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# A COMPACT FOUR PORT MIMO ANTENNA FOR MILLIMETER WAVES 5G APPLICATIONS

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## ABSTRACT

A novel compact microstrip MIMO antenna with high isolation and low envelope correction coefficient has been proposed and presented in this paper. The proposed antenna is compact in size with 3.22x4.86 $mm^2$ , operating over the frequency band of 60GHz. The MIMO antennas have been designed and simulated using electromagnetic design and verification platform of HFSS. Two ports MIMO antenna with the size of 3.22x1.93 $mm^2$ resonates at 58.6 GHz covering a band of 57.2-60 GHz, with the bandwidth of 2.8 GHz, gain of 3.2 dBi, and directivity of 4.67 dBi. It also provides an input reflection coefficient of -23.28 dB with isolation of -45.80 dB. Proposed four port MIMO antenna resonates at 58.1 GHz covering a range of 57.2 GHz to 60 GHz, with a bandwidth of 2.8 GHz, gain of 5.24 dBi, and the directivity of 7.75dBi. It provides good isolation with input reflection coefficient of -30 dB.

## 1. INTRODUCTION

A compact four-port multiple-input multiple-output (MIMO) antenna for ultra wideband (UWB) applications is presented in this paper. The proposed antenna has four unit cell antennas. Each unit cell is placed orthogonal to its adjacent elements. The radiation element of each unit cell is composed of a cut semicircular patch and a stepped microstrip feed line. The whole ground on the back side consists of four parts of defective ground and their extended branches, which are connected through a "卍" structure. The main decoupling technology used in the MIMO antenna is polarization diversity. In addition, protruded ground and parasitic elements are added to achieve a higher isolation. This compact antenna has a small area of 45 mm × 45 mm and is printed on a single layer substrate (FR4) with an $\varepsilon_r = 4.4$ and a thickness of 1.6 mm. This antenna has an impedance bandwidth (S11 < −10 dB) of 3.1–13.1 GHz (123%) and an isolation of less than −17 dB. The envelope correction coefficient (ECC) is less than 0.02 and the average gain is 4 dBi. The ultrawide bandwidth and compact size of the proposed antenna make it a promising candidate for UWB applications. This paper embodies the design and development of a compact Coplanar Waveguide (CPW) fed connected ground Multiple- Input-Multiple-Output (MIMO) antennas operating in the sub-millimeter-wave 5G New Radio (NR) n257/n258/n261 bands. The planar geometry leads to a small and compact structure while achieving a wide operating bandwidth, high gain, and better radiation efficiency. The top surface of the antenna comprises a modified CPW in the form of two circular structures that feeds the centrally

