure 4.S-parameters(simulated)of four-port antenna without reflector

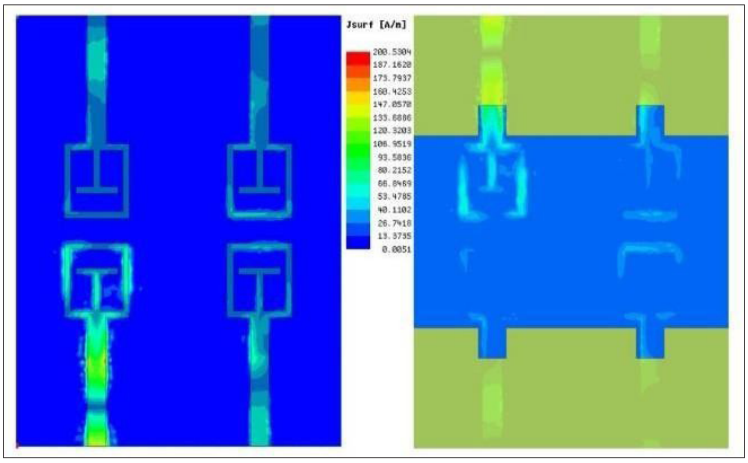
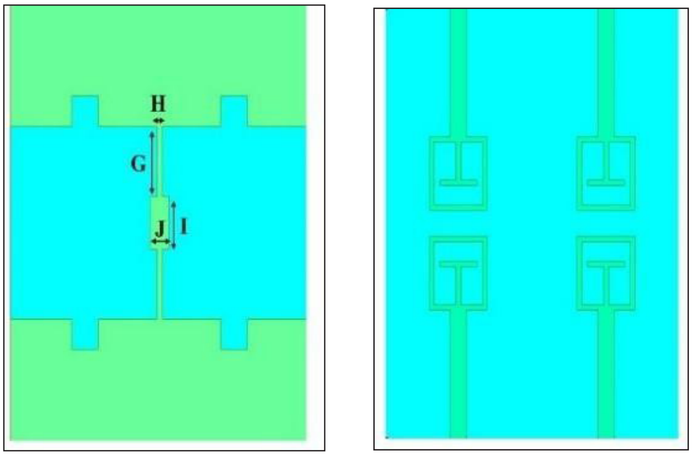


Figure 5.Surfacecurrentonthefour-portantennabyexcitingthe first port at 26 GHz



(a) (b)

Figure 6.MIMOantennamodelwithisolation:(a)front picture and (b) back picture

only the first port, as shown in Figure 5. This surface current flow decreases antenna gain, operational bandwidth, and radiation efficiency. The disconnected ground plane denotes the multiple reference voltage levels, which is impossible in any circuit.

With Isolation Technique

The first and second antenna components' mutual coupling(S21)inthefourportantennashowninFigure 3 is closeto10dB,indicatingthat10%ofpowerislostdue

to coupling. A mutual coupling of less than -15 dB should typically exist between any two antenna units. The problems of high mutual coupling and discontinuous ground plane are solved in this work by introducing the reflectors in the ground plane.

The reflector approach has two benefits: it reduces mutual coupling and connects each antenna unit's ground plane to keep a single reference voltage. The reflector is of step impedance type and is introduced on the back side of four-port antenna, connecting all the ground planes.

The reflector cuts the surface current flow from one port to another, thereby improving the isolation. The four-port MIMO antenna design with isolation technique is illustrated in Fig. 6(b), and the dimensions are given as follows: G =3.2 mm, H= 0.3 mm, I= 2.4 mm and J = 1mm. The S-parameters of the four-port MIMO antenna are shown in Figure 7. The S21curves in Figure 4 and Figure 7 show that the isolation between the adjacent antenna units increases after adding the reflectors. The isolation is improved from 10 dB to 15 dB, which is a highly acceptable value.

Figure 5 and Figure 8 illustrate the surface current distribution between four antenna elements with and without reflectors at 26 GHz. Since no reflector is present in Figure 5, the surface current created at the first port also flows to the second port. The isolation between the antenna units is improved in the second scenario, i.e., Figure 8, because the reflector prevents the surface current entering the second port. This increases the isolation between the ports.

The other advantage of the proposed reflector technique is improving the isolation without changing the other parameters like radiation pattern, gain, reflection coefficient, etc. Figure 9(a) and 9(b) show that the radiation pattern remains the same even after adding the reflector.

