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A Compact Two Element Orthogonal MIMO Antenna for Millimeter Wave Applications

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Abstract— ***A novel compact orthogonal Multiple- Input-Multiple- Output (MIMO) antenna is proposed for milli-meter wave based wireless communications. It operates with an impedance-bandwidth of 17.7GHz from 24.4- 42.1GHz for S_{11}< -10dB. The isolation between two orthogonal MIMO elements is greater than 45dB. The anticipated orthogonal MIMO antenna model is analyzed at significant frequencies 26GHz, 28GHz, 30GHz and 33GHz. At these frequencies, results are investigated for far-field radiation characteristics, current densities with port isolation, DG (Diversity Gain) and ECC (Envelop Correlation Coefficient). Investigated results signify that the projected orthogonal MIMO antenna is appropriate for milli-meter wave based wireless applications.***

Index Terms— ***Current densities, Diversity gain, ECC, Millimeter wave communications, Orthogonal MIMO antenna, Mutual coupling, Port isolation.***

I. INTRODUCTION

Millimeter waves can realize the demands of a well-organized and flawless 5G communications [1]. FCC (Federal Communications Commission) has proposed 28GHz and 38GHz bands for 5G principles and Ofcom (Office of Communications) developed 26GHz test-beds for 5G applications [2]. Ka band has lower absorptions, reduced signal fading and lesser path loss [3, 4]. Hence, Ka band is highly recommendable in millimeter bandwidth. High bandwidth antenna is required, which can support multiple standards for 5G have been aggravated by these variants. 5G antennas are desired to be compact and low profile for better performance. Many authors had proposed various MIMO antenna structures and their conformabilities suitable for milli-meter wave based wireless applications ranging from 20GHz to 40GHz in [5-11]. Their respective operating bands, gain and other performance characteristics are described in these papers. An offset fed single element defected ground structure (DGS) antenna is proposed in [12]. It operates from 24.3GHz to 41.95GHz with an extensive bandwidth of 17.65 GHz. In this research article, MIMO-antenna model with two orthogonal elements is projected for antenna model proposed in [12]. As the elements are placed orthogonal to each other, proposed MIMO antenna has better polarization diversity and isolation between the two ports. Section-II describes the proposed orthogonal MIMO antenna and its design specifications. Section-III presents simulated results; S-parameters, current densities, 3D gain plots, far field radiation characteristics and radiation efficiency characteristics, MIMO performance parameters; ECC and DG characteristics. Section-IV gives the conclusion of the paper.

II. DESIGN SPECIFICATIONS OF PROPOSED ORTHOGONAL MIMO-ANTENNA

Fig.1 reveals the geometrical structure of anticipated MIMO-antenna model with orthogonal elements. Single element antenna model contains a staircase structured offset fed micro-strip line integrated with J-shaped balun structure as the top layer of substrate. The bottom layer is a printed dipole-antenna as DGS on the ground plane. Two MIMO elements M1 and M2 are placed in orthogonal to attain polarization diversity and fine separation among the elements. The designed model is simulated in ANSYS HFSS EM simulator tool. The substrate thickness is 0.25mm (dielectric constant = 2.9, and tan δ = 0.002. Geometrical requirements regarding the design of orthogonal MIMO-antenna model are given in Table 1.

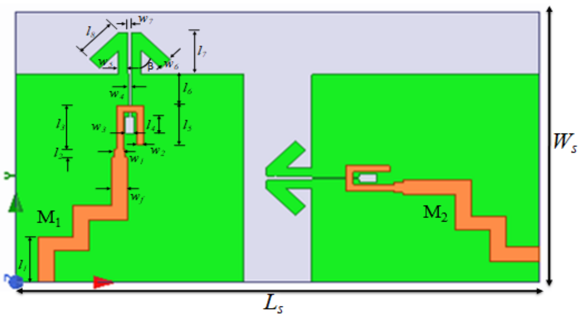

Fig.1. Proposed MIMO-antenna model with orthogonal elements

Table 1 Geometrical specifications of proposed orthogonal MIMO antenna

Parameter	Size(mm)	Parameter	Size(mm)
L_s	23	W_s	13
l_1	1.5	w_f	0.68
l_2	0.4	w_1	0.5
l_3	2.1	w_2	0.3
l_4	0.8	w_3	0.4
l_5	1.9	w_4	0.1
l_6	1.2	w_5	0.4
l_7	2	w_6	0.5
l_8	1.8	w_7	0.2

