International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

A Compact Dual-Band 28/38 GHz Two-port MIMO Antenna for 5G mm-wave Applications

G. Kalyani[1], T. Vasantha Likitha[2], A. Elisamma[3]

[1]Assistant Professor, Dept of ECE, Bapatla Women's Engineering College, Bapatla, AP, India.
[2,3]UG Students, Dept of ECE, Bapatla Women's Engineering College, Bapatla, AP,India.

Abstract

This paper introduces a novel dual-band multiple-input multiple-output (MIMO) antenna is designed for applications of 28/38 GHz 5G mm-wave wireless communication. The proposed antenna is made on Rogers RT5880material and has dimensions of 7 mm x 15 mm x 0.8 mm. The MIMO antenna employs rectangular slots positioned identically within the patch, along with the y-shaped slots in the ground, to achieve resonant frequencies at 28GHz and 38 GHz. To improve the isolation between each MIMO element, a rectangular slot is strategically positioned in between them. The designed dual-element MIMO antenna functions effectively at resonant frequencies of 28 GHz and38 GHz and the isolation between its components is > 25 dB. The proposed antenna achieves return loss of -22dB at 28GHz and -24dB at 38 GHz, peak gains of 4.9 dBi at 28 GHz and 2.7 dBi at 38 GHz and the radiation efficiency of >75% within the operational frequency bands. The designed antenna results an envelope correlation coefficient (ECC)below 0.005 and diversity gain (DG) of almost 10 dB. The designing and simulation of the MIMO antenna are carriedout through CST Software.

Keywords: 5G Mm-Wave, Multiple Input Multiple Output, Isolation, Wireless Networks, DG And ECC

1. INTRODUCTION

In the past few years, significant progress has been made in MIMO technology, leading to higher- order MIMO systems with greater numbers of antennas. These advancements have resulted in improved data rates, increased spectral efficiency, and enhanced coverage and reliability in wireless communication networks [1]. Millimeter-wave frequency bands are increasingly explored by research societies worldwide, positioning them as strong contenders for the next generation of mobile communication [2]. Frequency bands such as 28 GHz, 38 GHz, 60 GHz, and 73 GHz are under consideration for the next generation of mobile communication. However, millimeter waves at these frequencies face challenges like atmospheric absorption and path loss. Designing high-gain antennaswith compact sizes is crucial yet challenging, offering promising solutions for overcoming these obstacles [3]. An antenna operating at 28 GHz, designed to enhance gain performance, was presented[4]. In reference [5], an eight-element microstrip antenna array designed for 28 and 38 GHz frequencies for upcoming 5G communications was introduced. These frequencies are chosen because rain attenuation and atmospheric absorption minimally affect electromagnetic wave propagation [6].Narrow and broadband matching techniques are discussed, including quarter-wave transformer taper lines, stubs, and lumped elements [7]. Isolation methods include the utilization of a decoupling and matching network (DMN), as described in [8], and a rectangular microstrip stub with a defected ground structure, as outlined in [9].

In [10], a four-element antenna featuring H-shaped slots on the patches is introduced for dual-band operation. These antennas are printed on the substrate and arranged orthogonal to minimize mutual coupling, eliminating the need for conventional decoupling mechanisms. While the mentioned antennas offer excellent isolation, their designs tend to be complex and large in size. A planar four port MIMO antenna is presented in [11] attain dual band at 28 GHz and 38GHz frequencies without any complex decoupling structure. Therefore, there's a growing need for a simple, compact MIMO design with improved isolation for mm-wave communication. As a result, a straight forward, small MIMO design with enhanced isolation is needed for mm-wave communication.

This study introduces a novel compact MIMO structure for 28/38 GHz wireless communication applications. The proposed antenna characterized by dimensions of 7 mm x 15 mm x 0.8 mm, is simulatedvia micro strip feed excitation. To enhance isolation between port elements, a rectangular slot is placed between antenna elements. The design exhibits strong impedance matching and isolation properties at both 28 and 38GHz frequencies. Moreover, it demonstrates low ECC, substantial peak gains, acceptable radiation efficiency across the entire ground plane. The upcoming sections will cover the analysis of the antenna design, results and conclusion.

2. ANTENNA DESIGN AND GEOMETRY

The antenna design process consists of three main stages. Initially, a single-element patch antenna has been developed for operation at 28 GHz. Secondly, to achieve a second operating band at 38 GHz, rectangular slots are etched on the patch. Consequently, the resulting antenna operates at frequencies of 28 GHz and 38.5 GHz. In the second stage of antenna design, the second band of 38GHz is not obtained perfectly. Thirdly, to achieve a second operating band at 38 GHz, y-shaped slot is etched on the ground plane. Lastly, employing the developed antenna from stage 3 as a constituent element, a two-element dual-band MIMO antenna is designed on Rogers RT 5880 substrate. The dimensions of propose antennais 7 mm × 15 mm, possesses a relative permittivity of 2.2, a dielectric loss tangent of 0.0009, and has a thickness of 0.8 mm. The main radiator elements and ground plane are constructed using copper material, which has a thickness of 0.035 mm. Figure 1 illustrates the three design stages, while Table 1 provides the dimensional details of the antenna. The suggested antenna is created using the CST Studio Software, which is commercially available. The following subsections offer a detailed explanation of the three design stages.

A. SINGLE-ELEMENT ANTENNA

1. Patch Antenna

In the initial stage, Fig. 1(a) represents basic patch antenna with a microstrip feed line. The objective isto achieve resonance at 28 GHz. Initially the designed conventional patch antenna produced a wide operational frequency range of 26.4-31.6 GHz, centered at 27.9 GHz.