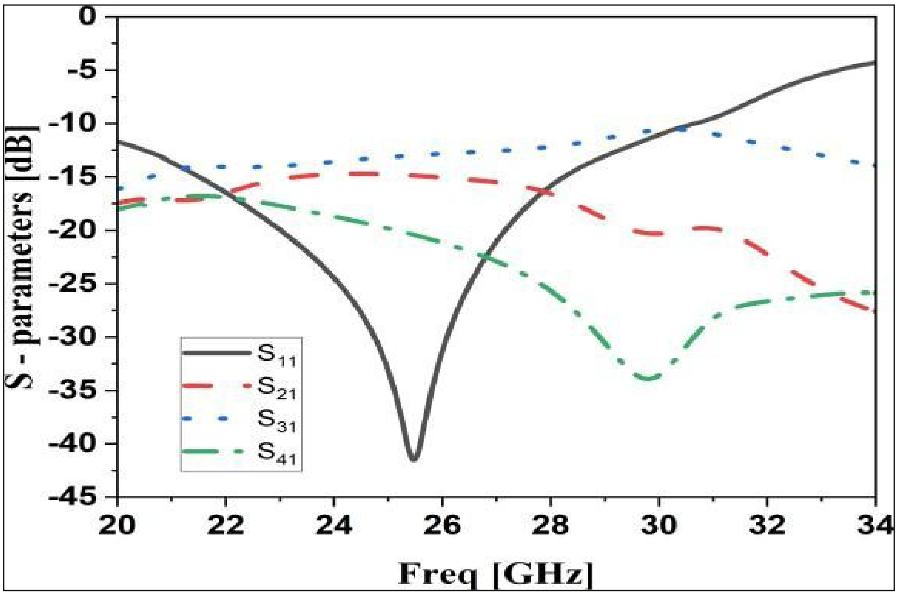


Figure 7.S-parameters(simulated)of four-port MIMO antenna with reflector

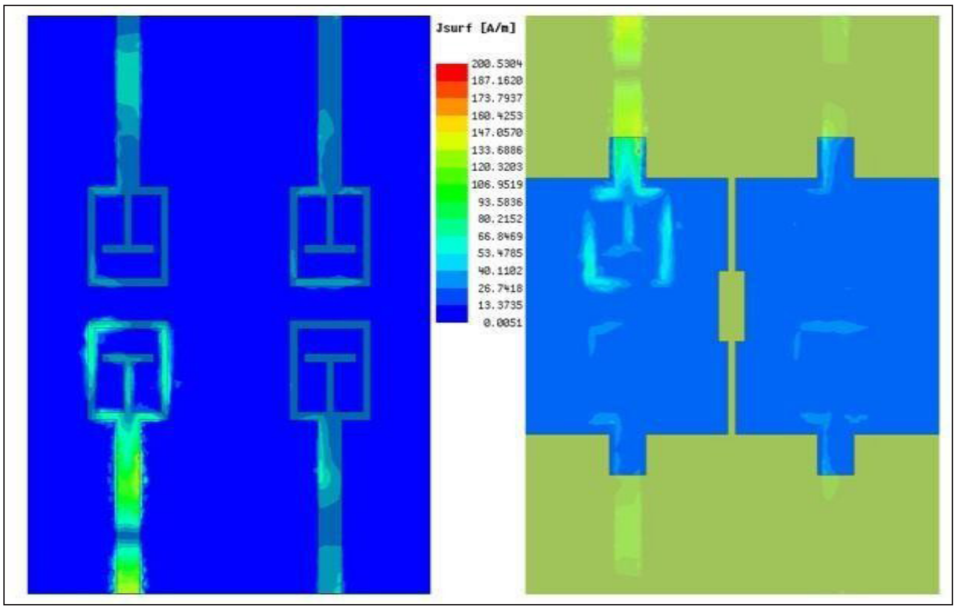
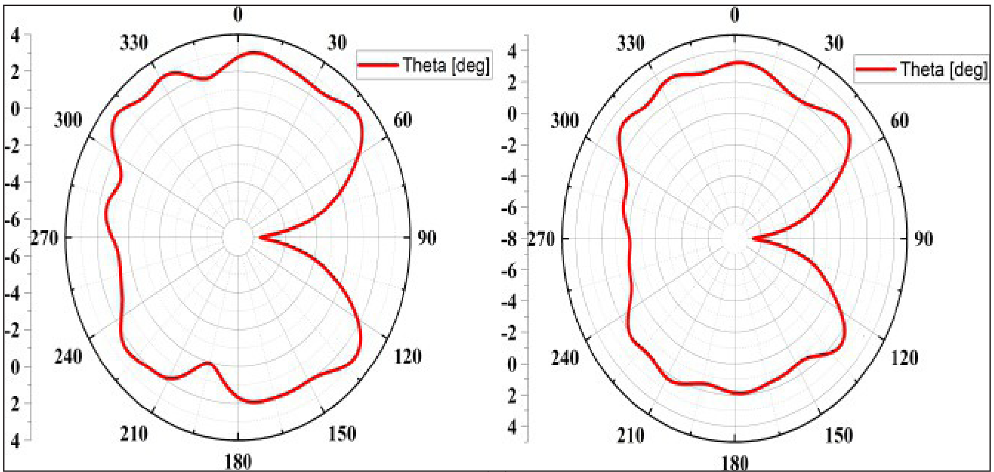
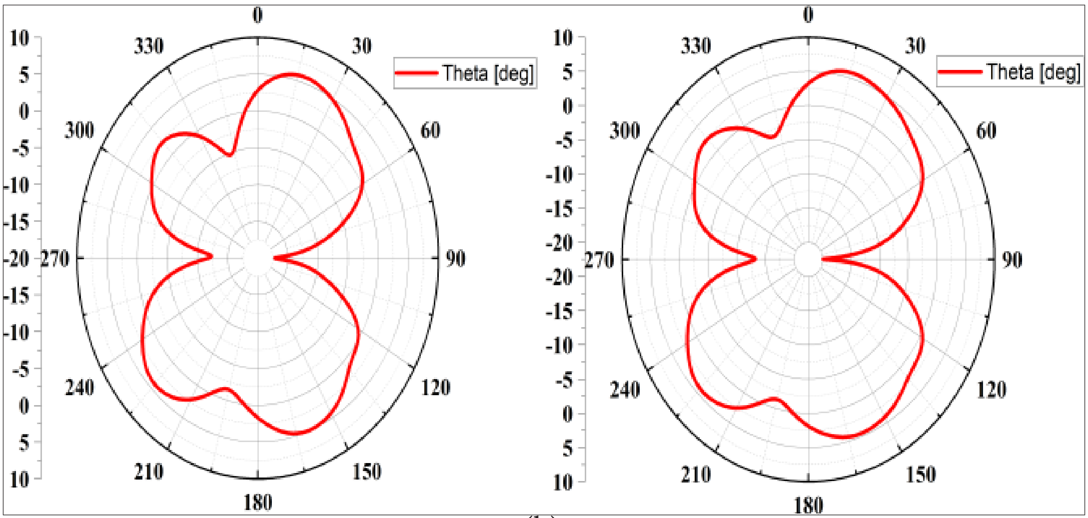


