UWB CPW FED 4-PORT CONNECTED GROUND MIMO ANTENNA FOR SUB-MILLIMETER-WAVE 5G APPLICATIONS

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ABSTRACT

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. 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 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 good isolation l6evels across the band of interest. The sub-mm-wave resonating 4- port antenna achieves a compact size of 24 X 24 mm^2, a wide bandwidth, the maximum gain and minimum efficiency across the bands of interest.

1. INTRODUCTION

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 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 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 unidirectional radiation patterns, the maximum gain of 8.6 dBi, minimum efficiency value of 85%, and 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 modeling. A precise milling machine is used for fabricating the single and 4-port antennas over a flexible FR-4 Substrate. Vector network analyzer (VNA) is used for measuring scattering and transmission coefficients. As well as, a shielded anechoic chamber is utilized 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

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 multi gigabit 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 millimeter wave 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. The most challenging task in the MIMO antennas is the isolation between the multiple antennas while achieving a connected ground structure [7–8]. Many techniques such as decoupling stubs [9], Defected Ground Structure (DGS) [10], Electronic Band Gap (EBG) [11–12], and Split Ring Resonator (SRR) [13] have been proposed that improve the isolation between antennas in MIMO applications. Another requirement of UWB technology is wide bandwidth which is not possible using regular patch antennas as they suffer from very narrow bandwidth. For implementing MIMO antennas with wide-bandwidth, different techniques are proposed like slotted micro strip-fed [14], 4 steeped lines incorporated modified rectangle along with the corners [15].

3. EXISTING SYSTEM

The antenna element presented in Figure 6.1 yields a peak gain of 6.84 dB and it operates in the. 37 GHz frequency band dedicated to 5G applications. The gain achieved is not enough to compete with the challenges that are possible at the mm-wave transmission. Thus, at the mobile level transmission, a minimum gain of 12 dB is usually preferred for satisfactory transmission. Therefore, there is a need to improve the gain of the single element; one of the simplest methods is the array technique, which utilizes multiple antenna elements in the form of an array to improve the gain, where the power is fed using a single feed.

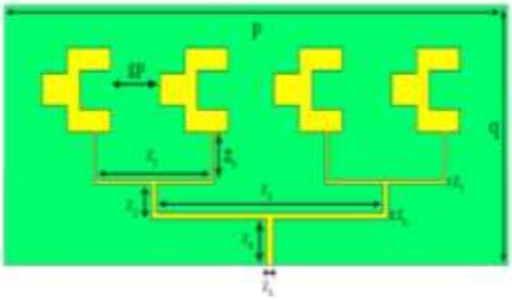


Fig 1. Structure of the four element array antenna of existing

The geometry of the 1 × 4 array is presented in Figure 2. In the array structure, a power divider is involved which is optimized so as to make sure of the same power delivery to each antenna element, in order to have good radiation characteristics. The spacing between the elements is maintained to be 1.9 mm, which is 0.25 of the wavelengths at 37 GHz, in order to avoid coupling among the antenna elements, which is the main issue in the case of array structures that is tackled quite carefully in the proposed design of the 1 × 4 array by maintaining a suitable spacing of 1.9 mm.

4. PROPOSED SYSTEM

The single element that is a part of a 4-port MIMO antenna is proposed. The single element antenna geometry comprises a modified CPW in the form of two circular structures that feed the centrally slotted circular patch. Followed by the analysis carried out on a single element antenna, the same is arranged in a rotational orthogonal manner with the separate ground as shown in Fig. 6.3. To achieve the spatial diversity performance, the minimum distance between MIMO elements is kept λ/ 2 for minimizing the mutual coupling effects. Moreover, the beauty of the proposed design is it avoids the limitations of the linear array in which the distance between array elements is to be selected based on the connector spacing. Four ports MIMO antenna structure has been simulated using HFSS software. It shows that excitation of the antenna at different operating frequencies leads to minimizing leakage current which is obvious due to spatial diversity and separate ground profile. To embed in a commonly printed circuit board (PCB) layout, it needs at least one common path between all the ground planes without affecting the performance of the individual elements.