2. Patch Antenna with slots

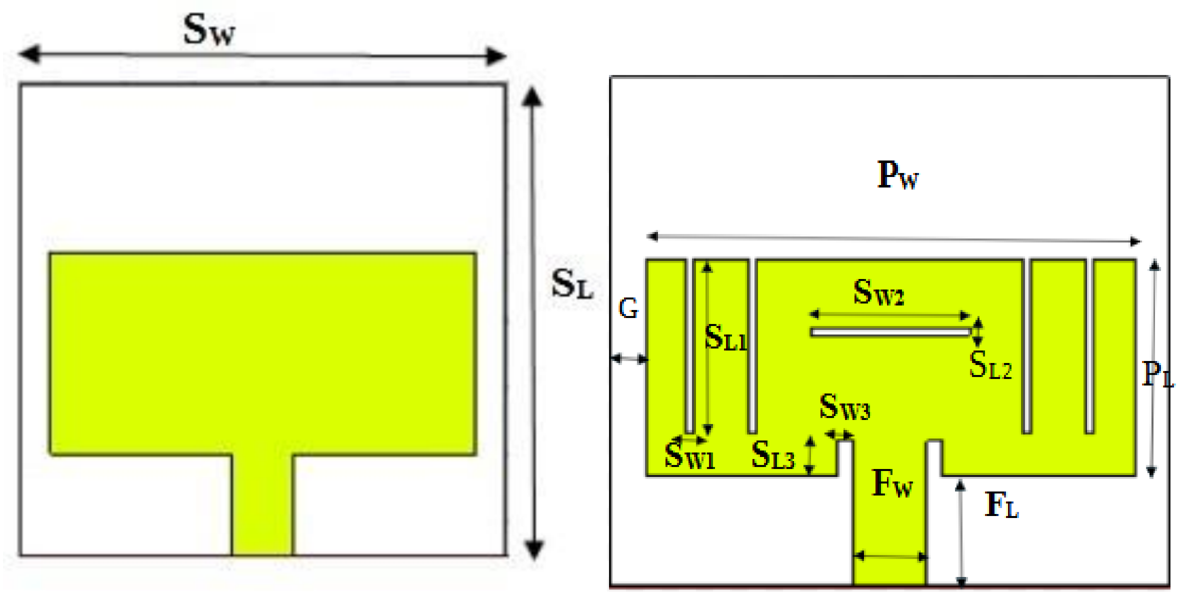
The designed simple patch antenna is further modified to create second resonance at 38GHz. For this purpose, a rectangular-shaped slots are etched onto the main radiating patch which is shown in Fig. 1(b).The simulation results of Fig. 2(a) illustrate the two resonance bands of this antenna, spanning from 26-29 GHz at 28 GHz and 36.5-40 GHz at 38 GHz.

3. Ground with slots

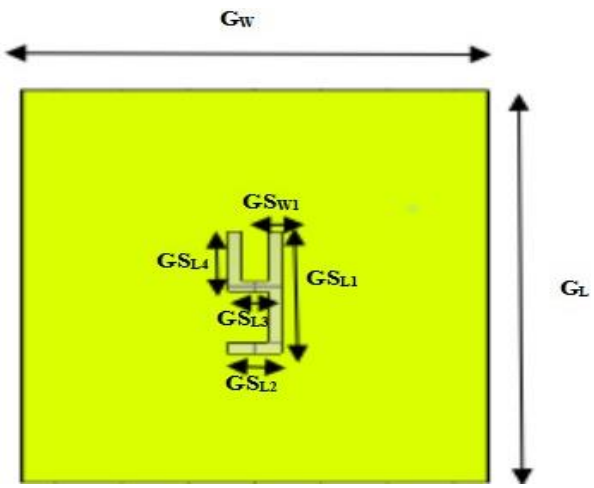
In the second stage, the designed antenna achieves dual-band functionality, but the second band occurred at a frequency of 38.5 GHz. In the third stage, to achieve perfect bands at 28 GHz and 38 GHz frequencies, y-shaped slot is etched on the ground plane. Finally, the designed conventional patch antenna produces a wide operational frequency range of 26.4-29.5 GHz, centered at 28 GHz, and 36.3-39.2 GHz at 38 GHz.

