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REGULAR ARTICLE

A Lower 6GHz MIMO Antenna with EBG Structure in 5G Applications

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In modern wireless communication, the enhancement of 5G wireless applications vigorously increases the growth for gaining in MIMO (Multiple Input Multiple Output) technologies. In the conventional method, the MIMO antenna is not efficient by having 5GHz with a resulting 75 % and the interference is difficult to exclude. The proposed MIMO antenna design is modeled by four truncated circular patches of radius 9.35 mm at the top layer with a dual partial ground of 10 mm × 60 mm at the bottom to provide better performance. The FR-4 epoxy substrate is counted with the dimensions of 70 mm × 60 mm × 1.6 mm. An impedance bandwidth ranging from 1.7 GHz to 12.4 GHz with 10 dB return loss and isolation of 15 dB is observed for all four planar antennas. The defective ground sketch in the planar plane is functioned by several slots, metamaterials, etc. achieved by the band-notch. The proposed system is obtained to improvise the performance by HFSS simulated results for operating frequency by MIMO antenna as 1.7 GHz to 12.4 GHz. It provides the directivity as 4.6 with a relative permittivity of 4.4 and isolation as 15 dB. Further, the gain of 5.7 dB with an efficiency of 87.95 % has been achieved by the insertion of the Electromagnetic Band Gap (EBG) structure between the two partial ground planes at the bottom. Hence the proposed EBG is proven better than the conventional method SISO antenna in all performance aspects through the MIMO antenna in 5G applications.

Keywords: Multiple Input and Multiple Output(MIMO), Fifth Generation (5G), Electromagnetic Band Gap (EBG), HFSS, WC.

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1. INTRODUCTION

Multiple-input multiple-output (MIMO) technology is derived from wireless transmission diversity of antennas as well as smart antenna technologies. It is a hybrid of multiple-input single-output (MISO) along with single-input multiple-output (SIMO). The MIMO system has several antennas at both the point of transmission and reception device. It has the potential to significantly increase wireless transmission reliability and data throughput without boosting bandwidth or transmitted energy. MIMO technology is utilized at both the ends of the transmitter and receiver to enhance the channel capacity and variability in communication over wireless networks, as well as to increase data transfer capacity.

The primary disadvantage of MIMO technology is the fading of multiple paths and the possibility of mutual interference. Phenomena that include multiple paths, small-scale fading, and interference between channels can be mitigated by making appropriate design changes. Additionally, the system's capacity may be considerably boosted by employing numerous antennas. However, because of the short distance between antenna components in smaller devices, mutual coupling may grow increasingly severe.

A Pacman-sshaped antenna is designed to operate at 2.9-15 GHz with MIMO configurations [1, 2, 8]. A UWB MIMO antenna is comprised involving two similar monopole antenna components that include a comb-line layout on a horizontal plane and a Super compact planar antenna to improve impedance matching and enhance isolation. A Super compact planar antenna that operates at 28 GHz for future 5G mobile communication is proposed with less complexity due its single-layer composition [3-4]. The suggested multibaryonic H-shaped combined microstrip antenna may operate on 2.5, 8.2, and 34 GHz for Wi-Fi, WiMAX, as well as 5G applications [5]. A unique very small 2 × 2 planar MIMO antenna functioning system bands varying from 2 GHz to 12 GHz, with mutual coupling among both components less than – 20 dB across the transmission bandwidth [6-10].

A revised circular ring formed shape slot antenna, integrating the circular ring-shaped slot along with the U-formed slot far-field characteristics of the suggested radiator, is reliable for the transnational network for cellular (GSM) (1.8 GHz) as well as interoperability across the globe for Access to Microwaves (WiMAX) (3.7 GHz) applications [11-13]. Two tapered square monopoles placed parallel and vertically on the surface of the

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ground plane are intended to increase isolation when the slot is located on the ground plane, reducing the mutual connection between a pair of radiators. Three stubs are inserted to increase spatial variety [14-16]. An innovative miniaturized drifted slot-line-depend on quad-band multiple-input-multiple-output (MIMO) antenna system employs drifted slot-line as well as responding active loading miniaturization approaches to manage the antenna in sub-1 GHz bands alongside a lightweight design that corresponds to its smallest functioning band. The antenna's tiny size of 18 × 22 × 1 mm^3 allows for antenna system miniaturization [12].