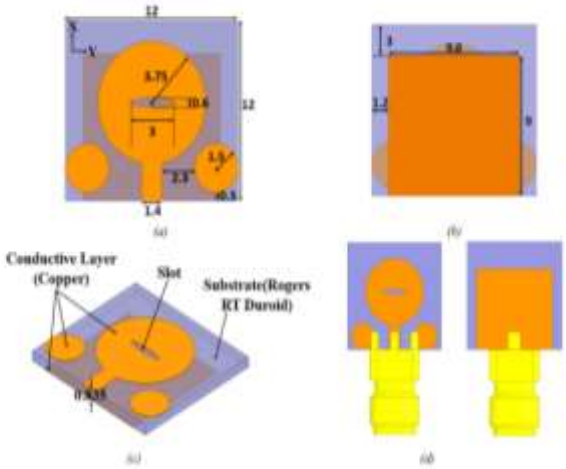
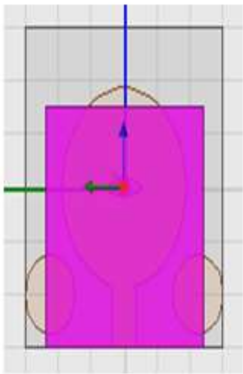
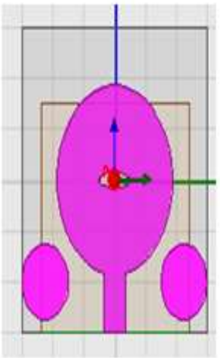


Fig 2. a) Top view (b) back view c) side view d) SMA connector position

To achieve a connected ground structure, a hollow circular ring having a radius of 3.75 mm and thickness of 0.25 mm touching the partial ground planes of all the 4 ports is added as shown in Fig. 7.4 show the top, bottom, and perspective view of a 2 X2 compact MIMO antenna. It is visible that even with the addition of a hollow circular ring that forms a connected ground structure, the coupling of current in the operating bandwidth is very low, which proves better isolation between elements.





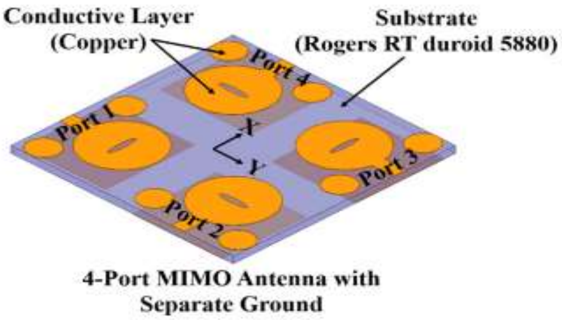


Fig.3. Four Element Antenna Geometry with separate ground

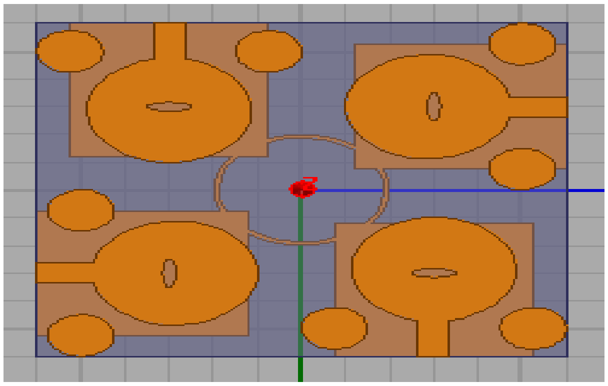
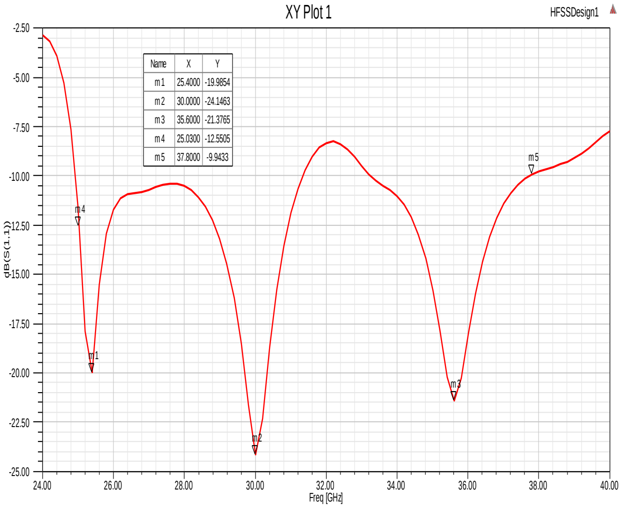


Fig 4. Four Element Antenna Geometry With common ground

5. RESULTS



Name	X	Y
m1	25.4000	-19.9854
m2	30.0000	-24.1463
m3	35.6000	-21.3765
m4	25.0300	-12.5505
m5	37.8000	-9.9433

Fig 5. Reflection coefficient of one Element Antenna

Furthermore, the effect of modified CPW feed is also carried out where reflection coefficient performance is checked by using both circles of single element. Maximum of S11 24.45 dB occurs at 30GHz is shown in fig 5. The VSWR of single element antenna was shown in fig 6. Entire band maintain <2.