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III. DISCUSSIONS ON RESULTS

A. S-parameters

Simulated S11 and S12 S-parameter characteristics in dB are illustrated in Fig.2. An impedance bandwidth of 17.7GHz from 24.4 - 42.1GHz is achieved for S11 < -10dB. The minimum value of S11 is -44dB at 26 GHz. The values of S11 at 28, 30 and 33 GHz are -21.2dB, -22.6dB and -15.7dB respectively. Isolation between the two elements in the entire operating band is observed to be more than 45dB from S12 characteristics. Hence, the isolation between the elements is good. Due to symmetrical structure of two elements, port-2 S-parameters: S22, S21 Vs frequency characteristics (not shown) are alike as that of port-1 S-parameters: S11, S12 characteristics.

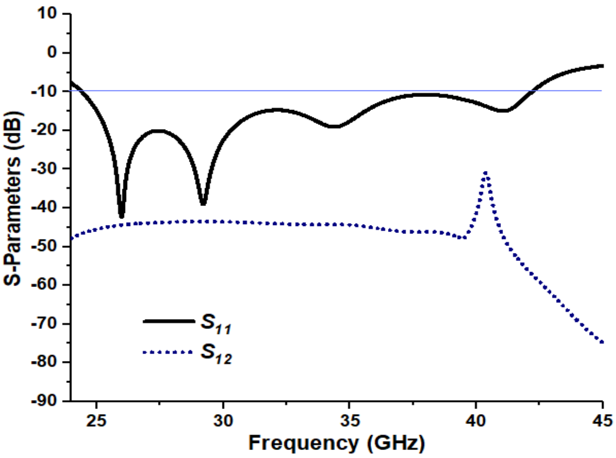


Fig.2. S-parameter characteristics of proposed orthogonal MIMO antenna

B. Distributed Surface Current Densities

Distributed surface current densities of the anticipated orthogonal MIMO antenna are investigated for 26, 28, 30 and 33 GHz frequencies and are illustrated in Fig.3. The current density distributions are scaled to 150A/m for all investigation frequencies. Fig.3(a) (i) and (ii) represent the current distribution at 26GHz for port:1 and port:2 excitations. It can be clearly analyzed that when port:1 is in excitation, port:2 remains cut-off and similarly when port:2 is in excitation, port:1 remains cut-off. Therefore, mutual coupling among the two orthogonal elements is very low. Similar phenomenon is observed for 28, 30 and 33 GHz frequencies as exposed in the Fig.3 (b), (c) and (d).

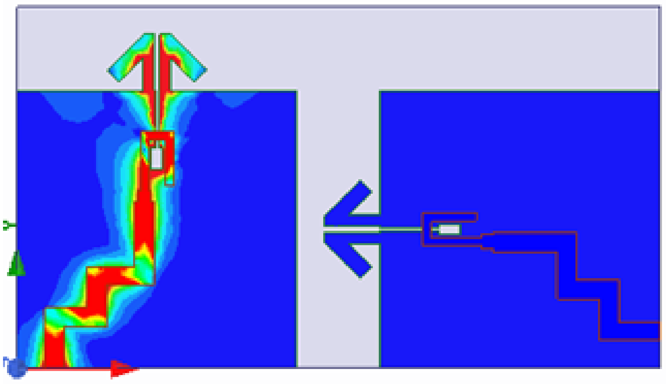
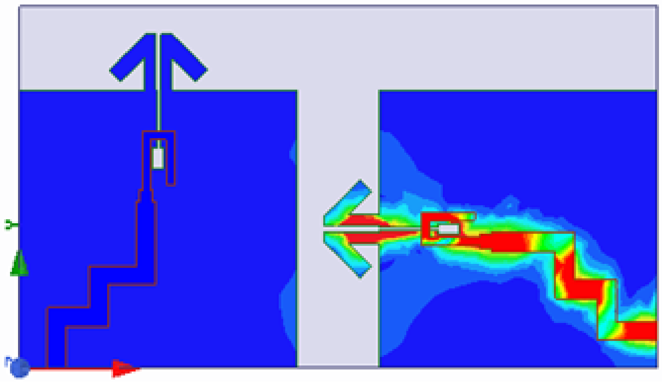


