Design of MIMO Antenna for 5G Smartphone Application Using Decoupling Structure

Abi T M Zerith, Angel P Rajam, Mallipeddi Samyuktha, Jasmine A Sheeba, Shiney V Rebecca and M Nesasudha

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Abi T Zerith M
Department of ECE
Karunya Institute of Technology and Sciences
Coimbatore, India
abitzerith@gmail.com

Angel Rajam P
Department of ECE
Karunya Institute of Technology and Sciences
Coimbatore, India
angelrajam24@gmail.com

Mallipeddi Samyuktha
Department of ECE
Karunya Institute of Technology and Sciences
Coimbatore, India
samyukthamallipeddi2662@gmail.com

Jasmine Sheeba A
Department of ECE
Karunya Institute of Technology and Sciences
Coimbatore, India
jasminesheeba7@gmail.com

Shiney Rebecca V
Department of ECE
Karunya Institute of Technology and Sciences
Coimbatore, India
romanshiney05@gmail.com

Nesasudha M
Department of ECE
Karunya Institute of Technology and Sciences
Coimbatore, India
nesasudha@karunya.edu

Abstract— **In this paper, a 5G MIMO antenna system is designed with self-decoupling technique in mobile terminals. The MIMO system has pair of antenna blocks placed on the long frame of the smartphone system, each block consists of two closely spaced antenna elements. A grounding block is shared to pair of antennas forming compact decoupling structure. The MIMO array is tuned to operate in the n78 band (3.6-3.8GHz) with isolation lower than -18 dB in the entire band of operation. The system operates with total efficiency greater than 60%, and gain greater than 4.5 dB in the utilization band. The MIMO parameters such as ECC and DG are calculated and is observed to be lower than 0.13 and 10 dB respectively, ensuring satisfactory MIMO operation.**

Keywords—Fifth –generation (5G), multiple-input-multiple-output (MIMO), compact decoupling structure, envelope correlation coefficient (ECC), diversity gain (DG), self-decoupling technique, n78 band.

I. INTRODUCTION

In recent days, to improve the advancement in wireless communication system, 5G MIMO antenna system has been introduced which has been initiated in many countries. As the technology grows, there is a huge development in the field of 5G communication systems. Nowadays, smartphones are designed with full touch screen model, where the space allotted for the antenna is very less. The challenging task is that placing MIMO antenna in that limited space. Most of the researches are trying to bring solution for the challenge. There are many parameters taken into consideration for this MIMO design. One such parameter is isolation. The techniques that are used to improve isolation are neutralization line, self- decoupling, metamaterial structure, defected ground structure, pattern diversity and self-isolation. In [1], 4-port MIMO system using decoupled antenna pair technique for 5G applications in mobile terminals is proposed which operates in n78 band with isolation lower than -17 dB. In [2], an eight-antenna element based on slot modes for 5G metal frame mobile terminal is proposed which covers n77, n78 and n79 bands with isolation better than -10 dB The pattern diversity technique is applied in 4×4 MIMO system to achieve isolation at 3.5 GHz in [4]. In [4], the authors obtained isolation better than -14 dB. In [5], 4-port MIMO system and 8-port MIMO system is designed in single mobile case where isolation is lower than -20 dB and -17 dB. The isolation is lower than -16.5dB when quad port MIMO system is introduced which operates in 3.5 GHz [6]. Decoupling structure is introduced which operates in 3.5 GHz and 4.9 GHz where isolation is lower than -17.5 dB and -20 dB is presented in [7]. The self-decoupled structure is introduced where isolation better than -25 dB is demonstrated in [10]. From [1], [7] and [10], it gives clear conclusion that self- decoupling technique is one of the good way to improve isolation while designing MIMO system. In this paper, a 4- antenna with lumped port MIMO system based on self-decoupling design technique of antenna pairs is proposed. The performance metrics of proposed MIMO system is confirmed by simulation (obtained using ANSYS HFSS).