B. TWO ELEMENT MIMO ANTENNA

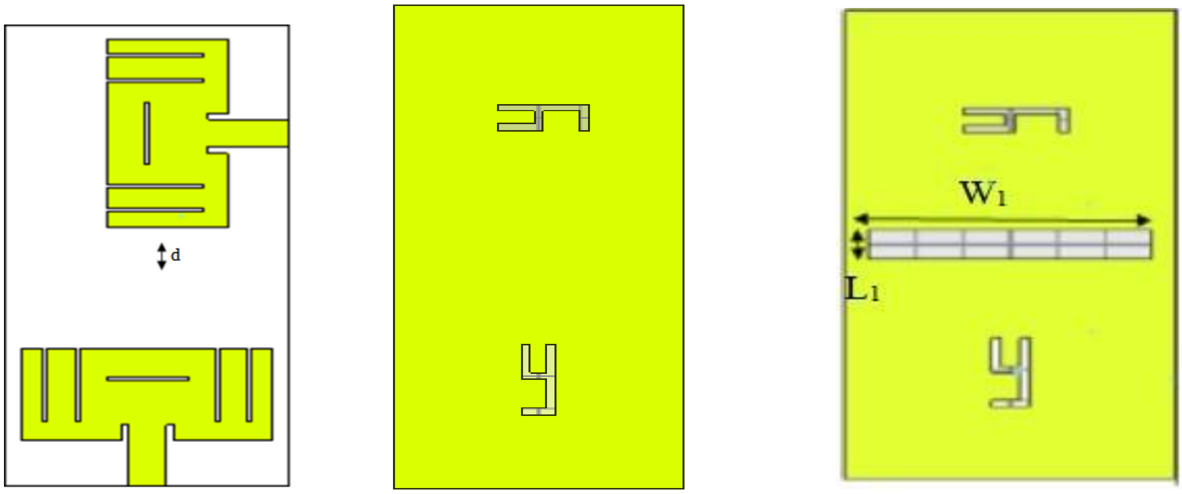
After achieving the constituting antenna element, the design evolves to obtain the dual-band MIMO antenna. As shown in Fig. 1(c), the two constituting antennas are positioned orthogonally with a spacing of ’d’ units. This orthogonal arrangement enables polarization diversity and could be utilized to further reduce the mutual coupling between antenna components with the application of slot between the antenna elements in the ground plane. The board measures a total dimension of 7 mm × 15 mm. The Return loss and Mutual Coupling results of proposed MIMO antenna are shown in Fig. 2 (a) and (b).



(a) **(b)**



(c)

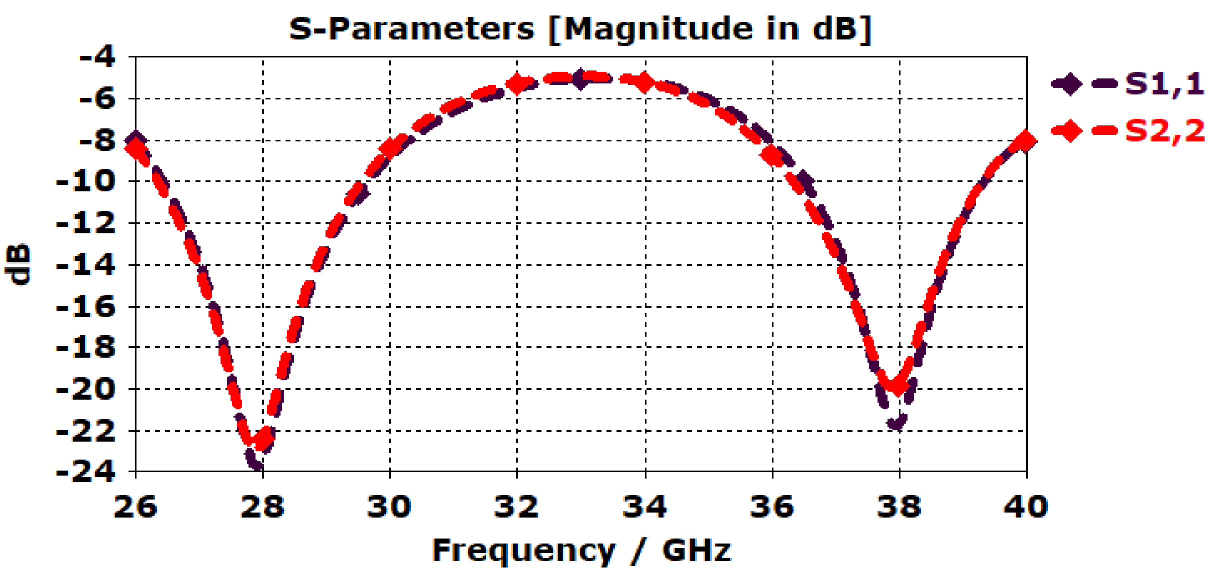


(d) (e) (f)

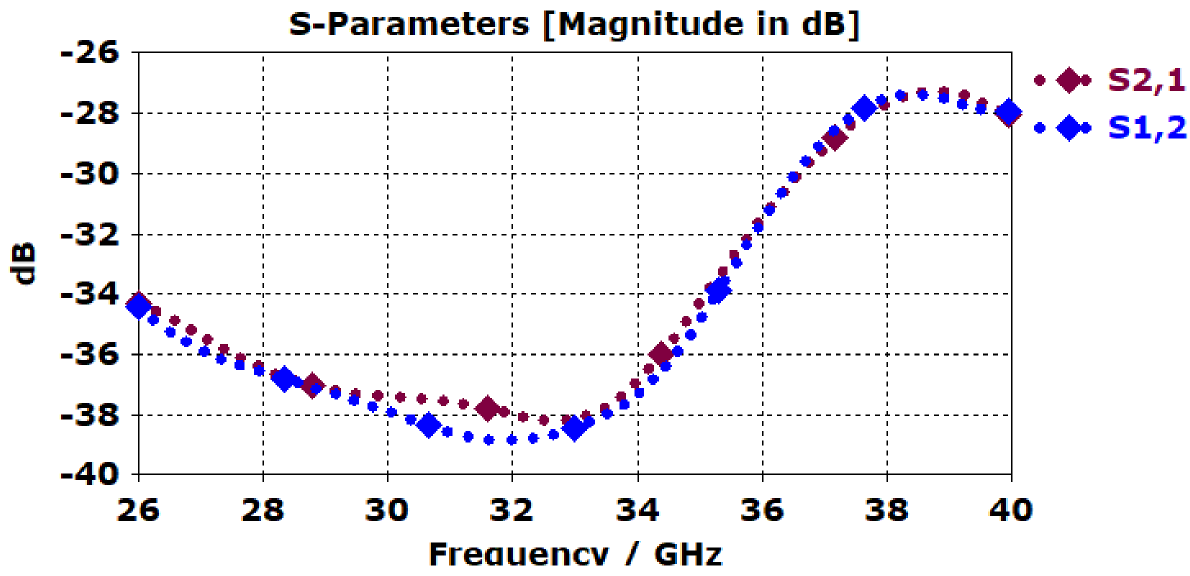
Fig 1. The proposed MIMO antenna development stages: (a) Patch antenna, (b) Patch antenna with slots, (c) Ground with slots, (d) Proposed MIMO Geometry, (e) Ground without slot for isolation, and (f) Ground with slot for isolation.