Fig.3(a) (i) Port1 excited and port2 isolated



(ii) Port2 excited and port1 isolated

Fig.3 (a) Surface current density at 26GHz

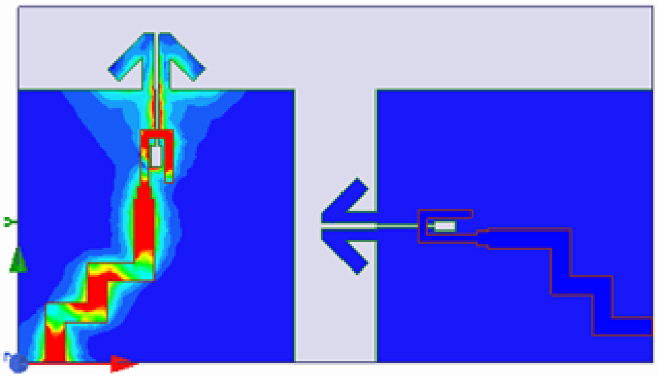


Fig.3 (b) Surface current density at 28GHz

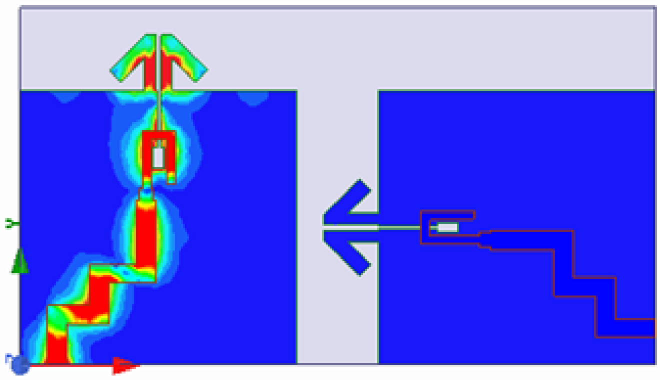


Fig.3 (c) Surface current density at 30GHz

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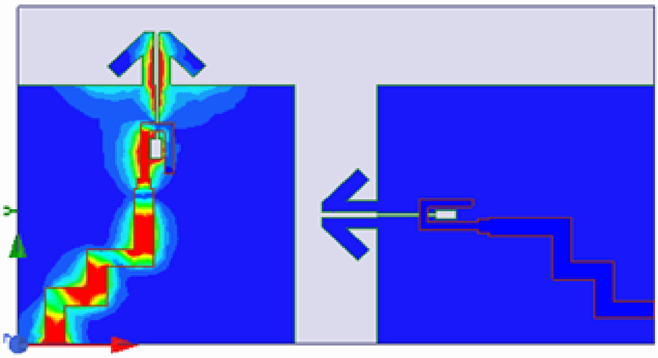
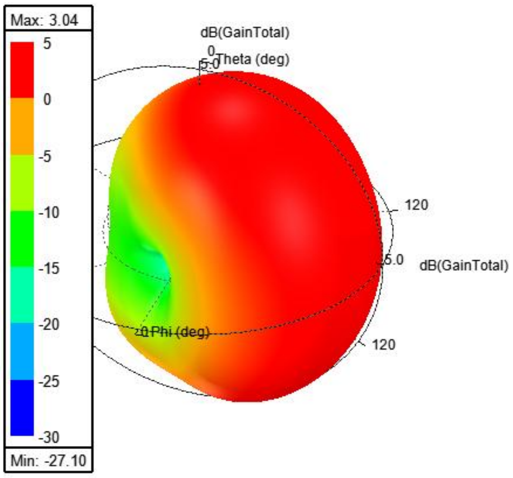