II. PROPOSED MIMO ANTENNA SYSTEM

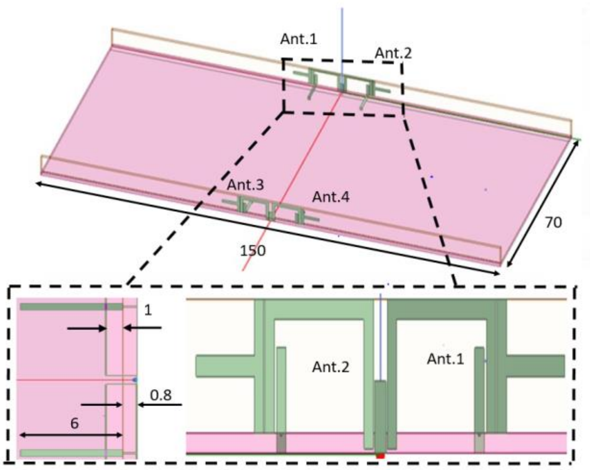

Fig. 1. Mensuration of the 4-port 5G MIMO system of antenna pairs. All units are in millimeters.

The mensuration of the proposed 4-port MIMO antenna system for smartphone application is shown in Fig. 1. The substrate and long frame acts as mobile case. The material used for the substrate and long frame is FR4 (relative permittivity = 4.4 and loss tangent = 0.02). The dimensions of the substrate are 150 mm × 70 mm × 0.8 mm while the size of ground plane is 150 mm × 66.4 with a 1.8 mm clearance along two side edges of system substrate. Two antenna pairs are printed separately and located at the long frame of the phone. Each antenna pair is located in the middle of the antenna frame. The total area occupied by each antenna pair is 31.6 mm × (5.2+0.8 mm). Each antenna pair consists of three identical antenna blocks. They are I-shaped feeding block, U-shaped radiator block and T-shaped block. The two pairs of antenna blocks share a common grounding block that is coupled with the U-shaped radiator block. The width of the three block traces is 0.8 mm. The width of grounding block is 1 mm. The horizontal coupling gaps between the I-shaped grounding block and U-shaped radiator block and gaps between U-shaped block and T-shaped block are all fixed at 0.1 mm. The horizontal gap between I-shaped feeding block and U-shaped radiator block are fixed at 0.2 mm. The distance between two adjacent U- shaped radiator block is fixed to 1.2 mm. The perfect outcome of the proposed MIMO system is obtained by tuning the lengths of the feeding block, radiator block and grounding block. The design technique which is used to obtain better isolation is the self-decoupling technique.

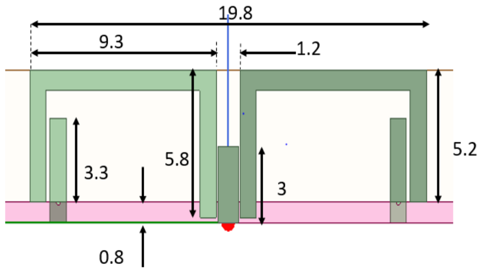

Fig. 2 Geometry of antenna patch without T-shaped branch. All units are in millimeters.

Fig. 2 shows the antenna patch geometry without implementing T-shaped branch. With that structure, the antenna resonates at 3.7 GHz. The resonance obtained is only -10 dB.

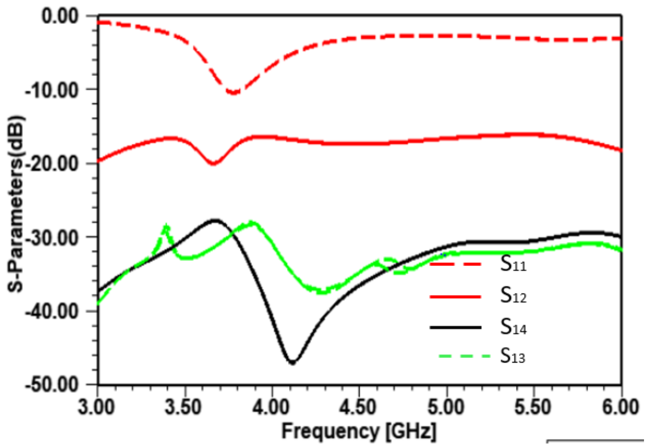

Fig. 3 Simulated S-parameter plot of all antennas obtained from Fig. 2 design.