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slotted circular patch. The single antenna structure is arranged in a rotational orthogonal manner forming a 4-port structure. The ground plane on the bottom of a 4-port structure is connected using a circular ring which is carefully optimized for achieving isolation levels>20 dB across the band of interest. The sub-mm-wave resonating 4- port antenna achieves a compact size of 24  24 mm2 , a wide bandwidth of 24.8–44.45 GHz (79.35%), the maximum gain of 8.6dBi, and minimum efficiency of 85% across the bands of interest. The proposed antenna element is fabricated over Rogers 5880 substrate and experimental tests are carried out, where a good correlation between the scattering parameters, transmission. In the proposed work efficiency > 90% is achieved at 0.06 (for Rogers Substrate, thickness = 0.8 mm and f = 24.8 GHz, dielectric constant 2.2) which meets the 1st criteria for surface mode suppression. The second criteria for interelement spacing are not meeting the k0/2 criteria although the MIMO antenna connected ground structure is optimized in a manner to keep the isolation levels well above the safe limit of 15 dB. The comparison of the proposed antenna performance with and without the SIW is not carried out as the analysis of antenna after inclusion of SIW will deviate from the idea of proposing a wideband antenna resonating at sub-mm-wave since that was the main motto and not about achieving antenna with high Q factor. A compact 4 port circular-shaped antennas (24  24 mm2 ) having an elliptical slot at the center with modified coplanar feed and a partial ground-plane is proposed for wideband mm-wave applications. The enhancement in bandwidth is achieved by carefully optimizing the ground plane and the central elliptical slot. The proposed 4-port antenna operates in the frequency range of 24.8 to 44.45 GHz and provides better than 20 dB isolation between ports. The connected ground profile provides satisfactory isolation and MIMO diversity performance. The simulation and testing of the proposed design are carried out using Computer Simulation Technology (CST), vector network analyzer, and anechoic chamber, respectively. The proposed antenna provides omnidirectional radiation patterns, the maximum gain of 8.6 dBi, minimum efficiency value of 85%, Envelope Correlation Coefficient (ECC) 9 dB over the entire frequency span of interest. Simulated and measured results show good similarity that verifies and recommends applicability of the proposed antenna in sub-millimeter-wave 5G applications. A coplanar waveguide (CPW) fed flexible interconnected 4-port MIMO antenna is proposed for UWB, X, and Ku band applications having a size 0.67λ × 0.81λ × 0.0028λ (at 3.58 GHz). The antenna parameters are characterized by using sets of real measurements to validate the antenna design and modelling. A precise milling machine is used for fabricating the single and 4-port antennas over a flexible FR-4 Substrate. Vector network analyser (VNA) is used for measuring scattering and transmission coefficients. As well as, a shielded anechoic chamber is utilised for measuring the far field radiations and the gain of the antenna under test (AUT). The basic antenna that is a part of the 4-port structure consists of a CPW fed octagonal structure surrounded by an octagonal-shaped slot.

## 2. LITERATURE SURVEY

Multiple antennas at the transmitter and receiver are used in MIMO technology. This manages to suppress channel fading due to its multipath characteristics and can significantly improve the spectrum utilization. In order to integrate multiple antenna elements on a small substrate, appropriate decoupling is introduced between antenna elements to increase the isolation.Many decoupling methods have been proposed. In [1], a neutralization line is added between two radiation elements, and it connects to the elements. The neutralization line contains two metal strips connected via rhombus plate. The line effectively reduces the coupling current at ground and achieves a wideband decoupling current. A high isolation is achieved by exploiting the polarization of the multiple elements [2]. A UWB MIMO antenna with a high isolation (less than −22 dB) by loading a parasitic unit decoupling structure on the floor was proposed in [3]. The parasitic element consists of a T-junction and a pair of symmetrical bending lines. Other decoupling methods include defective ground structure (DGS) [4], protruded ground [5], self-decoupling, electromagnetic band gap (EBG) structures [6], decoupling network, and metamaterial [7]. The frequency selective surfaces (FSSs) [8,9] could enhance the antenna's gain for UWB frequencies. In [2], a four-element MIMO antenna with polarization diversity technology has a high isolation and a small size. However, the substrate of this antenna is Rogers TMM4. The material is very expensive. The size of the four-element MIMO antenna mentioned in [10] is small, but the isolation is not good, only less than −16 dB. For the antennas described in [11,12], due to their single decoupling structure, their isolation is not ideal; it is about −15 dB for both.A compact four-port MIMO antenna for UWB applications with a high isolation and a wide bandwidth is proposed in this paper. The antenna achieves a high isolation, less than −17 dB, by using the polarization diversity method, protruded ground structures, and parasitic elements. Besides, this antenna provides a good impedance matching from 3.1 to 13.1 GHz and has a good average gain of about 4 dBi. In addition, the ECC result is less than 0.02. It indicates that the antenna meets the polarization diversity requirements. In summary, the highlights of the proposed antenna are its ultrawide bandwidth and compact size. At the same time, the other properties are also good, including the isolation, the gain, and the ECC.