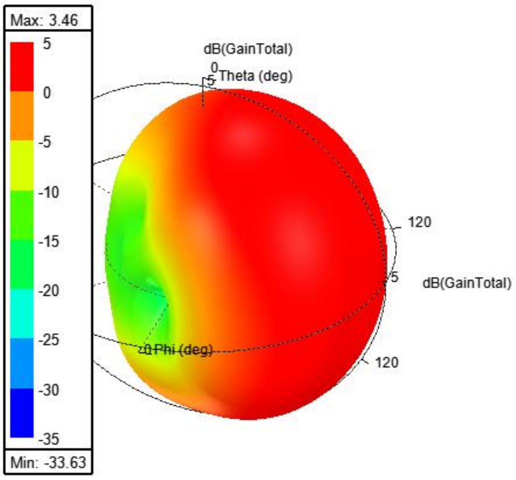
Fig.3 (d) Surface current density at 33GHz

C. Far-Field Characteristics

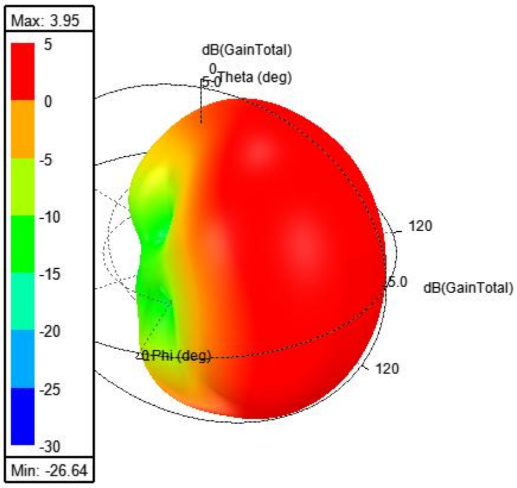
Fig.4 illustrates 3D-gain patterns of the projected orthogonal MIMO-antenna model at resonant frequencies 26GHz, 28GHz, 30GHz and 33GHz.