Fig. 3 shows the S-parameter plot for the Fig. 2 design. The isolation is achieved better than -17dB in required band. The challenging task in the design is to obtain and maintain both S_{11} and S_{12} in the same band of operation. To improve the S_{11}, a T- shaped branch is introduced in the patch. The included T-stub improves the antenna operation at 3.7 GHz from -10 dB to -15 dB. The geometry of the patch after introducing T-shaped structure is shown in Fig.4.

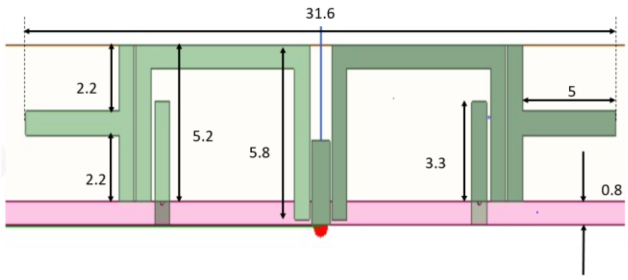

Fig. 4 Geometry of proposed antenna patch. T-shaped antenna trace is introduced. All units are in millimeters.

Fig.5 shows the simulated S-parameter for Fig.4. The S-parameter is improved to -15 dB and isolation is lower than -18 dB in n78 band. The important point to note from the geometry is that when the length of feeding block varies, the S-parameter and operating frequency of the 5G MIMO system changes, but there is no change in isolation. When the length of the antenna trace nearer to grounding element varies, the bandwidth gets affected. For better signal quality, bandwidth is one of the important parameter which is taken into consideration. When the length of the grounding element varies, it affects resonance frequency, impedance matching and antenna isolation. Thus, from the proposed design, the principle of working and the impact on the length of grounding block on the performance outcome is studied.

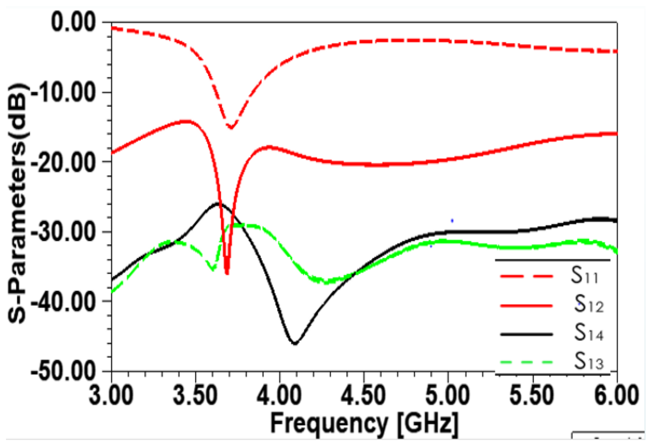

Fig. 5. Simulated result of S-parameter of all antennas for the proposed antenna design.

III. Results and Discussions

Fig. 6 illustrates the current which is distributed throughout the surface of antenna pair at 3.7 GHz when only one antenna is excited and the remaining terminated with 50 ohm. The common grounding branch placed between the two antenna elements provide the required isolation between them. The current is coupled between the antenna 1 and common grounding branch, rather than antenna 1 and antenna 2, and is clearly visible from Fig. 6.