Figure 8. Surface current on the four-port MIMO antenna with reflector by exciting the first port at 26 GHz



(a)



(b)

Figure 9.MIMOantennamodelwithisolation:(a)front picture and (b) back picture

Conclusion

This paper starts with the design of a single port T- shaped wideband antenna with a 10 dB return loss bandwidth of 21-29 GHz. Then, a four-port antenna is created using the proposed single-element design and later introduced a reflector to make it work for MIMO operation. The reflector improves theisolationby5 dB without altering the other antenna parameters. The reflector-based isolation technique is demonstrated only for four-port in this work, but it is expected that this technique can be easily applied to any number of antenna elements and thus supports the massive MIMO operation.

References

1. Sharawi,M.S,"PrintedMIMOantennaengineering"(ArtechHouse, Norwood, MA, 2014)
2. Tikhomirov,Andrey&Omelyanchuk,Elena &Semenova,Anastasia.(2018), "Recommended 5G frequency bands evaluation,"pp. 1-5.
3. Chen, S.C.,Wang, Y.S.,Chung, S.J, "A decoupling technique forincreasing the portisolation between two strongly coupled antennas,"IEEE Trans. Antennas Propag., 2008, 56, (12), pp. 3650–3658.
4. Anitha, R.,Vinesh, P.V.,Prakash, K.C.,Mohanan, P.,Vasudevan, K,"Acompactquadelementslottedground-widebandantennaforMIMOap plications," IEEE Trans. Antennas Propag., 2016,pp. 4550–4553.
5. Lee,H.,Lee,B,"Compactbroadbanddual-polarizedforindoorMIMOwirelesscommunicationsystems,"IEEETrans
6. .AntennasPropag.,2016,pp. 766–770 .
7. Luo, C.M.,Hong, J.S.,Zhong, L.L, "Isolation enhancement of a verycompact UWB-MIMO slot antenna with two defected groundstructures,"Antennas Wirel. Propag. Lett., 2015,pp. 1766– 1769.
8. Su, S.W.,Lee, C.T.,Chang, F.S, "Printed MIMO-antenna systemsusing neutralization-line technique for wireless USB- dongleapplications,"IEEE Trans. Antennas Propag., 2012,pp. 456– 463.
9. Bait- Suwailam,M.M.,Boybay,M.S.,Ramahi,O.M,"Electromagneticcouplin g reduction in high-profile monopole antennas using single-negative magnetic metamaterials for MIMO applications," IEEETrans. Antennas Propag., 2010,pp. 2894–2902.
10. O.Sokunbi,H. Attia, A.Hamza, A. Shamim,Y. Yu and A. A. Kishk,"New Self-Isolated Wideband MIMO Antenna System for 5G mm- WaveApplicationsUsingSlotCharacteristics,"inIEEEOpenJournalof Antennas and Propagation, vol. 4, pp. 81-90, 2023.
11. S. Dey, S. Dey and S. K. Koul, "Isolation Improvement of MIMOAntenna UsingNovelEBGandHair-Pin Shaped DGS at5G MillimeterWave Band," in IEEE Access, vol. 9, pp. 162820-162834, 2021.
12. Z. Siddiqui, M. Sonkki, M. E. Leinonen, J. Chen, M. Berg and A.Pärssinen, "A Differential Dual-band Dual-polarized Antenna for 5GmmWave Communication System,"2020 2nd 6G Wireless Summit(6G SUMMIT), Levi, Finland, 2020, pp. 1-4.
13. B.Thomas.Qorvo:IsYourHandsetRFReadyfor5G?Accessed:Feb.2018.