TABLE 1. The single and proposed MIMO antenna parameters and their values (unit: mm)

Parameter	**S_W**	**S_L**	**G_W**	**G_L**	**F_W**	**F_L**
Value(mm)	7	7	7	7	0.9	1.5
Parameter	**P_W**	**P_L**	**G**	**SL1**	**SW1**	**SW2**
Value(mm)	6.13	3	0.435	2.4	0.1	2
Parameter	**SL2**	**SW3**	**SL3**	**GS_{W1}**	**GS_{L1}**	**GS_{L2}**
Value(mm)	0.1	0.2	0.5	0.2	2	0.8
Parameter	**GS_{W3}**	**GS_{L4}**	**d**	**w1**	**L1**	
Value(mm)	0.4	1.1	1	6	0.96	



(a)



(b)

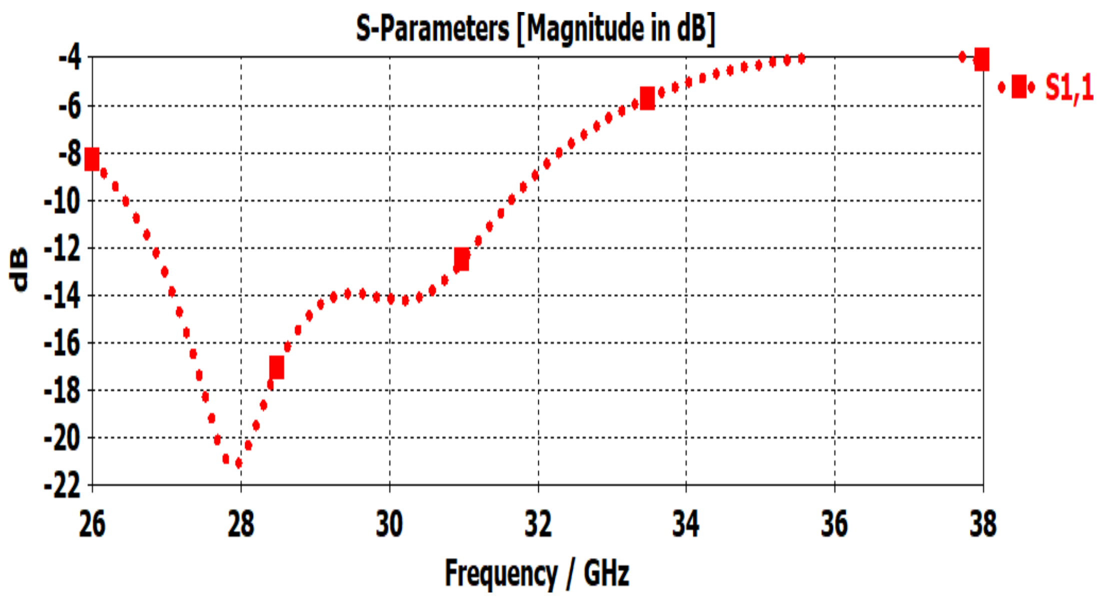
Fig 2. S-parameters of proposed MIMO Antenna (a) Return Loss and (b) Mutual Coupling

3. RESULTS AND DISCUSSIONS:

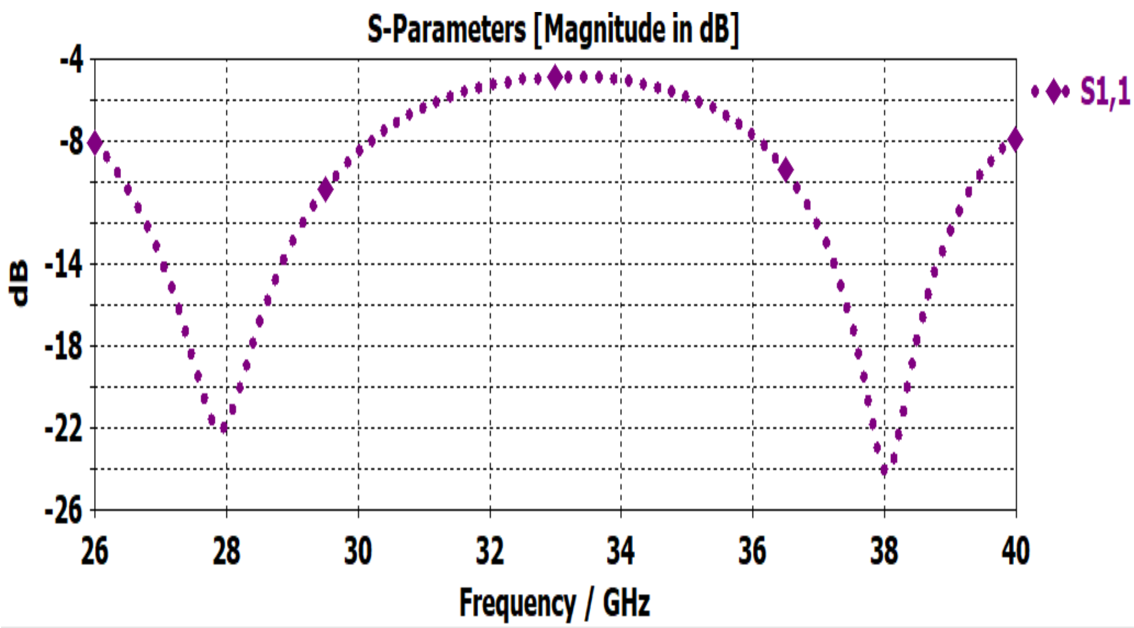
The MIMO antenna performance is analyzed using S- Parameters, Surface Current Distribution, Radiation Characteristics, and Diversity performance metrics.