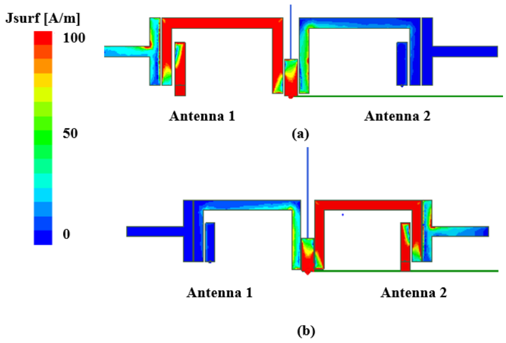

Fig. 6. Surface current distribution of antenna pair at 3.7 GHz (a)Antenna 1 excited, (b)Antenna 2 excited

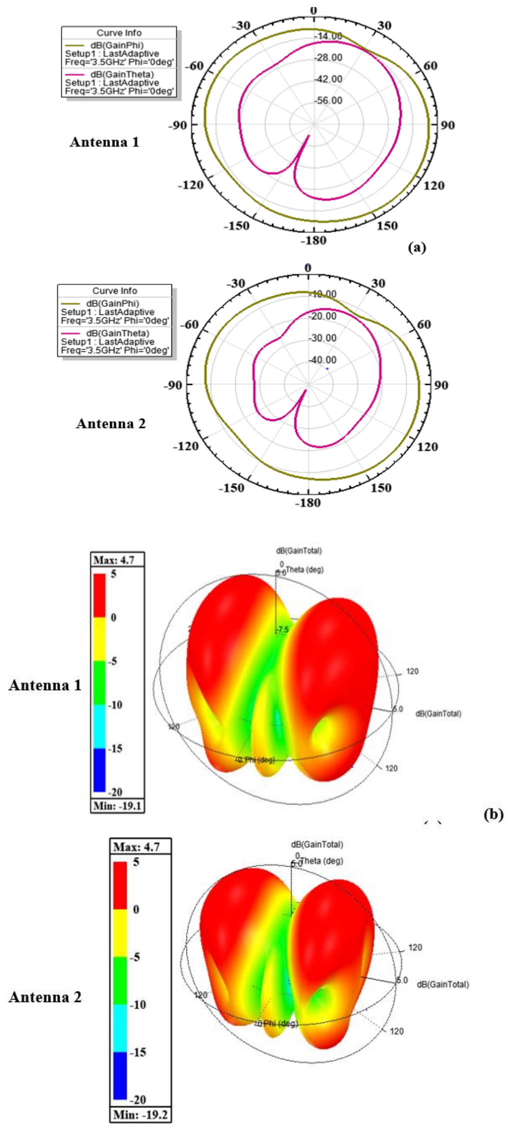

Fig. 7. Radiation Pattern for the proposed design *a)2-D pattern b)3-D pattern*

The radiation pattern tells the radiation properties of the antenna in graphical plot. The radiation pattern is calculated in far field region[21]. Fig. 7(a) and Fig 7(b) shows the 2D and 3D view of radiation pattern of antenna 1 and antenna 2 respectively for the proposed design. The maximum gain of 4.7 dB is achieved by antenna 1 and 2 of proposed design.

Gain is a measure that takes the antenna efficiency and its directional capability into account. Gain is the ratio of the strength in a given direction to the scattering strength that would be obtained if the power accepted by the antenna were scattered isotropically [21]. Fig. 8 shows the peak gain of antenna1 and 2 for the proposed design, and is better than 4.5 dB in the entire band of operation.