Due to high data rates, spectral efficiency, latency, cost, and channel capacity demand for an advanced communication system, lower frequencies of 5G NR sub-6 GHz have already been utilized for large area coverage in the present time [1–3]. Hence, the need to address the new millimeter-wave frequency band in 5G New radio (n257/n258/n260/n261) is in the development stage for other applications which require multigigabit per second data speeds [4,5]. Many countries include the USA (28 GHz, 37 GHz, and 39 GHz), Japan (27.5– 28.8 GHz), China (24.25–27.5 GHz, 37–43.5 GHz), and Korea (28 GHz) has proposed the frequency bands for 5G millimeterwave applications [6]. The modern communication system requirement of both wide bandwidth and high gain are covered by using UWB technology that plays a vital role in wireless communication. However, UWB technology is mainly affected by multipath fading degradation in cable-free communication. One of the solutions for multipath fading is the use of MIMO antennas which enhances the capabilities of wireless communication systems.

## 3. EXISTING SYSTEM

This phase consists of the design of the square patch antenna with inset feed. Figure 6.1 shows the geometry of the antenna. The objective of the inset feed is to achieve proper impedance coupling by making the transmission line connect to an internal point of the patch. The size of the resulting 1 × 2 array is smaller since a quarter-wave transformer will not be used in the antenna source. 1 × 2 array is shown in Figure 6.1. It is formed with two of the antennas from Figure 2 (Base antenna). A power combiner is used with impedances of 100, 50 and 100 Ω in segments 1, 2 and 3 as a feeding point of 1 × 2 array.

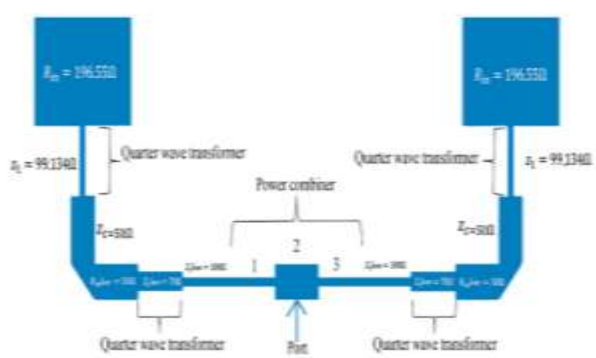


Fig 1. 1×2 array of square patch antenna with quarter-wave coupled

## 4. PROPOSED SYSTEM

A single patch of microstrip patch antenna has been designed on 0.2 mm height of low cost FR-4 substrate with dielectric constant of εr=4.4 at millimeter wave frequency of 60 GHz. This simple patch antenna has been fed using 50 Ω transmission lines. To match the impedance of the patch antenna and the 50 Ω transmission line, a quarter wave transformers has been designed. The dimensions of the single patch antenna has been calculated using the equations [14] with length L=1.11 mm and width W=1.52 mm. The fed line of 50 Ω has been designed at 60 GHz to energize the patch antenna. The dimensions of the 50 Ω line is length $L_{50}$=0.68 mm and W50=0.37 mm. The dimensions of the quarter wave transformer is length $L_q$=0.75 mm and width Wq=0.045 mm. The dimension of the single patch with the feed network is 1.11x1.93 $mm^2$ as shown in Figure.