A. S-Parameters

Figure 3 displays the S-parameters of simple patch antenna without and with slots. In Fig. 3(a) the simple patch antenna resonates at 28 GHz with return loss of -21dB. However, introducing slots in patch and ground creates an additional resonance at 38 GHz. In Fig. 3(b) the proposed design provides return loss of - 22dB at 28GHz and -24 dB at 38 GHz. This indicates that the presence of slots alters the electromagnetic behavior of the antenna, causing it to resonate at multiple frequencies.



(a)



(b)

Fig 3. S-parameters (a) without slots and (b) with slots

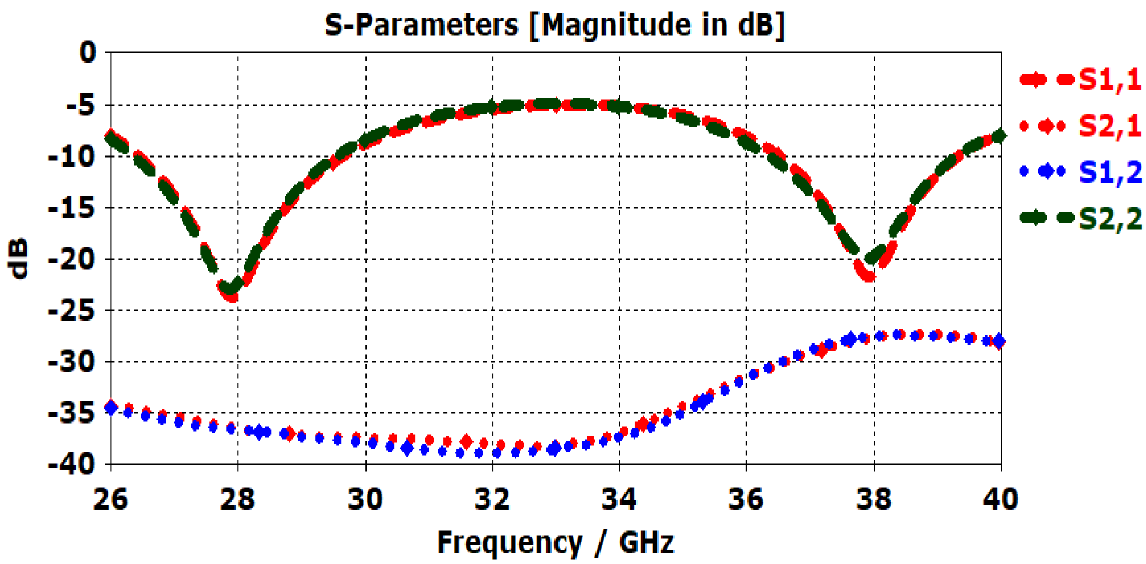
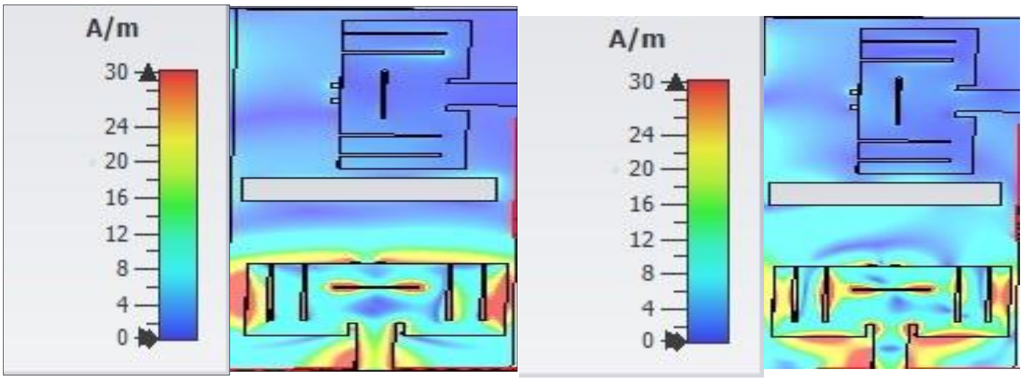


Fig 4. S-parameters of MIMO antenna.

Fig 4. Illustrates the S-parameters of proposed MIMO antenna. The design demonstrates return loss of -24 dB at 28 GHz and -20 dB at 38 GHz, along with isolation of >25 dB in both operating bands. Therefore, the antenna shown in Figure 1(d) is selected as the suggested MIMO antenna in this paper. The band at 28GHz frequency is considered as N257 band and that is named as LMDS band and another band at 38GHz frequency is considered as N260 band and it is named as Ka band. By placing slots in between antennas in the ground plane the isolation can be improved.