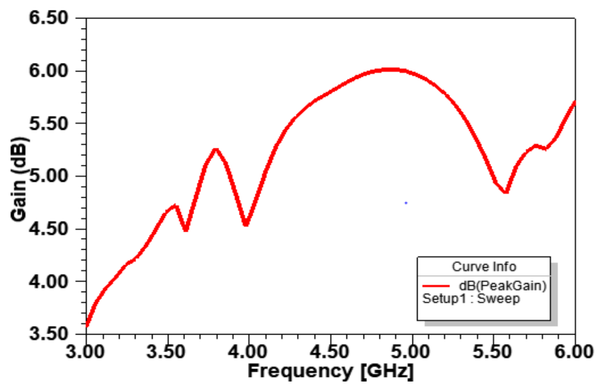

Fig. 8. Gain of antenna 1 and 2 for proposed design

Efficiency of the antenna tells the quality of the performance of the antenna. The antenna with higher efficiency is said to be the antenna of good quality. Total antenna efficiency takes losses at input terminals and within the structure of antenna into account [21]. Fig. 9 shows the total efficiency and radiation efficiency of antenna 1 and antenna 2 for the proposed design. Total efficiency is greater than 60% and radiation efficiency is greater than 70% in the complete utilization bandwidth.

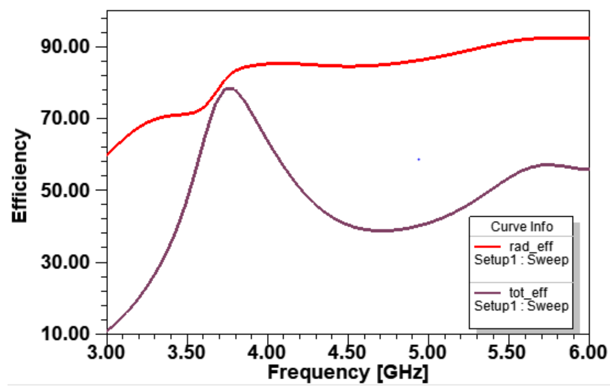

Fig. 9. Simulated total efficiency and radiated efficiency of antenna 1 and antenna 2

IV. MIMO DIVERSITY PARAMETERS

MIMO array diversity is estimated using parameters such as envelope correlation coefficient (ECC) and Diversity gain (DG). ECC tells how independently two antennas are radiating. So, if one antenna is said to be completely horizontally oriented and the other is said to be completely vertically oriented, the two antennas are intersected to zero. Fig. 10 shows ECC of proposed design, and is lesser than 0.13 in the entire operating band. The DG of the system is plotted in Fig. 11, and is nearly equal to 10 dB in the operating band ensuring satisfactory MIMO operation.

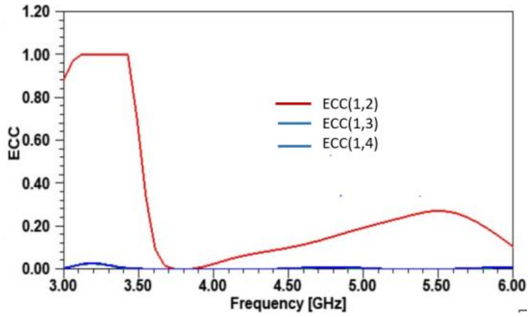

Fig. 10 ECC of proposed design

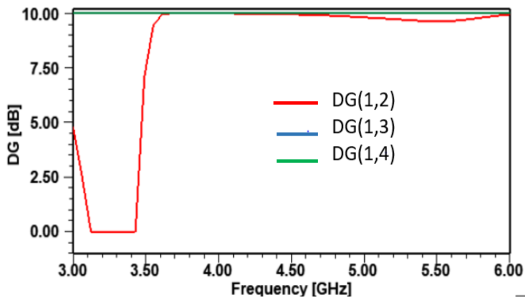

Fig. 11 DG of proposed design

V. CONCLUSION

A compact self-decoupled 4-port MIMO antenna operating in n78 band (3.6 – 3.8 GHz) for 5G smartphone application is presented in this paper. The pair of antennas which share common grounding branch and implementing T-shaped stub provides quiet good isolation and impedance matching even when the pairs are very close to each other. The self-decoupled antenna system has isolation lower than -18 dB in the utilization band. The system operates with total efficiency and gain greater than 60% and 70% respectively in the entire band of operation. The gain of the system is also better than 4.5 dB. The ECC and DG in the antenna system are lower than 0.13 and 10 dB respectively, ensuring satisfactory MIMO operation.

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