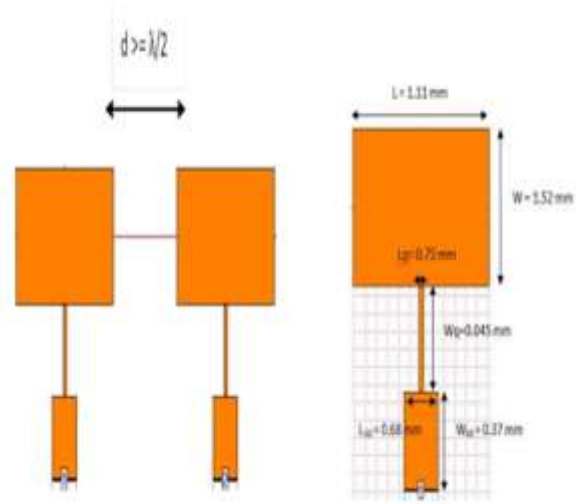


Fig 2.Single and Two port Microstrip antenna

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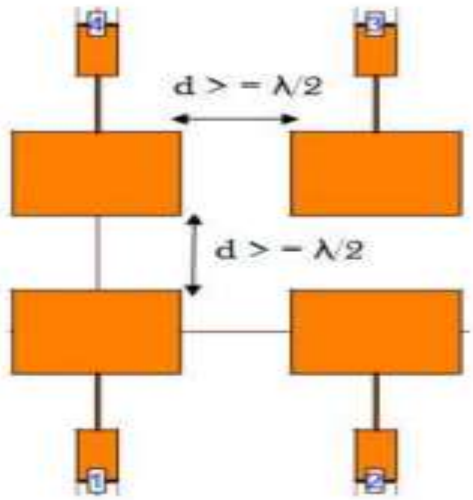
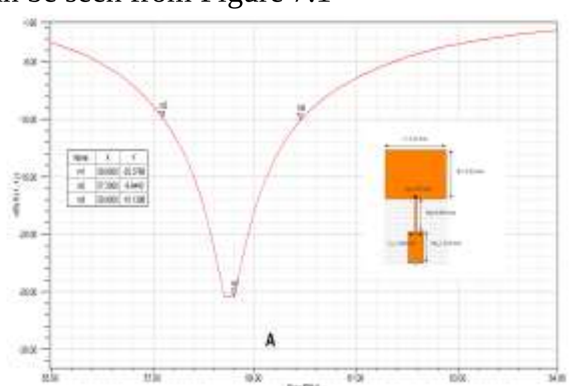



Fig 3. Four port Microstrip MIMO antenna

To investigate the best MIMO antenna design which provides the best possible results for millimeter wave applications, two designs of MIMO antenna having two and four ports is presented. The two port antenna is designed by adding one more single patch antenna to the existing one. The distance between the two patch antennas is maintained at greater or equal to λ/2, to minimize the effect of mutual coupling. The dimension of the two port antenna is 3.22 x 1.93 $mm^2$ . Two port antenna systems is shown in Figure 2. Four port antenna systems have been designed with 4 patch antennas separated with the distance greater or equal to λ/2. The dimension of the four port antenna is 3.22 x 4.86 $mm^2$

## 5. RESULTS

In this section, the microstrip patch antennas, presented in the previous sections, have been analyzed and simulated using HFSS simulator based on moments of methods. It is observed that the single port micro strip patch antenna resonates at 58.6 GHz covering a band of frequencies from 57.2-60 GHz, providing the bandwidth of 2.8 GHz. The S11 for the single port antenna wasat -25.37 dBas depicted in the Figure4. The two ports MIMO antenna resonates at 58.6 GHz with the cover range of57.3-60 GHz, having bandwidth of 2.7 GHz. The reflection coefficientwas found to be at -23.28 dB, it also provides a good isolation of -45.80 dB as can be noticed Figure 7.1. The four port MIMO antenna resonates at 58.6 GHz with input reflection coefficient of -23.62 dB, providing a bandwidth of 2.8 GHz over a frequency range of 57.2-60 GHz. S parameter graph can be seen from Figure 7.1. The more the number of ports there will be a mutual coupling existing between the ports, which degrade the antenna system. The four port MIMO antenna gives a very good isolation between all four ports making the system desirable for millimeter wave communication. It provides a good isolation of -19 dB to -30 dB as can be seen from Figure 7.1