2. DESIGN SPECIFICATIONS OF FOUR-ELEMENT MIMO WITHOUT EBG STRUCTURE

MIMO (four) annular patch antennas of radius 9.35 mm with its dual partial ground of 10 mm × 60 mm designed in the dielectric substrate whose dimension is 70 mm × 60 mm × 1.6 mm, which is given below in Fig. 8. This proposed two-band rejection with the microstrip-fed antenna is passed by etching U straight-shaped slots. The defective ground and the slots in the patch helped to achieve the desired band. In addition, the Electromagnetic Bandgap structures between the elements of the antenna are used to increase the isolation among them. This MIMO design can reject interference from the two Centre frequencies between 3.5 GHz to 5.5 GHz such as (i) Worldwide Interoperability for Microwave Access (Wi-Max) (ii) Wireless Local Area Network (WLAN).

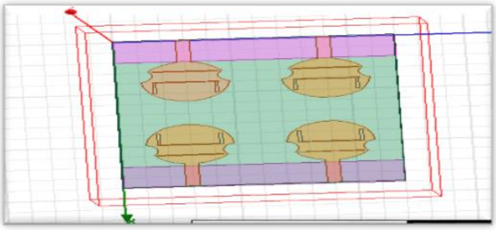
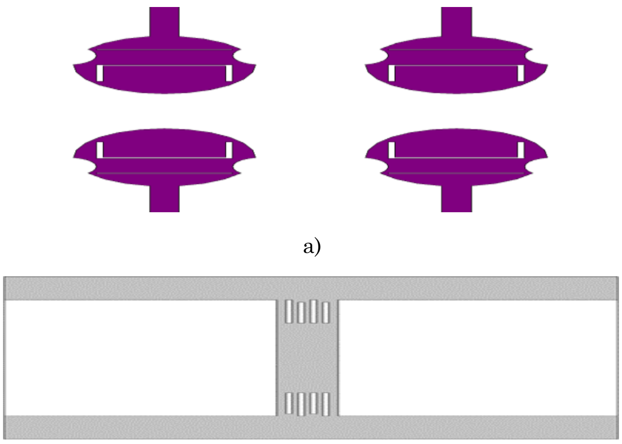


Fig. 1 – MIMO Antenna



a)

b)

Fig. 2 – (a) Top view of four element MIMO antenna, (b) Bottom view of four-element MIMO antenna

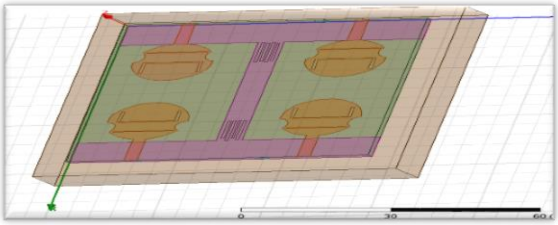


Fig. 3 – Proposed MIMO antenna with EBG structure

The placement of the antenna is optimized to obtain the current distribution and isolation as needed and the top view, bottom view, and the proposed EBG MIMO antenna are given in Figures 1 and 2.

3. ANTENNA PARAMETERS

The various antenna parameters for the above-simulated antenna design are tabulated below in Table 1 for MIMO with band-notch. These are the dimensions of the designed antenna model using HFSS 13.0 for the frequency range of the lower 5G band or Sub 6 GHz.

3.1 Return Loss(S11) and Gain

A compact micro strip-fed antenna with two-band rejection is proposed. The proposed antenna operates from 1.7 GHz to 12.4 GHz and the simulated results are depicted from Figure 3 and Figure 4. The gain of 5.78 dB was achieved for MIMO with slots of two band rejections as given in Figure 5.