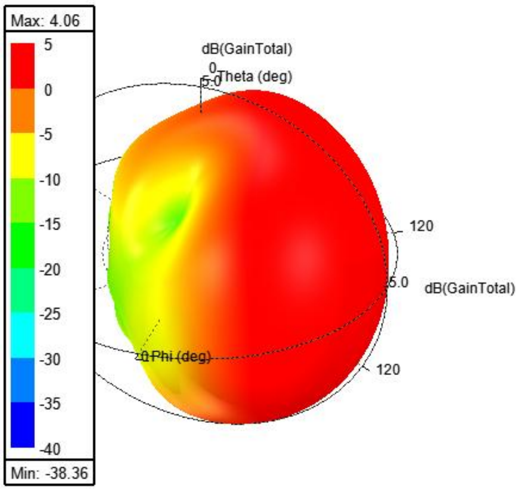
(a) 26GHz



(b) 28GHz

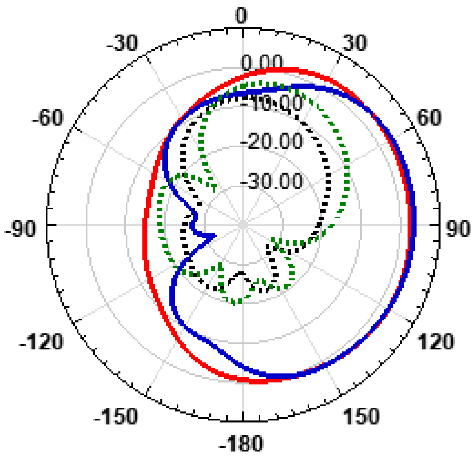


(c) 30GHz



(d) 33GHz

Fig.4 3D-gain patterns of anticipated orthogonal MIMO-antenna model



(i) yz- plane

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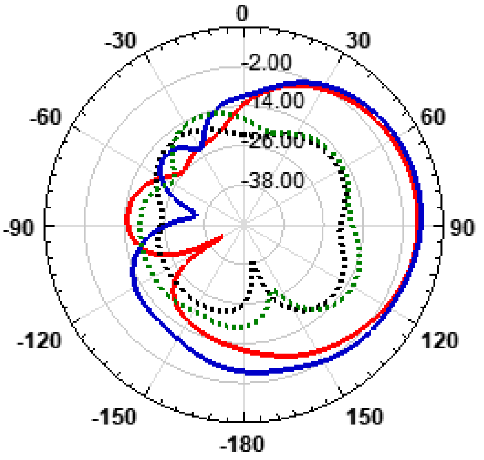
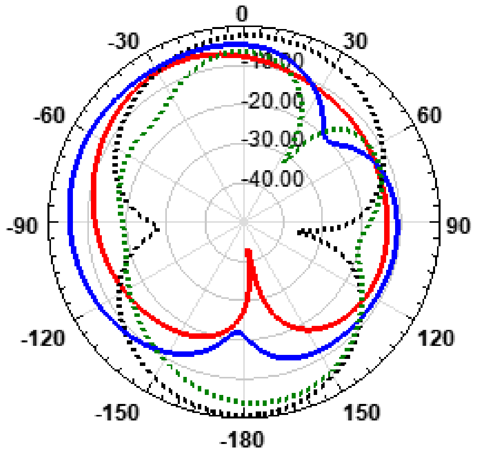


(ii) xy- plane

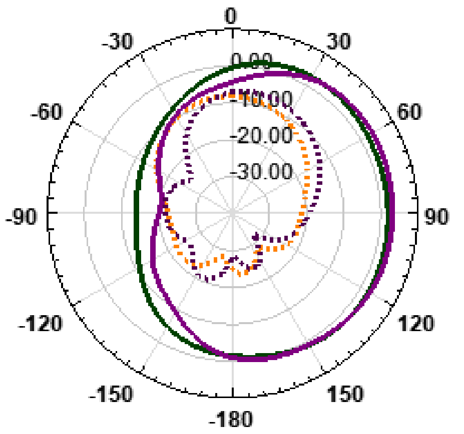


(iii) xz- plane

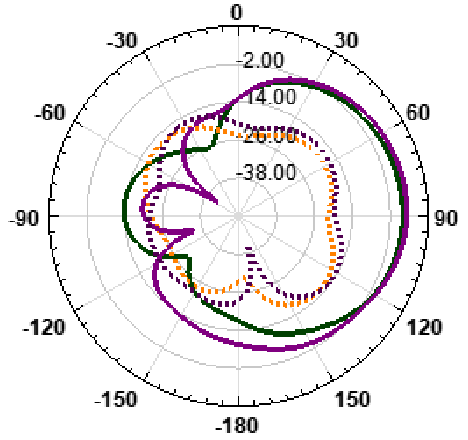
Gain-phi (dB) at 28GHz   Gain-theta (dB) at 28GHz

Gain-phi (dB) at 33GHz   Gain-theta (dB) at 33GHz

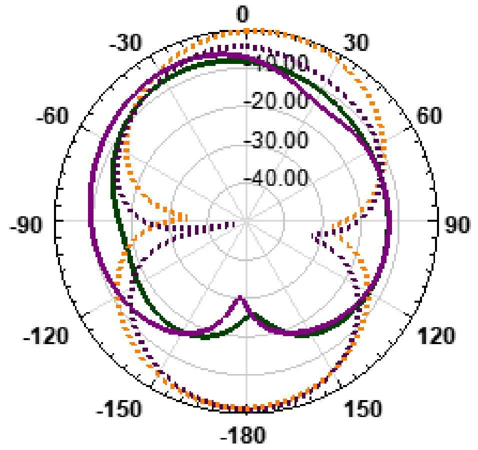
Fig.5(a) Radiation patterns of anticipated orthogonal MIMO-antenna model



(i) yz- plane



(ii) xy- plane



(iii) xz- plane

Gain-phi(dB) at 26GHz   Gain-theta(dB) at 26GHz

Gain-phi(dB) at 30GHz   Gain-theta(dB) at 30GHz

Fig.5(b) Radiation patterns of anticipated orthogonal MIMO-antenna model

Fig.5(a), (b) signify simulated 2D radiation characteristics of projected orthogonal MIMO-antenna model in xy, yz and xz-planes for different center frequencies. The projected MIMO-antenna model is designed in xy plane i.e. phi-plane, gain phi becomes co-polarization and gain theta becomes cross-polarization. Co and cross polarizations at 28 and 33 GHz are presented in Fig.5(a), while Fig.5(b) represents co and cross polarizations at 26 and 30 GHz. Antenna radiation planes are xy and yz planes. It can be clearly observed that minimum levels are maintained between co and cross polarizations at the specified frequencies.