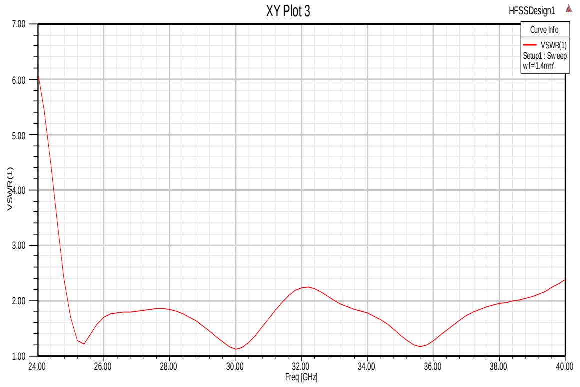
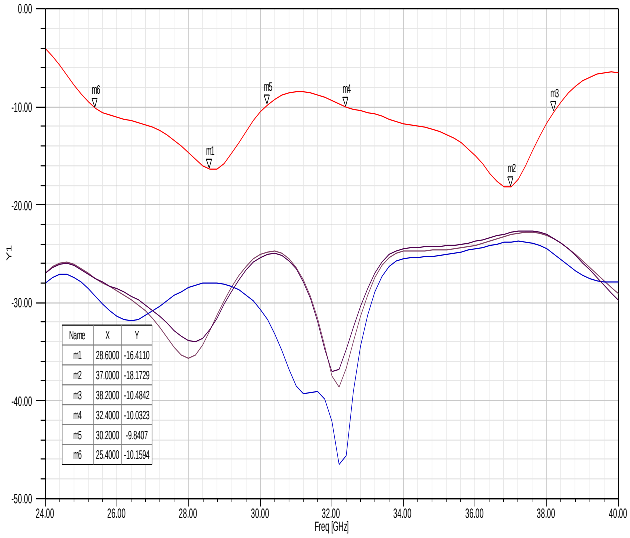


Fig 6. VSWR of one Element Antenna

To achieve the spatial diversity performance, the minimum distance between MIMO elements is kept λ/2 for minimizing the mutual coupling effects. Moreover, the beauty of the proposed design is it avoids the limitations of the linear array in which the distance between array elements is to be selected based on the connector spacing. Four ports MIMO antenna structure has been simulated using HFSS software. The surface current distributions over different frequencies (26 GHz, 30 GHz, 32 GHz, 36 GHz, and 40 GHz) are analyzed by exciting single port while keeping the other ports terminated with 50Ω load shown in Fig. 7 It shows that excitation of the antenna at different operating frequencies leads to minimizing leakage current which is obvious due to spatial diversity and separate ground profile. Moreover, the minimum coupled current from one antenna to another antenna can also be justified using scattering parameters which are shown in Fig.5 where it is visible that the isolation between the ports is better than 20 dB. Although the performance of the antenna shown in Fig. 5 gives very good results however the separate ground profile brings limitations for its practical usage. However, to embed in a commonly printed circuit board (PCB) layout, it needs at least one common path between all the ground planes without affecting the performance of the individual elements.



Name	X	Y
m1	28.6000	-16.4110
m2	37.0000	-18.1729
m3	38.2000	-10.4842
m4	32.4000	-10.0323
m5	30.2000	-9.8407
m6	25.4000	-10.1594

Fig7. S11, S12, S13, S14 of four Element Antenna with separated ground

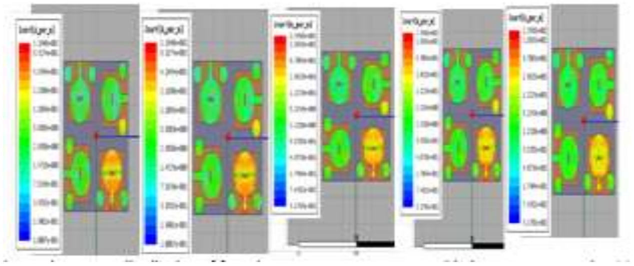
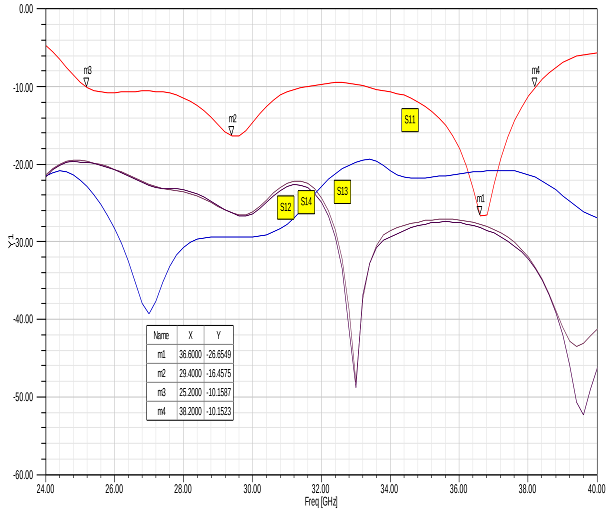


Fig 8.The current distribution of four elements antenna geometry with the separate ground at (a) 26 GHz (b) 30 GHz (c) 32 GHz (d) 36 GHz and (e) 40 GHz.