Table 1 – Tabulation for parameters of MIMO with band-notch

Parameters	Value
Gain	0.36dB
Efficiency	96.49%
Band coverage	1.7GHz to12.4GHz

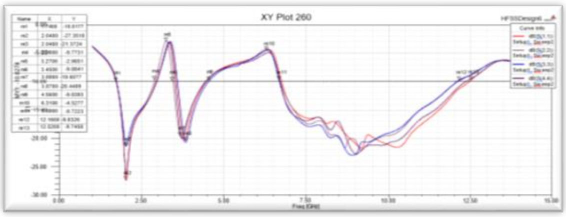


Fig. 4 – Return loss of the MIMO antenna at all ports

Fig. 5 – 3D gain for the final MIMO antenna design

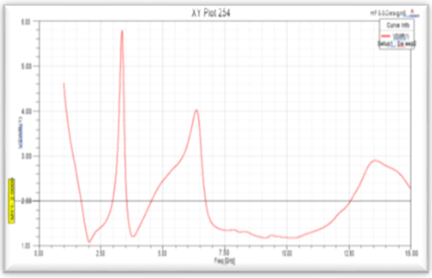


Fig. 6 – Frequency vs VSWR

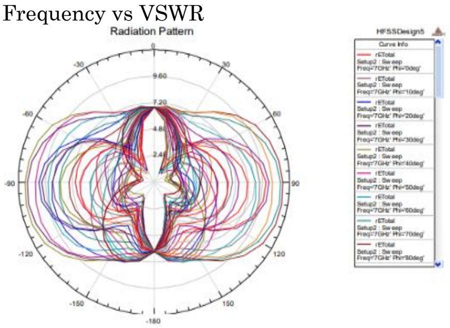


Figure 7 Radiation pattern of the designed antenna for all phi values

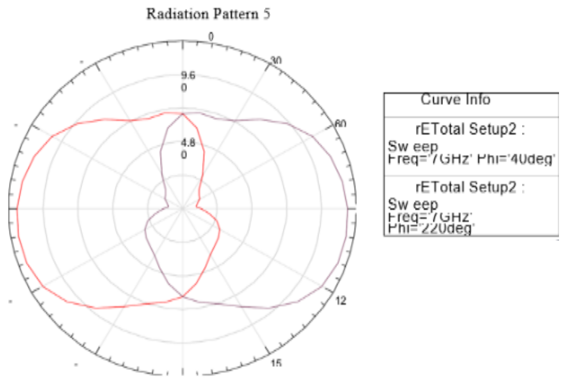


Fig. 8 – Radiation pattern of the designed antenna for the phi = 40 and phi = 220

Perfect reflection is observed in all the antennas at a particular radiating point. The simulated results are shown for radiation pattern, parameters from figure 7 to figure 8. The following figure illustrates the voltage standing wave ratio (VSWR) for the MIMO configuration as in figure 6.

3.2 MIMO Results (Directivity and Isolation)

The other antenna's surface current density does not significantly alter when either antenna-1 or antenna-2 is excited while the other elements remain unexcited, as can be observed in every instance. This indicates that the radiating qualities of any one element are free from the impact of another element, or that the element has high isolation characteristics. The simulated results of directivity, and ECC are given in Figures 9 and 11.

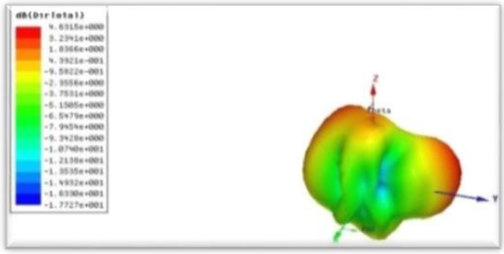


Fig. 9 – Directivity of the final MIMO antenna

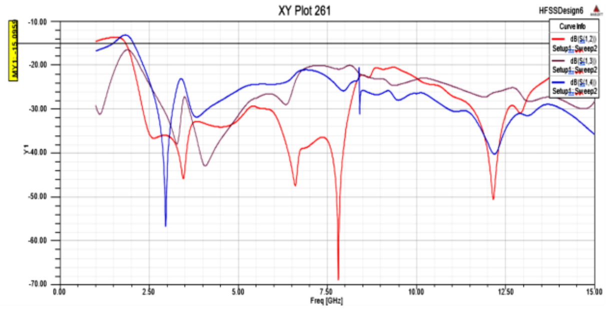


Fig. 10 – Isolation between patch1 and patch 2, 3, 4

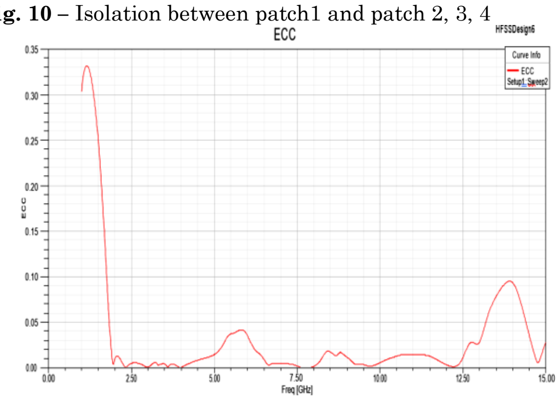


Fig. 11 – ECC for the final MIMO antenna design

The various antenna parameters for the above-simulated MIMO with EBG antenna design are tabulated below in the Table 2.

Table 2 – Tabulation for parameters of MIMO with EBG structure

Parameters	Value
Gain	5.78dB
Directivity	4.6
Band coverage	1.7 GHz to12.4 GHz
Efficiency	87.95 %

4. FABRICATED MIMO ANTENNA FOR LOWER 5G BAND

The simulated antenna design has been fabricated for the lower 5G band or 5G Sub 6 GHz which ranges from 2 GHz to 12 GHz. The fabricated MIMO antenna has an FR4 epoxy substrate of dimension 70 mm × 60 mm × 1.6 mm with dielectric loss tangent 0.019 and relative permittivity of 4.4.