Fig.6 describes the simulated radiation efficiency and gain(dB) characteristics. Gain values achieved at 26, 28, 30 and 33GHz are 3dB, 3.4dB, 3.7dB and 3.8dB respectively. In the operating band, peak gain is observed at 33 GHz. The simulated radiation efficiencies at 26, 28, 30 and 33 GHz are 99%, 98.7%, 98.5% and 98.4%. Printed dipole antennas are familiar for their elevated efficiencies. In practical, the overall efficiency may not be such high efficiency due to losses.

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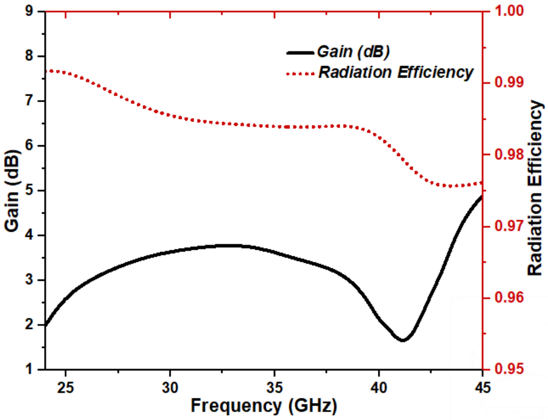

Fig.6 Radiation efficiency and gain (dB) characteristics of anticipated orthogonal MIMO-antenna

D. ECC and DG

ECC and DG are considered as MIMO antenna performance parameters. The correlation coefficient should be as minimum as possible and diversity gain should be close to 10 for better performance of MIMO antennas. Fig.7 illustrates ECC and DG plots of anticipated orthogonal MIMO-antenna model. It is viewed that DG is very close to 10 and ECC is not greater than 0.032 in the whole operative band.

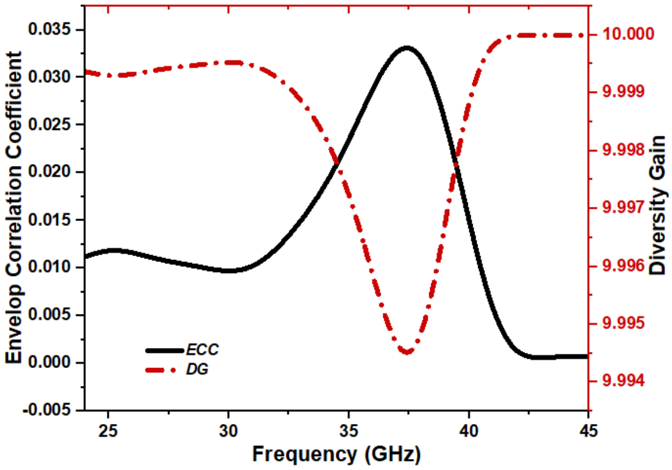

Fig.7 DG and ECC characteristics of anticipated orthogonal MIMO-antenna

IV CONCLUSION

A compacted 23 x 13 x 0.25mm3 MIMO-antenna with orthogonal elements is proposed for millimeter wave based wireless communications. The simulated outcomes of proposed MIMO antenna for 26GHz, 28GHz, 30GHz and 33GHz are investigated. The results; impedance-bandwidth, isolation among the elements, distributed surface current densities, far-field characteristics, ECC and DG of recommended orthogonal MIMO antenna are analyzed. A large impedance-bandwidth of 17.7GHz is acquired. Coupling among the two orthogonal elements of MIMO-antenna model is not greater than -45dB. ECC is as reasonable as 0.032 and DG is very nearer to 10. These analyzed results propose that the projected orthogonal MIMO-antenna is well applicable for milli-meter wave based wireless communications.

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