B. Surface Current Distribution

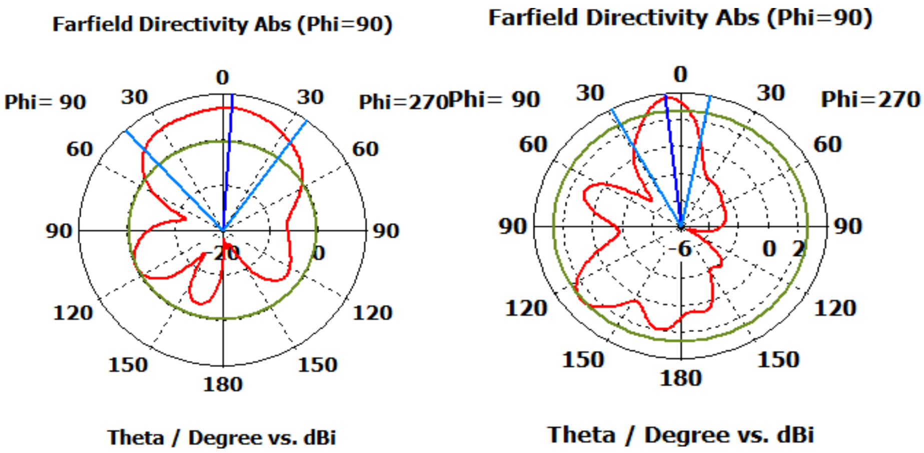


(a) **(b)**

Fig 5. Surface Current Distribution of port1 at (a) 28GHz and (b) 38GHz

From Fig 5. When port 1 is excited, the surface current flows only into port 1, while the slot terminates the flow of current into the second port. Vice versa, the same occurs for port 2, where the surface current flows exclusively into port 2, and the slot interrupts the flow of current into the first port.

C. 2-D Radiation Pattern



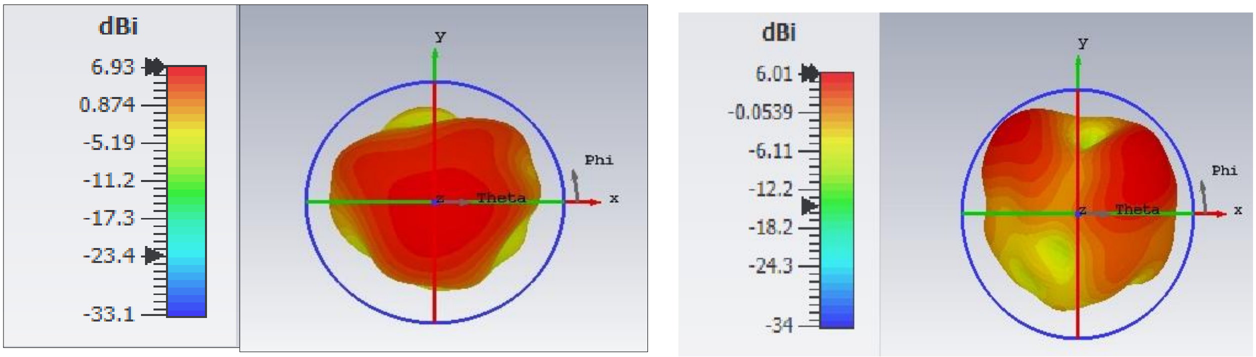
(a) **(b)**

Fig. 6 Radiation Pattern of port1 at (a) 28Hz and (b) 38GHz

The radiation performance of the presented MIMO antenna is demonstrated through the simulated 2D far- field radiation patterns, showcased in Fig 6. These patterns, representing the E-plane (XZ-plane) and Y- plane (YZ-plane) far-field radiation, are plotted at both 28 GHz and 38 GHz frequencies. At the resonant frequencies, the antenna demonstrates bi-directional E-plane (pi=0) radiation patterns and Omni directional H-plane (pi=0) radiation patterns.

D. 3D Polar Plot

To further validate the radiation characteristics, the 3D radiation patterns at these operating frequencies areshown in Fig 7.



(a) **(b)**

Fig. 7 3D Polar plot of port1at (a) 28GHz (b) 38GHz

E. Diversity Gain and ECC

This section presents the envelope correlation coefficient (ECC), diversity gain (DG). Fig 8. and Fig 9. illustrates ECC and DG results obtained from the proposed MIMO antenna. Across the entire resonant band, the antenna demonstrates an impressive ECC of less than 0.0005 and achieves a diversity gain of 10dB. These findings indicate that the antenna maintains excellent performance in terms of minimizing correlation between its multiple antenna elements and maximizing diversity gain, essential for robust and reliable wireless communication systems. ECC is among the important MIMO performance metrics associated with the correlation between two concurrently operating and closely positioned antenna elements.