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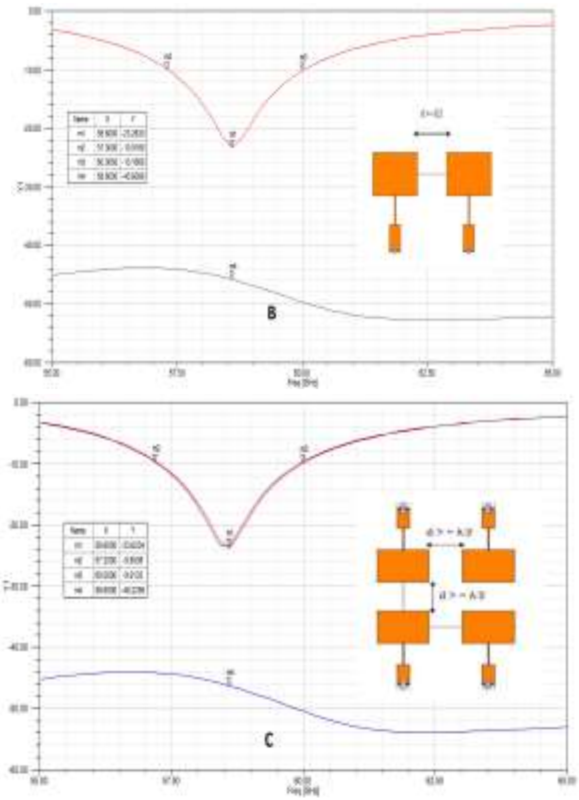



Fig 4. S parameter of A) Single port B) Two port C) four port of Microstrip patch antenna

The peak gain plot of the two ports and four ports MIMO antenna is presented in Figure 7.2 a,b. It is observed that, the two ports MIMO antenna it is noticed that the gain is 3.2 dBi and directivity is 4.67 dBi. For the four port MIMO antenna, it gives a gain of 5.2 dBi and directivity of 7.75 dBi. Voltage standing wave ratio (VSWR) for all the three designs is <2 as can be noticed from Figure 7.3a,b,c. Table 7.1 shows the comparative results of all three antennas and it is investigated that four ports MIMO antenna performs better in terms of gain and directivity which is the requirement for millimeter wave applications.

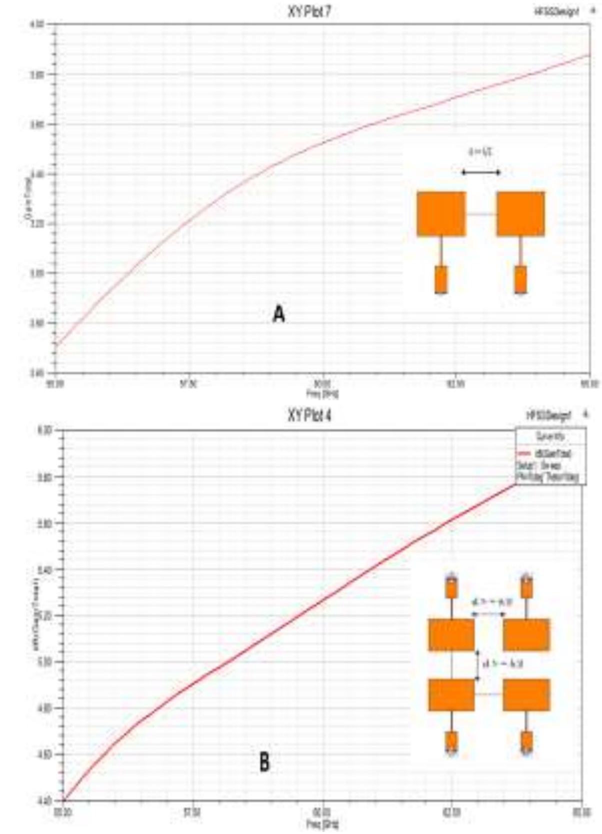
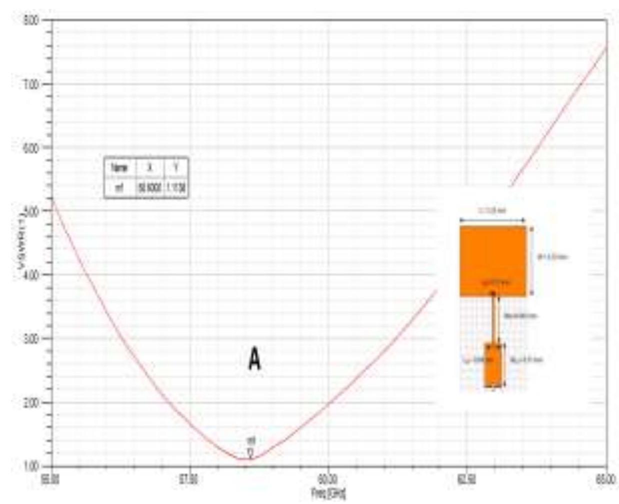