Name	X	Y
m1	36.6000	-26.6549
m2	29.4000	-16.4575
m3	25.2000	-10.1587
m4	38.2000	-10.1523

Fig 9. S11, S12, S13, S14 of four Element Antenna with common ground

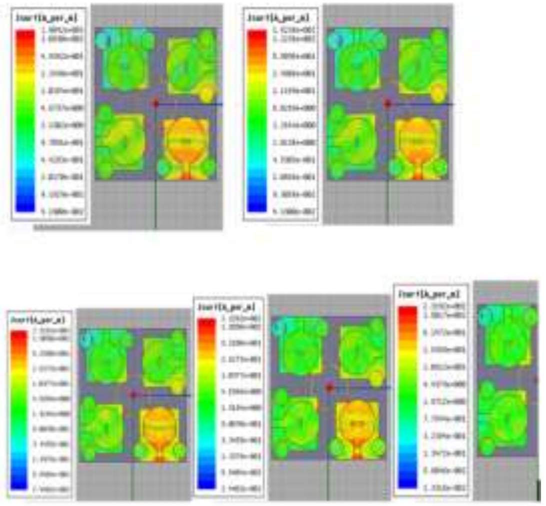


Fig 10. The current distribution of four elements antenna geometry with the same ground at (a) 26 GHz (b) 30 GHz (c) 32 GHz (d) 36 GHz and (e) 40 GHz

To Fig.6 Effect on reflection coefficient by varying central circle radius. Fig.7 Effect on reflection coefficient by varying ground (a) length (b) width. Achieve a connected ground structure, a hollow circular ring having a radius of 3.75 mm and thickness of 0.25 mm touching the partial ground planes of all the 4 ports is added as shown in Fig.10 show the top, bottom, and perspective view of a 2X 2 compact MIMO antenna.

The simulated and measured 2D co/cross-pol radiation pattern of the MIMO antenna is illustrated in Fig 11 concerning different operating frequencies.

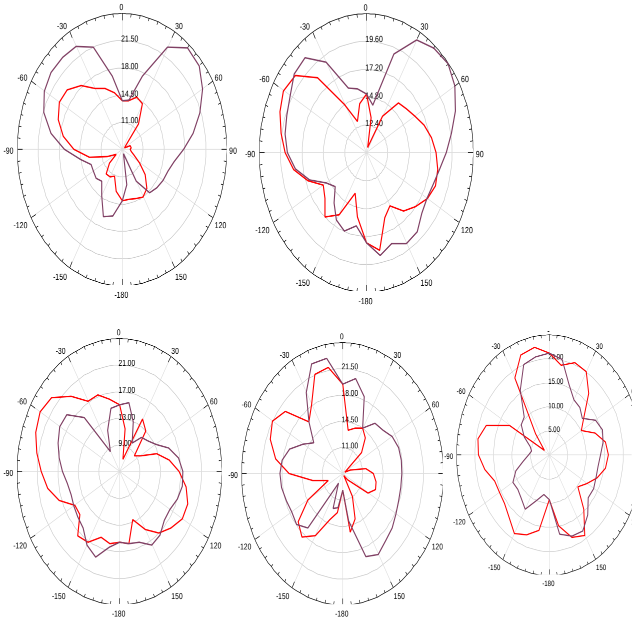


Fig 11. The Radiation pattern of four elements antenna geometry with the same ground at (a) 26 GHz (b) 30 GHz (c) 32 GHz (d) 36 GHz and (e) 40 GHz

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

A compact (24 X 24 mm^2) MIMO antenna with a connected ground structure has been proposed for mm-wave 5G systems. Design techniques, optimization based on performance parameters, fabrication of the proposed antenna, and MIMO diversity analysis have been thoroughly covered in the article. To achieve high bandwidth, the elliptical slot plays a vital role in the design. 2x2 connected ground MIMO array antennas give approximately 79.35% (24.8 GHz to 44.45 GHz) bandwidth, isolation between the array elements is better than 20 dB, unidirectional radiation patterns, ECC value < 0.008, DG > 9.5 dB, average gain and efficiency > 5.68 dBi and 85%, respectively proves the adequate performance of the proposed antenna for the 5G MIMO applications

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