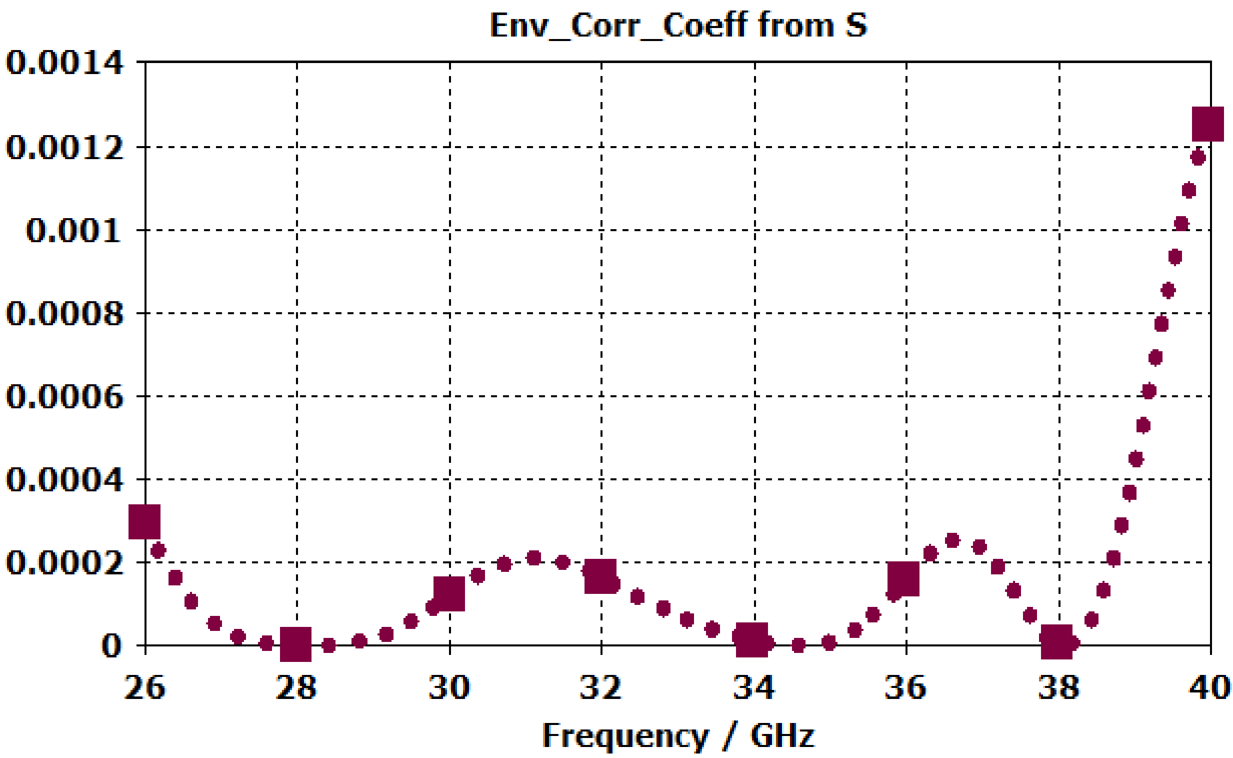


Fig 8. Envelop correlation coefficient for MIMO antenna

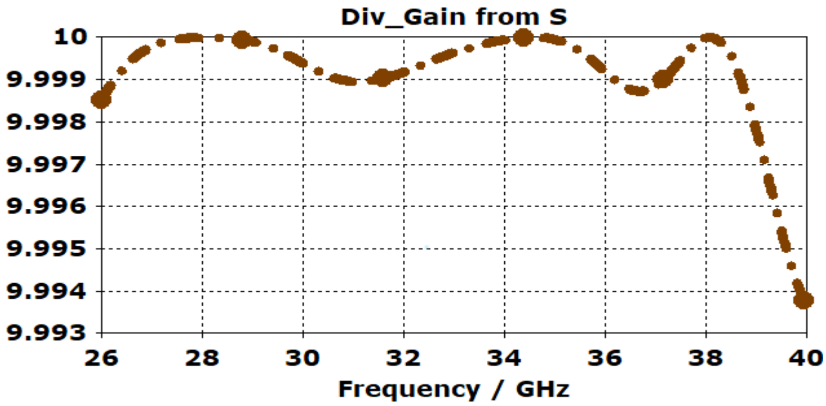


Fig. 9. Diversity Gain for MIMO antenna

F. Gain and Radiation Efficiency

Fig 10. illustrates the simulated gain of the MIMO antenna. The antenna has gains of 5 dB at 28 GHz and 3.3 dB at 38 GHz. Fig. 11 describe the radiationefficiency. The overall radiation efficiency is >75%.