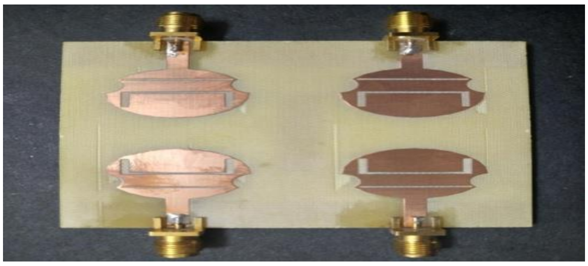


Fig. 12 – Bottom layer of partial ground with EBG structure of the fabricated antenna

The bottom layer has an EBG structure of 50 mm × 6 mm between the dual partial ground of dimension 10 mm × 60 mm shown in Figures 12 and 13.

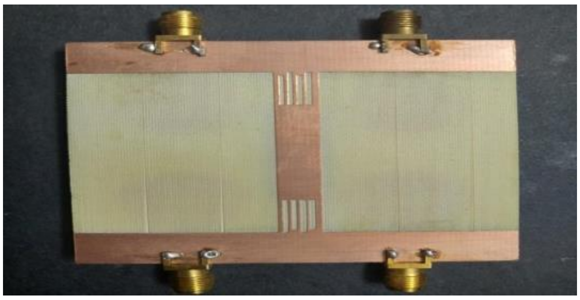


Fig. 13 – Top layer of truncated patches with U and straight slots of the fabricated antenna

5. CONCLUSIONS

In this research work, the design and analysis of a lower 5G or Sub 6 GHz MIMO antenna with two rejection bands (WiMAX and WLAN) were carried out. Hence novelty of the antenna design is proved in the perfect manner of a MIMO (Multiple-Input-Multiple-Output) micro strip patch antenna using a low-cost FR-4 epoxy substrate of dielectric loss tangent 0.019 and relative permittivity of 4.4. The EBG structured antenna has been evaluated with the simulated using HFSS 13.0 and also fabricated. The proposed MIMO antenna design has a (i) resonant frequency of 2 GHz, 3.8 GHz, and 9 GHz with an operating frequency range of 1.7 GHz to 12.4 GHz. (ii) the antenna design has better isolation than – 15 dB and VSWR with a maximum value of less than 2. (iii) The envelope Correlation Coefficient (ECC) is found and it lies at an acceptable level. Finally, the EBG structured antenna system evolved and has a maximum directivity of 4.6, efficiency of 87.95 %, and maximum gain of 5.78 dB which are desired in any MIMO system to tolerate interference and maintain user bandwidth. Recently the economic situation of the 5G was analyzed, whether the wireless transmission is sufficient and the 4 × 4 MIMO antenna is used to design on EBG in future technologies.

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MIMO антена для частоти 6 ГГц зі структурою EBG у додатках 5G

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У сучасному бездротовому зв'язку вдосконалення бездротових додатків 5G суттєво збільшує розвиток технологій MIMO (Multiple Input Multiple Output). У стандартному виконанні антена MIMO не ефективна, оскільки має частоту 5 ГГц із результатом 75 %, і наявні перешкоди важко прибрати. Запропонована конструкція антени MIMO моделюється чотирма усіченими круглими колами радіусом 9,35 мм у верхньому шарі з подвійним частковим заземленням 10 мм × 60 мм у нижній частині для забезпечення кращої продуктивності. Епоксидна підкладка FR-4 має розміри 70 мм × 60 мм × 1,6 мм. Для всіх чотирьох планарних антен спостерігається смуга пропускання імпедансу в діапазоні від 1,7 ГГц до 12,4 ГГц із зворотними втратами 10 дБ і ізоляцією 15 дБ. Дефектний базовий ескіз у плоскій площині функціонує декількома прорізами, метаматеріалами тощо, досягнутими смугою-надрізом. Запропонована система створена для покращення продуктивності за результатами моделювання HFSS для робочої частоти антени MIMO від 1,7 ГГц до 12,4 ГГц. Він забезпечує спрямованість 4,6 з відносною діелектричною проникністю 4,4 і ізоляцію 15 дБ. Крім того, посилення 5,7 дБ з ефективністю 87,95 % було досягнуто шляхом введення структури електромагнітної забороненої зони (EBG) між двома частковими площинами заземлення внизу.

Ключові слова: Кілька входів і кількох виходів (MIMO), П'яте покоління (5G), Електромагнітна заборонена зона (EBG), HFSS, WC.