Fig 5. Gain Microstrip patch antenna A) Two port B) four port of Microstrip patch antenna



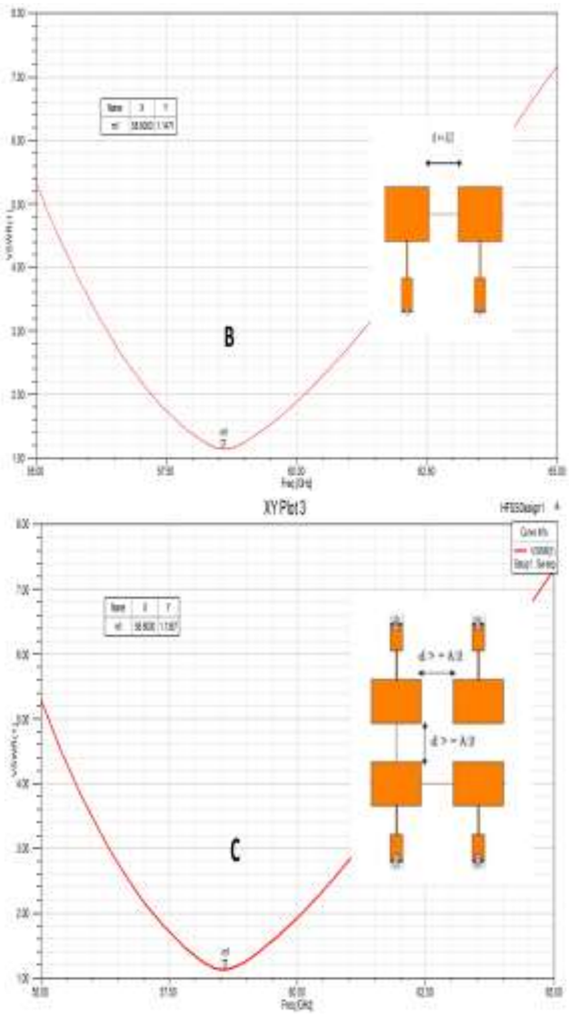



Fig 6. VSWR of A) Single port B) Two port C) four port of Microstrip patch antenna

Table.1 Comparative analysis of the antenna's

| Parameters | Single port | 2 Ports | 4 Port |
|---|---|---|---|
| Resonant frequency (GHz) | 58.6 | 58.6 | 58.6 |
| Bandwidth (GHz) | 2.8 | 2.7 | 2.8 |
| Input reflection coefficient (dB) | 25.37 | 23.28 | 23.62 |
| Gain (dBi) | 3.4 | 3.2 | 4.67 |
| Antenna efficiency (%) | 70 | 63 | 60 |

## 6. CONCLUSION

In this study, a novel compact Microstrip MIMO antenna has been designed and analyzed. The four ports MIMO antenna works perfectly for millimeter wave applications with the gain of 5.24 dBi and directivity of 7.75 dBi. It also gives a wide bandwidth of 2.8 GHz at 60 GHz band which is suited IEEE 802.11ad wireless networking standard. The MIMO performance metrics also has been analyzed and it is found that four ports MIMO antenna gives a good performance at the resonant frequency. The ECC is about 0.06 using far field radiation pattern and 0.9 using s parameter method of calculation. Diversity gain of four port MIMO antennas is greater than 7.8 dB with MEG of less than 1 dB.