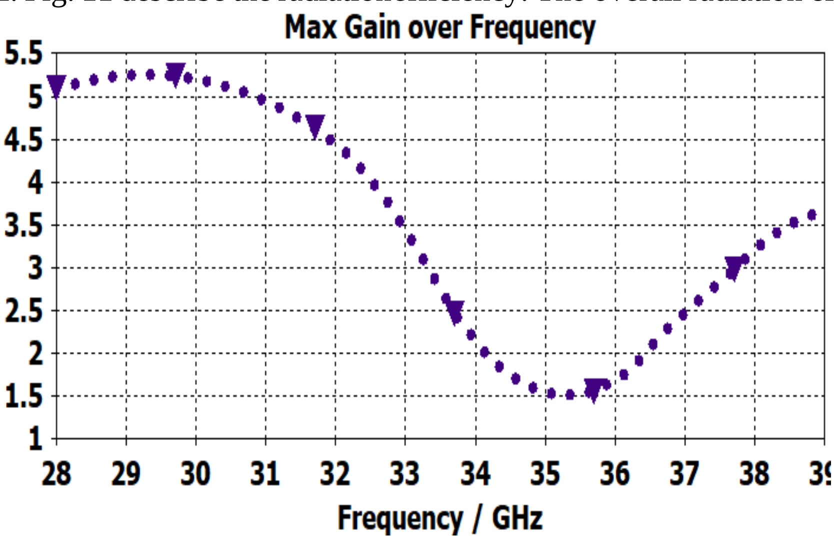


Fig. 10 The proposed antenna maximum gain

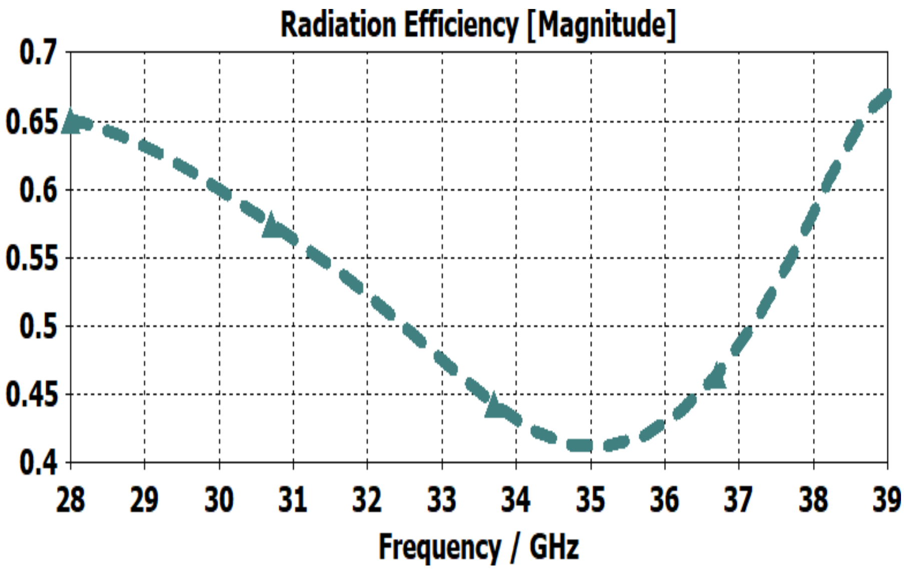


Fig 11. The proposed antenna radiation efficienc

CONCLUSION

A novel compact microstrip line feed two-port MIMO structure is developed for 28/38 5G mm-Wave wireless communications. The proposed antenna comprises two radiating elements with ground slots on the substrate's bottom side and rectangular slots on the top side. Rectangular slots are inserted between each MIMO antenna element to enhance isolation. The proposed two-element MIMO antenna operates at frequencies of 28 GHz and 38 GHz, achieving over 25 dB of isolation between the antenna elements. The antenna offers peak gains of 4.9 dBi at 28 GHz and 2.7 dBi at 38 GHz, with radiation efficiencies exceeding 75% within the operational bands. Furthermore, across the entire resonant range, the antenna maintains consistent patterns on the E and H planes, exhibiting an Envelope Correlation Coefficient (ECC) of less than 0.0005 and a Diversity Gain (DG) of 10 dB. These results unequivocally establish the proposed MIMO structure as a favorable choice for 28/38 GHz mm-Wave wireless communication.

REFERENCES

1. Babu, K. V., and B. Anuradha presented "Design of Multi-band Minkowski MIMO Antenna to Reduce the Mutual Coupling" in the Journal of King Saud University - Engineering Sciences in 2018.
2. Ashraf,N.,O.M. Haraz,M.M.M. Ali,M.A. Ashraf, andS.A.S. Alshebili, “ Optimized broadband and binary- band published niche antennas for unborn millimeter surge mobile communication, ” AEU#International Journal of Electronics and Dispatches,Vol. 70, 257 – 264, 2016.
3. Sulyman,A.I.,A.T. Nassar,M.K. Samimi,G.R. MacCartney,T.S. Rappaport, andA. Alsanie, “ Radio propagation path loss models for 5G cellular networks in the 28 GHz and 38 GHz millimeter#wave bands, ” IEEE Dispatches Magazine,Vol. 52, 78 – 86, 2014.
4. Ali,M.M.M. andA.-R. Sebak, “ Directive antennas for unborn 5G mobile wireless dispatches, ” General Assembly and Scientific Symposium of the International Union of Radio Science(URSI GASS), 1 – 4, 2017
5. Rafique Umair,K.H., “ Binary- band microstrip patch antenna array for 5G mobile dispatches, ” 2017 Progress In Electromagnetics Research Symposium — Fall(PIERS — FALL), 55 – 59, Singapore,Nov. 19 – 22, 2017.
6. M.J. Marcus, ‘‘ 5G and ‘ IMT for 2020 and beyond ’(diapason policy and nonsupervisory issues), ’’ IEEE WirelessCommun.,vol. 22,no. 4,pp. 2 – 3,Aug. 2015.
7. T.S. Rappaport etal., “ Millimeter surge mobile dispatches for 5G cellular It'll work!, ” IEEE Access,vol. 1,pp. 335 – 349, 2013.
8. Zhang,D. Wu,K.L. Yeung,L. Jiang, andR. Murch, ‘‘ Decoupling and matching network for binary-band MIMO antennas, ’’ IEEE Trans. AntennasPropag.,vol. 70,no. 3,pp. 1764 – 1775,Mar. 2022.
9. Yang,R.; Xi,S.; Cai,Q.; Chen,Z.; Wang,X.; Liu, G. A Compact Planar Dual- Band Multiple- Input and Multiple- Affair Antenna with High insulation for 5G and 4G operations. Micromachines 2021, 12, 544. doi10.3390/ mi12050544.
10. K. Raheel etal., “E-Shaped H- Slotted Binary Band mm- Wave Antenna for 5G Technology, ”Electron.,vol. 10,no. 9, 2021.
11. A.D. Tadesse et al, “ A Compact Planar Four- port MIMO Antenna for 28/38 GHz Millimeter-surge 5G operations, ” AEM,Vol. 11,No. 3, 2022.