## REFERENCES

[1] T.S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G.N. Wong, J.K. Schulz, M. Samimi, F. Gutierrez, Millimeter wave mobile communications for 5G cellular: It will work, IEEE Access 1 (2013) 335–349.

[2] R.G. Vaughan, J.B. Andersen, Antenna diversity in mobile communications, IEEE Trans. Veh. Technol. 36 (4) (1987) 149– 172.

[3] Z. Pi, F. Khan, An introduction to millimeter-wave mobile broadband systems, IEEE Commun. Mag. 49 (6) (2011) 101– 107.

[4] S. Kim, E. Visotsky, P. Moorut, K. Bechta, A. Ghosh, and C. Dietrich, ''Coexistence of 5G

with the incumbents in the 28 and 70 GHz bands,” IEEE J. Sel. Areas Commun., vol. 35, no. 6, pp. 1254_1268, Jun. 2017.

[5] J.-H. Lee, J.-S. Choi, and S.-C. Kim, ‘‘Cell coverage analysis of 28 GHz millimeter wave in urban microcell environment using 3- D ray tracing, ’’IEEE Trans. Antennas Propag., vol. 66, no. 3, pp. 1479_1487, Mar. 2018.

[6] A. Desai, T. Upadhyaya, R. Patel, Compact wideband transparent antenna for 5G communication systems, Microw Opt Technol Lett 61 (3) (2019) 781–786.

[7] R. Krishnamoorthy, A. Desai, R. Patel, A. Grover, 4 Element compact triple band MIMO antenna for sub-6 GHz 5G wireless applications, Wireless Netw. (2021) 1–13.

[8] M.S. Sharawi, Current misuses and future prospects for printed multiple-input, multiple-output antenna systems [wireless corner], IEEE Antennas Propag. Mag. 59 (2) (2017) 162–170.

[9] Irshad Khan, Muhammad, Muhammad Irfan Khattak, Saeed Ur Rahman, Abdul Baseer Qazi, Ahmad Abdeltawab Telba, and Abdelrazik Sebak. ‘‘Design and investigation of modern UWB-MIMO antenna with optimized isolation.” Micromachines 11, no. 4 (2020): 432.

[10] J. Banerjee, A. Karmakar, R. Ghatak, D.R. Poddar, Compact CPW-fed UWB MIMO antenna with a novel modified Minkowski fractal defected ground structure (DGS) for high isolation and triple band-notch characteristic, Journal of electromagnetic Waves and Applications 31 (15) (2017) 1550– 1565.

[11] I. Nadeem, D.-Y. Choi, Study on mutual coupling reduction technique for MIMO antennas, IEEE Access 7 (2019) 563–586.

[12] N. Kumar, K. Usha Kiran, Meander-line electromagnetic bandgap structure for UWB MIMO antenna mutual coupling reduction in E-plane, AEU-International Journal of Electronics and Communications 127 (2020) 153423, https://doi.org/ 10.1016/j.aeue.2020.153423.

[13] A. Ramachandran, S. Mathew, V. Rajan, V. Kesavath, A compact triband quad-element MIMO antenna using SRR ring for high isolation, IEEE Antennas Wirel. Propag. Lett. 16 (2017) 1409–1412.

[14] M. Sonkki, D. Pfeil, V. Hovinen, K.R. Dandekar, Wideband Planar Four-Element Linear Antenna Array, IEEE Antennas Wirel. Propag. Lett. 13 (2014) 1663–1666.

[15] A. MoradiKordalivand, T.A. Rahman, M. Khalily, Common Elements Wideband MIMO Antenna System for WiFi/LTE AccessPoint Applications, IEEE Antennas Wirel. Propag. Lett. 13 (2014) 1601–1604.